# Udder Health and Communication

Edited by H. Hogeveen
T.J.G.M. Lam

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# Preface

Mastitis probably is the most studied disease in the dairy industry. That is for obvious reasons. Mastitis has an effect on welfare, on milk quality, it disturbs working routines and it is an important reason for culling. Additionally, most antibiotics in dairy cattle are used in the udder.

We live in a dynamic world. The dairy industry is quickly changing with all over the world decreasing numbers of herds with rapidly increasing numbers of cows per herd. At the same time, in the rich part of the world, society is demanding. Animal welfare is becoming more important, as are requirements on safety, taste and price. These changes lead to technical innovations such as automatic milking systems that may have consequences on the health of the most important organ of the dairy cow: the udder.

The importance of continuous research is beyond doubt. Research leads to increased knowledge. Knowledge comes to value if it is used. Over the years we have learned that in order for knowledge to be applied, communication is as important as the technical content of the message. We need to have our technical knowledge up to standards and there is a continuous need to optimize that. At the same time we need to motivate farmers, veterinarians and other workers in the field to adopt new technologies and to optimize management. This requires knowledge about the (economic) effect of new technologies and improved management on udder health, but this also requires optimal communication.

In the changing dairy industry, not only the farms changed, the farmers also changed. Today's dairy farmer is not quite comparable to the dairy farmer of ten or twenty years ago. We can wonder whether advisers changed as quick as farmers did. And we can wonder whether we know enough about communication, about mindset and motivation to optimally serve that dairy farmer. From October 25-27 2011 a conference on this topic was held. It aimed at science that is useful for practice, in all its meanings. This book covers the proceedings of the material that is presented and discussed during the International Conference on Udder Health and Communication and consists of papers of keynote and other oral presentations and abstracts of all poster presentations.

We are happy that so many people show interest in this subject. On behalf of the organizing committee we are happy to invite you to use these proceedings to the best to further improve udder health. Finally, we would like to acknowledge all the people that made this conference and the publication of these proceedings possible: the authors, the scientific committee and the editors of Wageningen Academic Publishers.

*Henk Hogeveen and Theo Lam*

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# Keynotes

# National mastitis control schemes: experiences from implementation of a nationwide scheme in Great Britain

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## Abstract

To reduce levels of mastitis on British dairy farms, a mastitis control programme was developed, tested in a clinical trial, and is being implemented on a nationwide scale. The scheme, the DairyCo Mastitis Control Plan, is discussed here on the basis of describing some of the challenges encountered when attempting a nationwide scheme. We describe reasons for starting a new scheme, the major challenges faced, and how the scheme was designed and implemented. Lines of communication were important and sometimes difficult to manage; from the overseeing body through to scheme coordinators, to plan deliverers, to farmers and to the industry as a whole. Lessons were learned from other national mastitis schemes and a variety of communication methods have been used to reach farmers. Continued specialised training on farmer segmentation and motivators is being provided to plan users to further improve uptake. The control plan itself is heavily structured in terms of guiding plan deliverers to make a herd diagnosis of a mastitis problem and in providing a structured, farm-specific approach to identify the important areas of management that need to change. Bespoke software has been developed to enable this to be carried out. Each plan user receives direct support from the central team and this has proved to be one of the most popular and important aspects of the control programme. All farms that implement the plan are recorded and their data are (anonymously) analysed. In the first $2^1/_2$ years of the scheme, >250 vets/consultants have been trained, over 10% of British dairy cows have received the full plan, and a further ~10% have received a partial plan. Initial analysis suggests that, on average, a reduction of around 10-20% is being achieved in clinical mastitis and somatic cell counts.

**Keywords:** mastitis, control, national scheme

## Introduction

National schemes, programmes and campaigns have been used for mastitis control in dairy cows for many years. An early example in the 1960s was the five point plan in which a basic set of measures was proposed that were considered to have a beneficial effect on clinical and subclinical mastitis (Neave *et al.*, 1966). At this time, control plans were relatively straightforward, because with mastitis incidence and prevalence at very high levels (e.g in the UK the incidence rate of clinical mastitis was around 150 cases per 100 cows /yr), and contagious pathogens being responsible for the majority of mastitis that occurred, the scope for improvement using relatively simple measures, was huge. Since then, levels of production have escalated, cow genetics have altered radically and management systems have changed dramatically, thus the management of mastitis has become much more challenging. In general environmental pathogens have become increasingly important and the prevention of environmental infections is often more complicated than reducing the transmission of contagious pathogens; environmental management often requires more detailed, close to farm evaluations and farm-specific advice.

Implementing mastitis control on a national basis requires knowledge, motivation, widespread participation, excellent communication, financial backing, industry and political cooperation and probably most of all a dogged determination. Some very successful schemes have been set up, for example, Countdown Downunder (Australia), the SAMM Plan (now Smart SAMM. New Zealand), the Dutch Udder Health Program and the Norwegian Mastitis Control Program. A new scheme has recently been launched in Great Britain led by a collaboration of the national dairy levy board (DairyCo) and a team of researchers and veterinary surgeons. This scheme is not proposed here as the 'best way' to approach mastitis control, but is discussed on the basis of describing some of the challenges encountered when attempting to improve mastitis control on a nationwide basis. The aims of this paper are to describe the reasons for starting a new scheme in Great Britain, the major challenges faced, how the scheme was designed and works and the current situation.

## Why attempt mastitis control on a nationwide scale?

There are many reasons why a reduction of mastitis on nationwide scale is important, both to individuals and the industry. These include:

### *Financial benefits*

Mastitis is generally accepted, in financial terms, as the most important disease of dairy cattle, causing annual production losses of more than £170M in the UK (Bradley, 2002), US$ 2.0B in the USA (DeGraves and Fetrow, 1993) and A$ 150M in Australia (Mein and Smolenaars, 2000); the condition accounts for 38% of the total direct costs of the common diseases of dairy cattle (Kossaibati and Esslemont, 1997).

### *Dairy cow welfare*

The welfare implications of mastitis are severe and were highlighted in recent UK Farm Animal Welfare Council (FAWC) Reports on the Welfare of Dairy Cattle (FAWC, 2009). Indeed, FAWC stated in October 2009 that 'the incidence of endemic diseases in dairy cows, particularly mastitis and lameness, should be reduced urgently'. In a modern society, the wellbeing of farmed animals is a moral issue and, in the UK, public concern for farm animal welfare appears to be increasing.

### *Public health considerations and public perception*

The importance of mastitis in public health should not be overlooked. The extensive use of antibiotics in the treatment and control of mastitis has possible (though unproven) implications for human health through an increased risk of antibiotic resistant strains of bacteria emerging that may enter the food chain. Recent concerns about a new strain of MRSA in milk (Garcia-Alvarez *et al.*, 2011) recently reignited this debate in the UK and gained significant attention in the media. Although any direct link between antimicrobial use in dairy cows and the emergence of bacterial resistance is unclear, mastitis (therapy and prevention) constitutes a major reason for antimicrobial use in dairy cattle and thus optimising non-pharmaceutical prevention of the disease is viewed as critical. The responsible prescribing of antimicrobial agents for dairy cows is now coming under close scrutiny.

An example of the media hype surrounding antimicrobial use in dairy cows can be seen from copy in a national newspaper, which carried the following quote following the recent MRSA identified in bulk tank milk (Daily Mail, 2011):

> 'The discovery raises concern that intensive farming methods may be encouraging the emergence of new MRSA strains which are resistant to an ever-wider range of antibiotics'.... Organic farming lobby The Soil Association last night called for a complete ban on routine use of antibiotics in livestock because of fears they may promote drug-resistant bacteria. Helen Browning of the Soil Association, said: 'Under acute price pressure, dairy systems are becoming ever more antibiotic dependent. We need to get farmers off this treadmill, even if that means that milk has to cost a few pennies more.'

### *Food security*

Food security is becoming an increasingly important global issue. The Foresight report (www.bis.gov.uk/assets/bispartners/foresight/docs/food-and-farming/11-546-future-of-food-and-farming-report.pdf) published in 2011 set out to explore the pressures on global food supply up to 2050. These were key findings:

The global food system will experience an unprecedented confluence of pressures over the next 40 years:

- global population size will increase from nearly seven billion today to probably to over nine billion by 2050;
- many people are likely to be wealthier, creating demand for a more varied, high-quality diet requiring additional resources to produce;
- competition for land, water and energy will intensify, while the effects of climate change will become increasingly apparent;
- the need to reduce greenhouse gas emissions and adapt to a changing climate will become imperative;
- globalisation will continue, exposing the food system to novel economic and political pressures.

Efficient production in agriculture, including prevention of disease in farmed animals to minimise waste (culling and non-saleable product) has an important role to play in food security. Mastitis is one of the key production diseases worldwide that results in such wastage and thus national control programmes will help maintain national milk supplies going forward and improve either self sufficiency or export opportunities. For example, in the UK, the estimated number of cases of clinical mastitis is >1,000,000/yr. The milk retrieved if we could prevent half this number of cases would be sufficient to supply >50 small towns. If we could halve the number of cows culled each year because of mastitis, this would equate to around 250 extra dairy units containing 200 cows/unit. When food starts to become increasingly short and expensive, such losses will become important.

#### *Environment*

The impact of bovine mastitis on the environment has not been thoroughly evaluated. However, since it is clear that dairy farming is an important worldwide contributor to greenhouse gas emissions (FAO, Consulted November 2009), an increased incidence of mastitis will certainly be detrimental to the environment because of increased cow numbers required to produce a given quantity of milk.

### General challenges of setting up a nationwide scheme

There are a variety of obstacles to be tackled when setting up a national programme for mastitis control (or any other endemic disease), and good communication throughout the industry is an important feature (although often difficult to achieve!). These are some of the major challenges likely to be encountered.

***Who leads, starts initiates...?***

In the context of cow health, dairy industries can be rather fragmented, with no particular bodies responsible for nationwide initiatives. To whom should this responsibility fall? Many parties have an interest, from consumer through to government, but often there is no particular body or organisation who naturally takes the role of 'initiator' when it comes to endemic disease. Ideally, the lead body should have the respect of, and be credible for, all participants and stakeholders, and in addition have the motivation to carry out the scheme, excellent communication to carry along the industry, and sufficient financial capacity to ignite the scheme! In the UK, the initial driving body was the dairy levy board, DairyCo, who had the foresight to commission research around the design of a suitable control programme and since then have played an integral role in setting the national scheme in place.

***What type of scheme – what is the model?***

Early on in the development of a national programme, it is important to consider what general type of approach will be taken. This can be thought of as a spectrum from the promotion of very general control measures (e.g. regularity of milking machine maintenance, improved yard management etc) to very farm-specific measures (that can only by decided from a detailed evaluation of the farm itself). The advantage of the more general approach is that it is relatively straightforward to reach many farms. The disadvantage of a general approach is that the measures being promoted may already be in place or may be unimportant for mastitis control on many farms. For the British scheme, we decided to adopt the detailed approach at first (with possibly more general routes to follow later) so that despite the fact that farms may will be reached relatively slowly, once included the farms would obtain detailed farm specific information. Lessons about farmer segmentation and motivational differences from the Dutch programme and UK research, (Jansen *et al.*, 2010a,b; Rehman *et al.*, 2008) suggested that we would need to adopt a variety of methods to reach different farmers, and this is being adopted within the scheme (see later).

***Who coordinates and drives the scheme, who should participate, what is the structure?***

The organisation that initiates a scheme may not be the major player in terms of subsequent coordination and running of the scheme, and this is the case with the British programme. We have opted for a two stage process whereby in the initial three year period, during which time the scheme is being established, a small group of DairyCo staff and veterinary surgeons (from university and industry) conduct participant training and coordination of the set up phase. This period of time is nearing an end, and going forward it is anticipated that a steering group of enthusiastic participants will be formed, alongside staff at DairyCo and the University of Nottingham, to drive the scheme in future.

In terms of who delivers the DairyCo control programme on farm, it was decided from the outset that this could be vets, specialist farm advisors, or farmers. In practice, because the training is very technical in nature, the vast majority of trained participants are vets and specialist mastitis advisors. The scheme structure is described in detail below, but we have chosen a process whereby participants are required to undergo a 2 day training programme and then become official 'DairyCo Mastitis Control Plan' (DMCP) deliverers. To remain involved in the scheme, and to have continued access to software, written materials and support from the central team, participants are required to attend an annual update course. Participants deliver the plan onto farm and charge fees agreed locally. Farmers generally choose their own vet or advisor, but have the right to choose any deliver; all names and locations of deliverers are published on an interactive map (www.mastitiscontrolplan.co.uk).

***Evidence based?***

When deciding on specific control measures to be included in a national scheme, the strength of evidence required for any intervention has to be considered. How do you decide when there is sufficient evidence (whether published or expert opinion) for a measure to be included? This rather difficult issue was circumvented in the DairyCo scheme because it was decided to design a specific scheme and then test it in an intervention study. Whilst this made the whole process rather drawn out (the scheme was initially designed in 2004-5), it did mean that the effect of the scheme was evaluated and published (Green *et al.*, 2007).

## Communication structures: methods of outreach

Lines of communication in a nationwide scheme can be complicated and there are many links to be maintained. We found that the whole chain of communication was important and sometimes difficult to manage; from the overseeing body through to scheme co-ordinators, to plan deliverers, to farmers and to the industry as a whole. An essential component of a national scheme is to bring it to the attention of the industry in a positive manner, and maintain its profile over a prolonged period. In the first two years we have used a variety of methods of communication throughout the industry, to farmers, vets and advisors. Whilst this hasn't been perfect, the nationwide plan now has a clear branding and has reached a place of acceptance within the industry as an acknowledged route of mastitis control. This is demonstrated by the support and promotion of the scheme by the major retailers, regional funding bodies and also farmer groups and veterinary bodies. It has reached the psyche of the government veterinary advisors who have quoted the scheme as a successful industry initiative to combat an important endemic disease.

Routes chosen to communicate the scheme to stakeholders have included:

- widespread use of farming media (including publishing of success stories). Some examples are:
  - www.thedairysite.com/news/27151/vets-begin-training-on-dairyco-mastitis-plan;

- www.fwi.co.uk/Articles/2009/08/07/117064/Mastitis-plan-cuts-cases-and-saves-money.htm;
- www.farmersguardian.com/three-stage-control-plan-for-high-cell-counts-and-mastitis/27598.article;

- use of direct mailings from DairyCo to farmers;
- New DMCP website (www.mastitiscontrolplan.co.uk);
- agricultural and veterinary conferences;
- agricultural shows;
- veterinary media (journals and websites);
- farmer discussion groups;
- farmer meetings;
- local veterinary newsletters, e.g.:
  - http://www.highgate-vets.co.uk/farm/train/dmcp.htm;
  - www.xlvets.co.uk/userfiles/file/documents/Articles/FW%20DairyCo%20Aug%2009.pdf;
  - www.delawarevets.co.uk/files/DVG_Spring_2010_newsletter.pdf), secondary media;
- Independent sources, e.g.:
  - www.nfuonline.com/Your-sector/Dairy/News/Dairy-Cow-Welfare-Summary/.

One challenge for a national initiative is that there may be organisations or companies, with particular (often commercial) interests who do not wish to support the scheme. This can be problematic. However, as a scheme grows and gains momentum, many of these situations can be sorted out although vested interests may present a challenge to large scale schemes.

## Features of the on-going scheme: continuing to meet consumer and industry needs…

Although the DMCP is in its infancy, we are conscious of the need to plan for the future. Maintaining momentum and sustainability of the control scheme is critical and something we need to ensure. We believe it will be important that the scheme remains up-to-date and that new research is incorporated over time. To achieve this, we need to remain flexible, with an open mind about what the scheme looks like and how it is delivered. We will need to identify reasons for poor penetration and try to address these. For us, continued involvement and enthusiasm of plan participants is a critical element, and we hope that by having a wide involvement of participants in steering the scheme, we may be able to maintain momentum. Similarly, it is vital that the control scheme delivers what dairy farmers require and this should be evaluated regularly. Clearly, funding of the scheme in a sustainable manner is essential, and this is probably linked to delivering what the industry needs.

A further opportunity the scheme provides is as a basis for future research. Large quantities of data are being collected from each farm on the occurrence and patterns of clinical and subclinical mastitis as well as the management changes made. Funding has been secured to evaluate the cost effectiveness of different interventions in different farm situations and it is intended that results from this research will be used to directly inform use of the control plan.

## Our nationwide scheme

### *Development of the plan*

The principle when developing the DMCP was that it should be possible, by gaining a detailed insight and understanding of the mastitis epidemiology on an individual unit, to target mastitis control measures specifically and thereby provide farm-specific, cost effective mastitis control. A central precept of the plan was the requirement to 'diagnose' and define the mastitis patterns on a particular unit. Using this approach it was possible, through the analysis of data and strategic bacteriology, to categorise farms according to whether mastitis on the farm was mostly of dry period or lactation origin, whether the pathogens were behaving mostly in an 'environmental' or 'contagious' manner and what seasonal/age variations occurred. Once farms have been categorised in this manner, the principle was that interventions could then be 'targeted' to attempt to achieve the biggest return on investment.

Existing literature was reviewed to identify interventions associated with improved mastitis control. The plan now contains over 300 points (attempting to encapsulate best practice for UK conditions) but the concept is that the 'diagnosis' allows the user to target a small number (10-20) points in the Plan to achieve improved mastitis and milk quality control. To this end the Plan was divided into sections (mirroring cow management and the lactation cycle) and within each section different aspects are categorised as things the farmer 'could', 'should' or 'must' be doing – the exact weighting of these points then varies according to the 'diagnosis'. The approach is outlined below:

1. Define the herd situation, using a set method that comprises appropriate clinical mastitis and cell count indices.
2. Using software provided, compare farm management practices to the 'best practice' defined by the Plan.
3. Again using software, define areas of control that need to be addressed but prioritise them according to the patterns of mastitis identified on the unit.
4. Make an agreed action plan with the farm staff that incorporates 8-10 actions.
5. Confer with the farmer approximately every 3-4 months to re-appraise the data and re-assess the targeted control plan.

### *Testing the plan: an intervention study*

An intervention study was conducted in 2004/5 to validate and test the method of mastitis control and this has been described in detail (Green *et al.*, 2007). During the study, each farm was categorised according to the degree of compliance with respect to the carrying out the control measures, as follows; group 1: <33% of recommendations implemented, group 2: >33%

but <66% of recommendations implemented, group 3: >66% of recommendation implemented. The study found that intervention farms experienced an average decrease in mastitis incidence of approximately 20% in a year, compared to control farms. When the degree of compliance was considered in the analysis it became clear that the level of compliance was a significant factor in determining the likely benefit of the plan; significant improvements were only achieved by herds in compliance groups 2 and 3. The findings on compliance have formed an important component of subsequent training to deliver the mastitis control plan.

### *Follow up: a pilot study*

Following the successful implementation of the DMCP in a research context, the decision was taken to trial its implementation by a separate group of veterinary surgeons. This was done to identify potential issues that may be encountered with a nationwide 'roll out' and generalisation of the plan. In the summer of 2006 a number of farmers were approached to participate in the study. Once accepted they were asked to approach their veterinary surgeons to request their participation. Twenty two farms agreed to participate encompassing nineteen veterinary surgeons. A series of lessons were learned from the pilot scheme, especially; how training and support were provided; the difficulties with involving veterinary surgeons through their farming clients; the importance of communication both between the central plan team and the vets, and between the vets and farmers. Having completed the pilot study, DairyCo decided that a nationwide scheme was possible and worthwhile.

### *The DairyCo mastitis control plan nationwide*

In October 2008, a project started to commence delivery of the DMCP on a nationwide basis. In April 2009, following a campaign to launch the nationwide initiative, the first participants were trained to use the DMCP. Prior to launch, the following actions were undertaken:

- Bespoke software was developed which allowed easy and secure implementation of the plan on-farm.
- Supporting materials were developed including a Plan folder to act as a field resource.
- A website was developed to support implementation of the Plan.

Training of veterinary surgeons, advisors and farmers to become Plan participants was undertaken by the appointed Plan team. Training included all technical aspects of the Plan, approaches to facilitate improved farmer compliance and a consideration of the possible fee structures to be charged by Plan users. Attendance at an initial 2 day course was essential to become a DMCP participant, obtain access to the resources and carry out the plan on farm. The two training days were made up of Day 1, to introduce the concept of the plan, deliver instruction in how to use the plan and interpret mastitis data, as well as providing basic IT training where required and Day 2 (one month later and after the trainees have conducted the plan on one farm) to offer guidance in interpretation of the data and on farm findings.

Telephone and email support was provided for participants to implement the Plan on three farms in their first year of being trained. At the end of the first year a series of 'update' meetings were held, providing further in-depth training from experts in specific fields of mastitis control. These meetings also allowed feedback of experiences in the use of the Plan and act as a period of 'team building' and sharing of experiences, to foster a network of Plan Users. On an on-going basis, attendance at one annual update course is a prerequisite for continuing as a DMCP licensed participant and extends the ability of delegates to continue to use the electronic resources.

At the outset, DairyCo set a target of 150 plan participants to be trained and undertaking the plan within three years of the first training courses. The target number of farms to have had the DMCP carried out within the first three years was 750.

Two years and three months into the three year period since training commenced, there has been an excellent response to the initiative. Over 250 participants have been trained in use of the DMCP and over 760 farms have already received the plan. Since cow numbers on these farms is above average for British farms, we estimate that >10% of British dairy cows are on farms that have received the plan. Feedback from participants indicates that a partial plan has been used on approximately the same number of additional farms (although we cannot capture these data) and thus it is possible the plan has reached as many as 20% of British dairy cows in some form.

### *Measuring the outcome of DMCP implementation*

Data has been collected prospectively from Plan users and processed electronically by the DMCP team. Key performance indicators have been developed in consultation with DairyCo and comprise incidence rates of clinical mastitis and apparent infection rates calculated from somatic cell count (SCC) data. Farms are followed over time and the year before Plan implementation is considered the 'baseline' year for each farm to determine Plan effect. Headline figures from these analyses will be presented, and at the time of writing, the reduction in mastitis appears to be very similar to that found in the original research project.

### *Future of the DairyCo mastitis control plan*

Consideration is being given to how the nationwide scheme will continue and how the scheme will be funded going forward. Although details are not yet decided, DairyCo have declared the intention to remain involved and it is hoped that a steering group, to include enthusiastic plan participants, will be formed. We anticipate maintaining a similar structure to the present one, to include regular annual update meetings for participants, in particular to encourage participants to remain in close contact with each other and the scheme organisers. This should facilitate important exchanges of information about mastitis control. It is also hoped that future training in providing the plan will be undertaken by a wider group of tutors who are themselves experienced plan deliverers.

## Some highs and lows we experienced when developing the nationwide scheme

- Highs:
  - when DairyCo accepted a proposal to develop a structured plan suitable for nationwide delivery;
  - when it turned out the plan worked under research conditions;
  - when anybody (in fact 20 people) turned up for the first training meeting;
  - when suddenly six months later many people wanted to be trained;
  - when we reached 150 trained deliverers (the project target);
  - when we reached 500 farms and realised we definitely would hit the target of 750 within the first 3 years;
  - when we reached 750 farms after 2 years and 3 months.
- Lows:
  - when it dawned on us that taking 150 people through 2 days of intensive training in groups of about 25 people was a large task;
  - when we realised that software development was frustrating;
  - when it became apparent that plan deliverers (as with the trainers) didn't like to read instructions about how to use software;
  - when only about three people had used the website forum in the first year;
  - understanding that there was a large variation between vets in how they saw their role in terms of mastitis control;
  - realising that recording of clinical mastitis data was very poor in many herds, leading to an over-reliance on somatic cell count data.

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# Countdown Downunder: development led innovation in a national mastitis control program

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## Abstract

In the late 1990's the Australian dairy industry initiated a national mastitis control program named Countdown Downunder. This initiative continues to the present day. The program was responsible for providing leadership in milk quality, pre-farm gate, for farmers, their advisers and the wider industry. As such, it assumed the role of creating the resources around mastitis control best practice and driving change in this area towards defined goals. The route to change, facilitated by Countdown, required the continual refinement of a development process linking mastitis research with extension and education. The path required clear, consistent mastitis control messages that would create both the desire and means to achieve best practice on farm. It needed uptake by not only farmers, but all advisers contributing to mastitis plans and actions with their farmer clients. The development process for a change management program, such as Countdown, required a multi skilled approach from the program team where a thorough knowledge of the domain was vital. Development is an iterative process demanding a high degree of reflection, adaption and engagement of stakeholders. If considerable resources are not put into the development process the outcomes of research are likely to lead to poor extension outcomes.

**Keywords:** control program, mastitis, development, change management

## Introduction

Countdown Downunder is the Australian dairy industry's national mastitis and milk quality program. Commencing in 1999, the program has operated continually since that time with a varying level of resourcing from the industry. It is the oldest of the Australian dairy industry's national animal performance programs.

The program is funded through the resources of the national dairy development body, Dairy Australia, which in turn is funded via both farmer levy contributions and matching Federal Government funds. The program is now into its fourth cycle of development and implementation with most of the cycles being three years in length. Based on the collective experience of the program team, the process of how the program operates within a research, development and extension framework has evolved. This paper will describe aspects of that evolution.

Countdown Downunder (Countdown) is a change management program and should not be viewed simply as an extension program. As an industry good initiative, it has been charged with providing leadership in the area of mastitis, cell count and milk quality control. It has the responsibility of identifying the desired change around mastitis for Australian dairy farmers, their advisers and the wider industry, and creating the route to change to deliver the identified outcomes. The method by which the program team has articulated this path to change has become better understood as the program has aged.

One of the foundation principles of Countdown is the provision of clear and consistent mastitis control recommendations to all sectors of the industry – not just the dairy farming community.

## Identifying the dairy industry need around milk quality

Measurement and reporting of bulk milk or bulk tank somatic cell count (BMSCC) has occurred in Australia since the early 1980's and by the start of 1990 many processors were providing BMSCC information to farmers for each vat pickup. In 1992, one processor commenced a payment system which included a quality component based, in part, on BMSCC. The lead of this individual processor was soon followed and by 1995 many of the milk processors in Australia were enforcing a quality payment system. Part of the impetus for this was the recognition by processors that our overseas trading partners were moving towards a description of product quality based on somatic cell count. This was later confirmed through a European Union directive (92/46/EEC) indicating that raw milk with a BMSCC in excess 400,000 cells/ml geometric mean should not be used in the production of human food products. Approximately 50% of the milk produced in Australia is exported in a wide variety of dairy products.

Whilst common knowledge now, in the 1990's Australian dairy farmers did not fully appreciate that there was no post-farm gate solution for somatic cells in milk. The quality of the milk as it left the farm vat could not be manipulated at the individual vat level. What was also poorly understood was the impact the raw milk BMSCC had on the economics of manufacturing at the processor level. Milk with an elevated BMSCC, for example, increased the rate at which milk dryers became clogged with cellular debris necessitating the drying plant going off-line for cleaning. The imperative to reduce the operating costs of producing milk powder, cheese and yogurt by individual processors also drove the formation of quality payment systems based on BMSCC.

By 1998 there was also the realisation, again at the milk processor level, that pricing signals to farmers were not enough to bring about altered milk quality through a reduction in mastitis levels and new infection rates. Whilst the financial rewards were apparent there was a lack of consistent advice available to farmers to facilitate meaningful mastitis control plans on farm. In essence, the mastitis control advice being offered to farmers from different adviser groups, and within groups, was often poorly articulated and piecemeal in its technical content. The milk quality advice being delivered from the tanker driver was completely different from that on offer from the milking machine technician and the herd veterinarian. The net result was a significant degree of farmer confusion and widespread inaction.

Against this backdrop Countdown emerged in late 1998. The original goals of the program were: 100% of vats collected by the processor should be less than 400,000 cells/ml BMSCC, and 90% of vats should be under 250,000 cells/ml. The method of driving change would be the development and uptake of clear, consistent mastitis control messages both within the farmer and adviser communities. This was a program aimed at providing a strong alignment between best practice in mastitis control and tailored, farm specific actions at the individual farm level.

## Overview of Countdown development and activities

The four phases of Countdown, to date, are summarised in Table 1.

During the initial design and development of Countdown there was a departure from the more traditional model of extension employed by regional agriculture departments and associated organisations in Australia. It was clear that there had to be an intense engagement of the adviser sector as well as the farmer community. It would not be sufficient to only involve farmers with the program as this would not bring about the desired change in mastitis control. In addition to engaging the advisers in the program, the activities and resources of Countdown would target them first. Here the logic was that there would be market failure if farmer's expectations around mastitis control advice, being raised through program activities, was met with poor adviser-farmer interaction reflecting poor adviser technical skills. This development step was challenging given the funding of the program was derived from farmer levy funds.

The first six years of the program implemented both awareness and training activities for farmers and advisers. The awareness activities focussed on delivery of consistent messages about mastitis control. It was not the aim of these awareness activities to develop mastitis problem solving skills in either the farmer or adviser communities. Rather, it was an exercise to create the right environment for the industry where training would be viewed as the natural progression.

Underpinning the awareness and training activities where the foundation resources of Countdown: the Farm Guidelines for Mastitis Control (Brightling *et al.,* 1998) and the Technotes (Brightling *et al.,* 2000). The Farm Guidelines had both the farmers and advisers as the target audience. The Technotes provided the scientific and technical basis for the recommendations contained in the Guidelines and were only intended for use by advisers.

The Technotes were designed to be used by all advisers regardless of their professional group (eg: veterinarian, milking machine technician, processor field officer, dairy adviser). The Farm Guidelines and the Technotes were both built around the stages of lactation with specific

*Table 1. The substance of Countdown in previous and present program cycles.*

| Funding cycle and reports | Resources and activities |
|---|---|
| 1999-2001<br>'Countdown Downunder 1999-2001 Improving mastitis control on dairy farms' | **Core resources**: farm guidelines for mastitis control; technotes; adviser short course; farmer short course.<br>**Program principles**: using service providers as the frontline for extending best practice recommendations around mastitis control. Creating a regional advisory capacity for mastitis control. Promoting a multi-disciplinary approach solving mastitis problems. |
| 2001-2004<br>'Countdown Downunder 2001-2004 Building industry capacity to control mastitis and manage milk quality' | **Core resources**: mastitis investigation pack for advisers; 2003 technote update pack for advisers; certificate for the performance testing of milking machines; cell check program for milk processors.<br>**Activities**: widespread delivery of the countdown farmer short course. countdown 2003 adviser conferences (across the regions). |
| 2005-2009<br>'Countdown Downunder Report for project review on 1 June 2007'<br>'Insight to the dairy industry's capacity to manage mastitis'<br>'Countdown Downunder past, present and future' | **Core resources**: countdown MAX; 'cups on to cups off' (passed to National Centre for Dairy Education Australia); Mastitis Focus report.<br>**Activities**: adviser short course; somatic cell count solutions initiative for milk processors; countdown MAX delivered through select advisers, Mastitis Focus introductory activities with all herd test providers. |
| 2010 to present | **Core resources**: continued development of Mastitis Focus report; new *Streptococcus uberis* control Technote; continued support of 'Cups on cups off' farmer course<br>**Activities**: farmer, adviser and processor response to floods and wet conditions response in three dairy regions; mastitis control symposium for advisers |

recommendations covering mastitis control activities in the drying-off period, for example. This design step was important as the Australian dairy industry was made up of farms with seasonal, split and year round calving systems and the program did not wish to create specific guidelines depending on the calving system and regional location of the farm. It was one resource to be employed across the entire country.

Training for farmers was built around a six day short course. Here, farmers undertook to not only review best practice in mastitis control, facilitated by two Countdown trained adviser trainers but to then create a control plan for their farm specific to its individual needs.

Adviser training also involved re-aligning professional groups with best practice. However, the last half of the three day course involved advisers working in mixed profession teams addressing case study mastitis investigations. The rationale was that, when dealing with real farm mastitis investigations, the control options determined for the farm would be more robust if they drew on the technical and communication skills of a mix of advisers. This has also been the experience reflected in mastitis control programs in the United States through the 'Milk Money' team approach (Ruegg, 2009) and Ireland through the Euromilk program (McCoy and Devitt, 2010).

The third cycle of Countdown saw the introduction of a mastitis risk management service known as Countdown MAX (Penry *et al.,* 2011). The development of this service was driven off by an analysis of farm control plans as created by farmers completing the Farmer Short Course (Nettle *et al.,* 2006). Whilst the initial plans created as a result of the course were suitable for the specific farm need, the plans did not evolve and adapt according to the altering circumstances as defined by herd, people and environmental changes. Ultimately the MAX service, delivered through veterinary practices, did not achieve the widespread uptake anticipated by the program team. With few exceptions, veterinary practices and associated adviser businesses remained entrenched in a model where mastitis control work on farm was in response to farm problems and the associated investigations rather than a pro-active, risk management service paradigm.

Throughout all cycles of activity in the program, Countdown has been guided and assisted by individuals outside of the core program team. In the first eight years of the program's life a reference group (Australian Mastitis Advisory Council) was established to enable better alignment between the research and extension needs and the program development work. This group facilitated representation from all areas of the dairy industry and was led by a farmer chairperson. The program leader for Countdown always held a position on this group to create a firm connection between the reference group and the program. In addition to the reference group stronger ties have been created between the program team and social research scientists with a focus on action research in a rural community context. The Rural Innovation and Research Group, based at the University of Melbourne, have been instrumental in helping Countdown explore the mechanisms by which extension activities can be modified to create greater innovation and sustainability around the route to change.

## Refining the development process

From its inception Countdown, as a change management program in mastitis control has attempted to establish a mechanism by which the logic of program activities could be described. Previous attempts in Australia at linking mastitis research with activity on farm have relied on diffusion through the extension process. There was an assumption, within industry, that good ideas on mastitis control derived from research both locally and overseas would percolate through the adviser community and be implemented on farm. In effect good ideas would 'rise to the top' through vague market forces leading to better mastitis outcomes for farmers. This model of extension was not particularly effective as it did not articulate the path to change.

The development work undertaken by the program team is and has been, by its very nature, an iterative process. Since 1998 the development process behind the activities of Countdown has required constant revision and reflection. This process not only involves how the relevant mastitis science is selected for an Australian setting but the process by which best practice on farm is facilitated either through direct action with farmers or via their advisers as an amplification system. The program has done this always within the confines of the inherent tension that exists in any large project between resources, quality of outcome and time constraints.

In recent times the Countdown team has attempted to more fully articulate the development process behind change management programs such as Countdown through a study commissioned by Dairy Australia in 2010 (Brightling *et al.,* 2010). A visual representation of the design output of this work: D led innovation: a new model for operationalizing RD&E is contained in Figure 1. Here there is an emphasis on the cohesion and effectiveness of activities within a described domain where there is a good understanding of the fit between the technology with farming systems and the enabling environment.

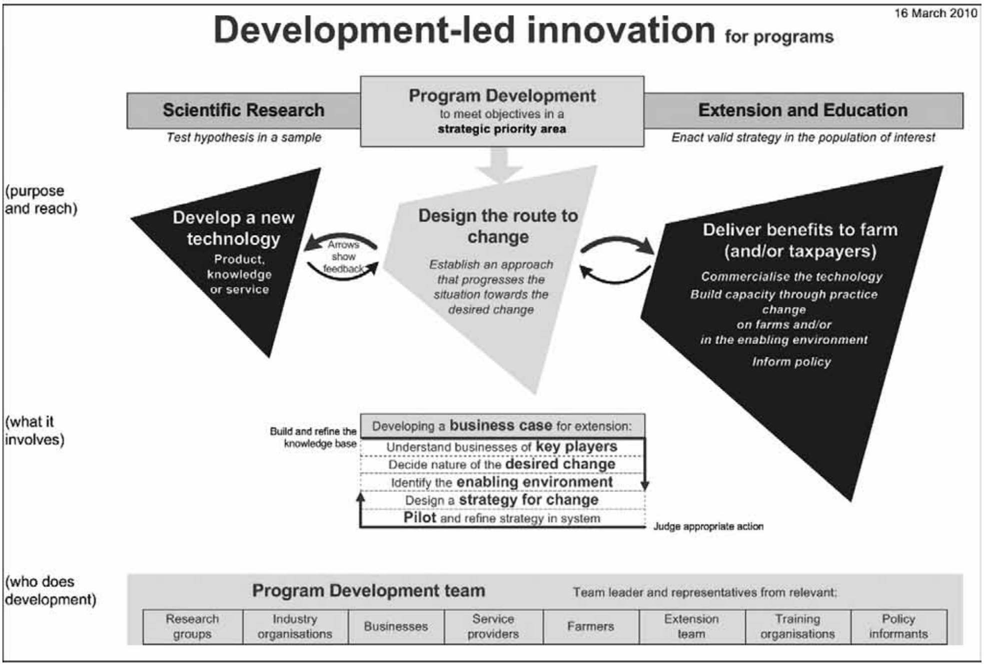


*Figure 1. The D-led innovation model (from Brightling* et al.*, 2010).*

The first order thinking in this process remains with the program development tasks in an attempt to avoid the risks of falling directly from research into extension where there is no established route to change. This model, where development has to be both the first step and a constantly revised step has hurdles, as doing the development properly creates a delay between concluding research findings and commencing delivery to farmers or advisers. It also requires significant resourcing and the creation of a wider program team with a collective skill set that is more than just command of a technical area (such as mastitis).

Putting development into practice firstly requires the establishment of a dynamic team. If the development process is left to one or two individuals, the chance of failure increases. The team also has to understand the importance of engagement between stakeholder groups as this will influence the program's success. In addition, the program team has to understand which part of the research, development and extension continuum they are operating in as observations from each sphere influences the others. In part, the learning from the development tasks should heavily influence both extension activities and priorities located within research. Finally, there is a requirement for the program to illustrate the business case for extension. Here the Countdown team has described five stages.

Firstly the team should be able to understand the business of the key players. This requires a true appreciation of how the various people involved in the domain operate, collaborate and the issues they face in reality. Secondly the team needs to decide on the nature of the desired change within the domain. For example, Countdown aimed for an overall increase in the mastitis investigation skills of advisers where they also recognised the importance of working in a multi-disciplinary team on farm. Thirdly there is a requirement to identify features of the enabling environment. In this way the team can establish what capacity is required in the people and systems involved. Fourthly there is the desire for a robust design around the route to change so that the players are engaged in the right tasks in a logical order. Simplicity is often the aim here. Finally, this design should be piloted and refined.

## Communication, information and performance

In many cases the technology being advanced by a program such as Countdown is not new. The advantages afforded by strategies such as post milking teat disinfection and dry cow therapy in mastitis control have been well described in the past (e.g. Barkema *et al.,* 1999). It has also been recognised that a focus on the herd is vital, particularly where disease may limit performance of the herd and farm business (LeBlanc *et al.,* 2006) and that large scale improvements in udder health are possible if the right approaches are taken (Green *et al.,* 2007).

From the outset the Countdown program was focussed on developing and delivering clear consistent messages around mastitis control. The development process, however, did not confine itself to limited communication methods. In the past in Australia, technical materials on mastitis control were conveyed to farmers and their advisers through publications which were styled on scientific journal articles. They were difficult to comprehend and often buried the true keys of best practice within a raft of text. When the Countdown Farm Guidelines were being designed a part of the process involved relinquishing the 'look and feel' of the text to an educational designer. The result was a set of Guidelines which could be more easily understood by farmers with a wide range of education experience. The Dutch Udder Health Centre has also illustrated the importance of design in farmer messages through their approach to conveying the importance of gloves for milkers in reducing mastitis risk (Jansen *et al.,* 2010a).

Creating the correct impetus for change has also been part of the Countdown strategy. After 2006 the program developed a module 'Cell Count Solutions' to be used by processors with farmers who were consistently dealing with elevated bulk milk cell counts. A tool that related the real economic benefit to the farm of sustainably dropping cell count bands in 100,000 cells/ml steps was developed and employed. It is now understood that farmers attitudes explains a significant degree of variance in mastitis indicators (Jansen *et al.,* 2009) and that farmers will not act if they do not think a problem is serious enough (Jansen *et al.,* 2010b,c). The use of a device that, in one page, laid bare the economic imperative to address cell count issues through a targeted control program, assisted in shifting some farmers from inaction to action.

There has also been the slow realisation that farmers cannot be considered to be part of a homogenous group and that their primary sources of information would vary. Part of the rationale of the wider communication plan within the program was to have all advisers expressing opinions on mastitis control with a similar view of best practice. Having the same message from multiple sources was important for sustained credibility (Lam *et al.,* 2011) and also an acknowledgement that farmers are likely to be requesting more specific information (Chase *et al.,* 2006). To that end, Countdown targeted all adviser groups perceived to have an influence over farmer opinions around mastitis control. The program did not limit itself to the veterinarians only.

Finally, the program has spent significant resources on the development and implementation of a mastitis information monitoring tool, Mastitis Focus, which has a particular application on the 48% of Australian farms enrolled in milk recording. Here we have taken a different tack compared to the data collection framework established by the Canadians through their National Cohort of Dairy Farms program (Reyher *et al.,* 2011). Rather than an emphasis on a select group of farms over a finite period, Mastitis Focus has been deployed on an as needs basis to enable both farmers and their advisers a time flexible and accurate view of the mastitis control performance of an individual farm. It is available at any time and minimal cost to approximately 3,200 farms. It was designed to give farms a real time assessment of their actual new infection rate so that mastitis control plans could be further refined and progress tracked with increasing effectiveness.

## Conclusion

Throughout the life of the program, the Countdown team has engaged in, and refined, the process of development to create a robust route to change. Here development is the linkage between research, illuminating best practice in mastitis control and the path to implementation of that best practice on individual farms. This process has demanded a strong team approach with frequent periods of reflection and refinement around the development process.

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# The role of economics in motivating farmers to improve udder health

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## Abstract

Economics is about allocating scarce resources between competing activities to achieve often conflicting objectives within constraints. It applies from farm to global level. As udder health affects the economics of Society as well as the farm business, it will be used to guide policy interventions and market incentives that motivate farmers to improve udder health as well as providing farmers themselves with associated decision support in their own economic interest. Changing agricultural policies that increase the exposure of farmers to global market forces and yet require them to address Society's objectives for higher standards of animal welfare, food quality, safety, security at minimum damage to the environment during a period of increased uncertainty enhances the role of economics. This paper addresses these issues and highlights some of the challenges for economics in motivating farmers to improve udder health in this context. These challenges include providing farm specific decision support in real time, dealing with information shortage and overload, allowing for trade-offs between long and short run goals, managing risk and the need to establish improved udder health within a whole farm context. Tools to address these challenges are briefly described by example. These range from basic cost-benefit analysis of competing udder health activities and diagrammatic representations of trade-offs through to interdisciplinary studies combining biological and economic models with operational research techniques and economic theory to establish the impacts of improved udder health on international trade and on the environment.

**Keywords:** dairy, cow, mastitis, decision making, costs

## Introduction

The Animal Health and Welfare Strategy (AHWS) for Great Britain (Defra, 2004) sets out key roles for economics in support of its vision that animals kept for human benefit are healthy and treated humanely. First it states that Government decision-making in this context must be understood, (based on sound evidence) and be proportionate to the costs and benefits of Government interventions on stakeholders. Furthermore, animal owners also need to understand the costs and benefits of their own actions so that their decision making is better informed and best practice recognised and adopted. It supports this position with the statement that mastitis results in a loss per year of between £137 and £244 million to the (GB) dairy industry (Bennett and IJpelaar, 2003). The point here is that economics is in both the 'carrot' and ‘stick’ of motivating farmers to improve udder health by supporting the business case for farmer action as well as the case for Government intervention if necessary. Some of the ideas raised in the AHWS, including partnership, communication and the principle that ‘prevention is better than cure’ are now incorporated into the EU Animal Health Strategy (2007-13) (European Commission, 2007).

The AHWS was in part a response to the notorious foot and mouth disease outbreak in the UK in 2001, which highlighted shortcomings in governance and that the repercussions of farm animal disease stretch far beyond the interests of farmers themselves (Donaldson *et al.,* 2002). Other farm animal disease epidemics before and since have reinforced the importance of safeguarding the health and welfare of farm livestock and hence the need to ensure that farmers are motivated to act appropriately in their own interests and in the interests of society as a whole. Growing concerns over food security threatened by increasing global demand for food coupled with decreasing natural resources all exacerbated by climate change (Foresight, 2011) is likely to lend considerable weight to this need given the importance of animal health for efficient food production at minimum damage to the environment (Gill *et al.*, 2010). While large exotic disease epidemics such as foot and mouth tend to hit the headlines and so illustrate key principles, it is progress against important endemic diseases like mastitis that offer potential for continuous efficiency gains in response to these global challenges. Higher standards of animal health and welfare brought about through effective actions to motivate farmers to improve udder health and other endemic diseases are also likely to reduce the risks of and/or impact from exotic disease incursions including foot and mouth disease (Bates *et al.,* 2001).

Despite the lessons of the foot and mouth crisis, dairy farmers were quick to shed many of the biosecurity strategies they applied during the crisis even though these were considered to be good practice at all times (Paterson *et al*., 2003). Subsequent work has shed further light on this, suggesting that cattle and sheep farmers in Great Britain see epidemic diseases as the responsibility of external actors and agents (e.g. Government) while endemic diseases are viewed as a problem for ‘bad’ farmers and thus of no concern to those who manage their stock well (Heffernan *et al.,* 2008). This problem of attribution or blame also featured in a pan-European study that focused on control of bovine viral diarrhoea (BVD), an important endemic disease of cattle (Heffernan *et al.,* 2009). These studies implicitly challenge the role of economics in motivating farmers to improve udder health and other diseases, suggesting that regional social, political and psychological factors govern their behaviour. In the case of mastitis, Hogeveen *et al.* (2011) report that farmers do not always respond to economic arguments but put this down to under estimation of their extent or to wider economic considerations. However, successful communication strategies aimed at persuading farmers to adopt improved udder health management in ways that best meet the farmer’s motivational state (Jansen *et al.*, 2010) suggest that a direct approach to behavioural change can be effective without recourse to direct economic arguments.

The above observations suggest that cost benefit analysis (CBA) alone is not sufficient to motivate farmers to improve udder health. However, there is more to economics than CBA. This paper therefore outlines the various roles that economics can play in this context. These must be combined as part of an integrated programme that uses insights from science, sociology, psychology and economics to understand the opportunities of and constraints to alternative actions and then draw on appropriate communication theory and practice to deliver the best outcome for all stakeholders, recognising that trade-offs will inevitably arise. A balance must therefore be struck between competing interests both for the individual farmer and between stakeholders. Economics addresses these situations.

As explained by McInerney (1996), misunderstanding of economics and flawed application has led to unhelpful mis-impressions of the potential roles economics can play in tackling the multidisciplinary problem of animal disease. A working definition of economics in the context of animal disease is therefore an essential basis for exploring its use in motivating farmers to improve udder health. From the farmer's point of view, economics addresses the problem of allocating scarce resources between competing activities in order to achieve objectives within constraints. It can help establish that improved udder health will further these objectives and how this may be achieved, perhaps by diverting resources from competing activities and/or by using existing resources more efficiently. Note that this definition does not rely on monetary valuations, profit maximisation, perfect information or the existence of a right answer. However, it does recognise the need for difficult choices with associated trade-offs. For example, higher profit choices often carry greater risks or damage future asset values. Economics provides an objective analysis of these choices, aiding decision making and helping to justify decisions to stakeholders.

## Costs of mastitis

Most studies in the scientific literature aim to put a 'cost' on mastitis, which may then be used to establish its comparative importance and hence encourage remedial action as illustrated above by the case of the AHWS in Great Britain. Halasa *et al.* (2007) reviewed the published costs of mastitis since 1990 and hence estimated the benefits of mastitis management. They found considerable variation in the estimates but also important omissions in some of the studies leading to a call for a proper economic framework for the analysis of the costs and benefits of the disease.

Hogeveen *et al.* (2011) provide the latest update on the total costs (output losses plus control expenditure) of mastitis. They put the total costs of clinical mastitis at between €61 and €97 per average cow on a farm per year with a further €13 for subclinical mastitis. These results confirmed that average mastitis costs were in the same range as other important causes of variation in efficiency of dairy farming such as reproduction and lameness. More importantly, they explain that what matters is the relative scope for cost effective improvement in the disease. They cite the study of Huijps *et al.* (2008), which reports the range of mastitis total costs on a sample of 64 farms in the Netherlands. The range was from €65/cow/year to nearly €182/cow/year. This suggests considerable scope for improvement on many farms. As most farmers tended to underestimate the total costs of mastitis, they may also fail to appreciate the relative return on investment in resources to improve udder health and so under-invest. However, this is a more difficult figure to establish than the total cost of mastitis, which may partly explain why economics has not yet made as much impression on farmer motivation as it might.

## Optimal control strategies

The issue of how to minimise the total cost of mastitis rather than simply establish its average total cost was set out in principle by McInerney *et al.* (1992). The principle was applied in practice by Yalcin *et al.* (1999). It involved plotting the average control expenditure of herds adopting a particular combination of mastitis control activities against the predicted output losses from mastitis. The result was a loss-expenditure frontier joining the most efficient (lowest output losses) control option at every level of control expenditure. The control option that minimises total costs can be located on the frontier. In Yalcin *et al.* (1999) for subclinical mastitis on 212 farms with high bulk tank somatic cell counts in Scotland it was dry-cow therapy, milking-machine testing and post-milking teat disinfection without udder preparation. Their total costs were about 0.66 of the average total costs for such farms, suggesting that about 0.33 of total costs were avoidable by switching to the optimum control strategy.

The above example demonstrates how economic analysis combined with scientific knowledge, commercial databases and farmers' records can deliver useful decision support information, which if delivered effectively should motivate farmers to improve udder health. However, the approach demands a considerable collective effort and delivers a collective result that individual farmers might reasonably feel fails to fully reflect their particular situation. Modern internet-based health schemes could overcome many of these difficulties and in any case, the economics provides a valuable framework that could help farmers and their advisers make better use of their collective knowledge. Nevertheless, a farm specific approach is called for (Hogeveen *et al.*, 2011). A useful economic framework in this context (a benefit function) was proposed by Tisdell (1995) as an alternative to the framework of McInerney *et al.* (1992) and applied by Stott and Gunn (2008) to BVD. The principles should apply equally well to mastitis and could convert data from simulation models of mastitis pathogen transmission such as that of Halasa *et al.* (2009) into decision support information.

Figure 1 shows two hypothetical benefit functions (curves) based on Stott and Gunn (2008). The upper curve shows a benefit at zero cost of intervention and thus represents an alternative situation to the default scenario, e.g. an improved dry cow therapy as in Halasa *et al.* (2010) or antimicrobial treatment of subclinical intramammary infection as in Van den Borne *et al.* (2010). The lower curve includes the default (reference) scenario at the origin, i.e. the *status quo* where no new intervention takes place and hence no added benefit ensues.

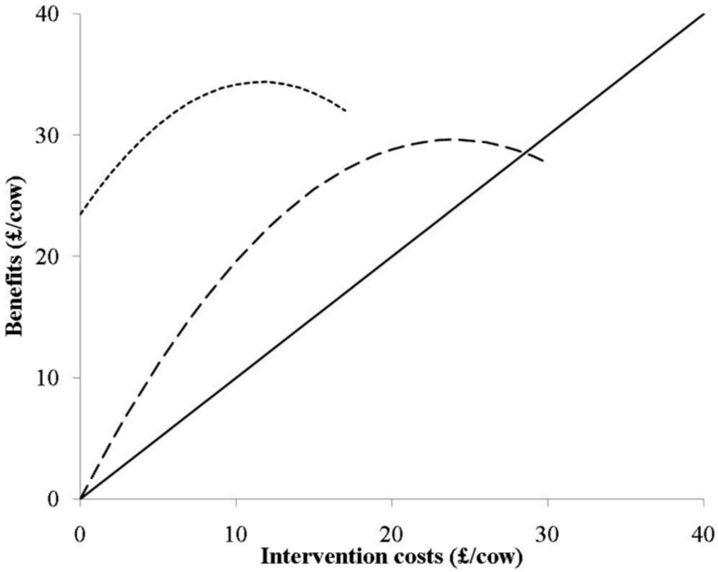


*Figure 1. Hypothetical relationship between the intervention costs and benefits (diseases losses avoided) of two alternative disease scenarios (dotted lines). The solid line is the cost function (break-even line).*

The x-axis represents progressively greater investment in a more or less continuous series of improvement options. In the example of Stott and Gunn (2008) this was biosecurity against the incursion of BVD virus. For mastitis, these might be the 18 management measures identified by Huijps *et al.* (2010) that farmers can use to improve udder health. As intervention costs increase, the marginal benefit declines i.e. the law of diminishing returns applies. Economic analysis therefore follows that of standard production economics (Ritson, 1978) i.e. investment should increase until marginal cost equals marginal benefit. This is the point at which net benefit is a maximum i.e. the distance from the curve to the cost function (solid line at 45°) is greatest. In the upper curve this occurs at about £10 cost, which delivers about £32 of benefit, a net benefit of £22. This is close to the maximum possible benefit and hence lowest level of disease. In the lower curve, the same cost, benefit and net benefit are about £15, £22 and £7 respectively. In this case maximum net benefit occurs below maximum benefit i.e. it is not profitable to control the disease to the maximum extent possible.

The above stylised example shows how, given the necessary data, complex combinations of disease control options, associated scenarios and the interactions between them can be evaluated. (Control of multiple diseases (e.g. mastitis caused by more than one pathogen) with limited funds can also be dealt with, see Stott, 2009). In the upper curve, little extra benefit is gained from additional intervention costs, i.e. the initial scenario substitutes for most of the benefits available from the interventions and adds more besides. Other scenarios might reveal complementarity (as in this example), independence or even competition between scenarios. Using economics to evaluate science-based model outputs in this way therefore addresses farmers' concerns about the need to fit advice to their circumstances rather than apply accepted dogma (or rules of thumb, see next section). As models and associated ICT develop it will become more feasible to address each specific case directly in real time and with confidence. In the meantime this interdisciplinary approach helps to justify the adviser's adherence to or rejection of accepted practice according to farm circumstances. This will strengthen farmers' motivation to improve udder health.

## Cyclical farming systems

Farming is a cyclical process and decisions made in one production cycle often impact on future cycles, increasing the complexity of decision making and demanding dynamic rather than static models to support such decision making. This means that optimal decision making based on current performance may have unintended negative consequences later. Failure to deal with this issue could make farmers wary of short term solutions and hence more reluctant to accept economic arguments to improve udder health. The trade-off between present and future (sustainability) in dairy farming was addressed by Santarossa *et al.* (2004). They showed that while farm net revenues per hectare increased with increasing productivity of the cow this may be accompanied by rising costs per hectare of grassland caused by increasing pressure on the land, soil erosion and hence reduced land values in the long run. The profit maximising level of productivity per cow was therefore unsustainable and needed to be tempered if the productive capacity of the farm land was to be maintained. Although this work focused on improving fertility in the dairy cow, it could be adapted to improvement in udder health. Udder health and fertility are in any case inter-related (Hudson, 2011). As well as the importance of time frame, this example also shows how economics in an interdisciplinary context can capture the whole farm perspective rather than just the cow or a disease and can incorporate the environmental cost to the farmer in terms of the impact of decisions on land value. This latter issue will become increasingly important as the EU seeks to further 'green' the common agricultural policy and so more closely links farm subsidy to the provision of environmental benefits from agriculture (Hart and Baldock, 2011).

The net benefit methodology described in the previous section makes some provision for the cyclical nature of farming through the models that provide the data for the economic analysis. The BVD example of Stott and Gunn (2008) used a 10-year simulation horizon. Results from the mastitis model of Halasa *et al.* (2009) were based on a single quota year after a four year run-in period to stabilise prevalence of infection. However, longer run issues such as the implications of culling on the net returns from replacements were incorporated in the model. These were based on Houben *et al.* (1994), who used a dynamic programming (DP) model to find the optimal replacement strategy for mastitic cows. The DP compares the expected discounted future net returns from keeping a current cow in a given state (e.g. level of mastitis, parity, milk yield etc.) including possible future states of the cow and its successors with a replacement. The technique provides a useful platform for economic analysis of mastitis related decisions that emphasises the future, risk and cyclicity. For a simple explanation of how DP works see Stott *et al.* (2005). A more recent DP application applied to udder health is that of Bar *et al.* (2008). They addressed the problem of balancing realism (complexity) with tractability, transparency and ease of use. These features make DP more likely to be used by farmers for decision support giving it the potential to motivate them to improve udder health. However, they concede that given the cost of implementing an optimisation process, farmers may prefer to use rules of thumb. They therefore go on to use their model to establish such rules, for example, they found that routine treatment of a first case of clinical mastitis was a reasonable policy. A useful compromise between rules of thumb and the use of complex bio-economic models of the individual decision situation may be to represent model outputs in ways that facilitate decision making. An example is shown in Figure 2.

Figure 2 illustrates the trade-off between milk yield and somatic cell count when selecting cows for replacement under particular dairy farming circumstances described in Stott *et al.* (2002) and showing in particular the difference between herds with a mastitis problem that might consider placing more emphasis on culling cows with a high somatic cell count. Other decisions and trade-offs could be depicted, for example insemination and clinical mastitis treatment decisions under various mastitis and milk yield states as dealt with by Bar *et al.* (2008). Frequent updates may be required to reflect significant change in background circumstances but these could be done by experts as necessary on a generic basis, leaving farmers and their advisers to work from the graphs when rules of thumb don't adequately reflect their changing circumstances.

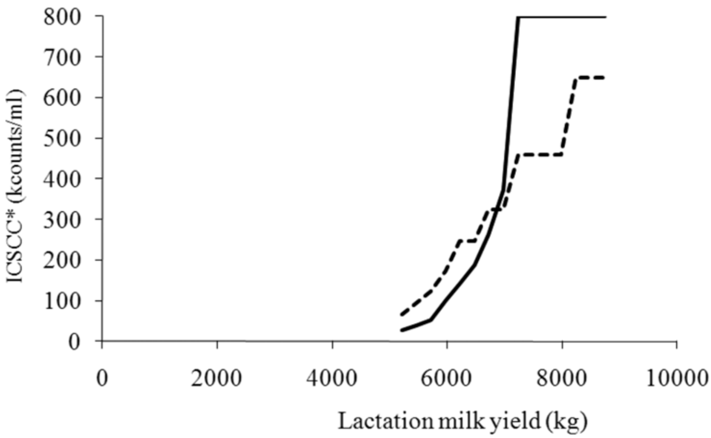


*Figure 2. Keep/replace decision boundaries based on the model of Stott* et al. *(2002) for cows in parity 3. Cows performing to the left and above the lines should be considered for replacement. Dashed line is for herds dealing with mastitis caused by* Staphylococcus aureus*. Solid line is for control herds.*
** ICSCC – individual cow somatic cell count.*

## Whole-farm context

The work of Santarossa *et al.* (2004) described above highlights the need for a whole farm perspective when supporting decisions related to animal disease, which most bio-economic models including DP don't fully address. Farmers must allocate their scarce resources between competing activities only some of which will be disease prevention and control and even fewer directly associated with udder health. Another role for economics in motivating farmers to improve udder health is therefore to place the problem in a wider farm management context. The classic tool for this purpose is linear programming (LP) (Williams, 2008).

There are few examples of LP applied to udder health. Zepeda *et al.* (1998) used it to choose between alternative *S. aureus* testing and control programmes in a single year but this study was not concerned with wider farm management issues. In the application of Stott *et al.* (2003), LP was used to select a biosecurity strategy from competing alternatives alongside other farm management decisions on Scottish beef suckler farms. This work demonstrated that herds free of BVD were able to achieve income targets with less intensive production than herds of unknown BVD status, reducing the pressure of their farming on their farm resources. Putting animal health in this context provides a further opportunity to link farmers' animal health investment with environmental benefits and sustainable production.

The objective of the BVD LP was to minimise deviations from target farm income rather than the more usual objective of maximising farm income. This placed emphasis on the role of biosecurity in reducing risk to farm incomes from disease rather than just on its average net benefit. Consideration of risk is a particularly important aspect of the economic evaluation of animal disease. The mean total costs of most endemic farm animal diseases are above the median i.e. the distribution of total costs is positively skewed (Stott *et al.,* 2010). This means that the majority of farmers suffer below average losses but run the risk of extremely high losses with much more serious consequences than an analysis based on average costs might lead them to believe. Exposing risk and supporting risk management decision making is therefore another role for economics that will help to motivate farmers to improve udder health. Santarossa *et al.* (2005) suggest a novel way in which this may be done, based on insurance industry methods.

## Demand side considerations

Several references have been made above to the public benefits of farmers' private investment in udder health and prevention/control of livestock diseases in general. Economics can assess these wider benefits, which may then persuade policy makers and/or food markets to incentivise farmers to deliver them. For example, Losinger (2005) calculated that an increase of 200,000 cell/ml in bulk tank somatic cell counts in the USA in 1996 represented a mean cost to consumers of US$ 3.1bn and a mean gain to dairy producers of US$ 1.7bn. (Mastitis restricts supply of milk causing prices to rise to the benefit of producers and the detriment of consumers). It follows that consumers (or tax payers on their behalf) could gain by providing farmers with incentives to improve udder health.

The response of the domestic milk market to improvements in udder health and hence the magnitude of associated change in farm gate prices will depend on the characteristics of the market concerned. For example, a country freely able to export the increased supply of milk following a successful national campaign to improve udder health may not experience the reduction in milk prices implied by Losinger (2005). Instead the extra milk appears on the markets of competitor countries, displacing output from producers in those countries who have failed to make improvements in udder health and are therefore disadvantaged. The reverse of course applies. If domestic producers fail to respond to the challenge to improve udder health they are at the mercy of competitors abroad who have. National Governments and representatives of the national milk industries therefore have an incentive to encourage individual farmers to improve udder health. They will use economics to inform their interventions. Partial equilibrium models, which can incorporate the trade and environmental impacts of innovation in a sector of the economy (Ashworth *et al.,* 2009) offer an attractive way to estimate the net benefits of an intervention to improve udder health at national level. These net benefits will accrue to the industry but also to the public in terms of reduced environmental footprint of the industry and improved animal welfare.

## Conclusions

This paper demonstrates that economics offers a wide range of tools and concepts that address the fundamental problem of how best to improve udder health under particular farm circumstances. However, to motivate farmers to improve udder health the most appropriate combination of tools and concepts must be selected and delivered in ways that meet the needs of the farmer concerned. This requires a flexible interdisciplinary approach that will benefit Society as well as the farm business concerned.

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# Effective communication to improve udder health: can social science help?

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## Abstract

Improved udder health requires consistent application of appropriate management practices by those involved in managing dairy herds and the milking process. Designing effective communication requires that we understand why dairy herd managers behave in the way they do and also how the means of communication can be used both to inform and to influence. Social sciences- ranging from economics to anthropology – have been used to shed light on the behaviour of those who manage farm animals. Communication science tells us that influencing behaviour is not simply a question of 'getting the message across' but of addressing the complex of factors that influence an individual's behavioural decisions. A review of recent studies in the animal health literature shows that different social science frameworks and methodologies offer complementary insights into livestock managers' behaviour but that the diversity of conceptual and methodological frameworks presents a challenge for animal health practitioners and policy makers who seek to make sense of the findings – and for researchers looking for helpful starting points. Data from a recent study in England illustrate the potential of 'home-made' conceptual frameworks to help unravel the complexity of farmer behaviour. At the same time, though, the data indicate the difficulties facing those designing communication strategies in a context where farmers believe strongly that they are already doing all they can reasonably be expected to do to minimise animal health risks.

**Keywords:** attitudes, behaviour, animal health

## Introduction

Science and policy often see the challenge of improving animal health on farms in terms of getting people (farmers, vets, visitors to the countryside, consumers) to do things they haven't done before, or to do them differently, or more frequently or more assiduously. The most common tools in this endeavour are evidence-based information and rational argument. But we know from other spheres that people – including us – do not necessarily respond in what we might regard as sensible ways to information, persuasion and rational argument. Other people are very adept at subverting the rationality of our well intended efforts, perhaps with anecdotal counter-evidence: 'Did you know that smoking reduces life expectancy?' 'Well, my mother smoked 20 a day and lived to 104'. Or by preferring not to be confronted with evidence:

as the smoker said when he handed back a packet of cigarettes to the shopkeeper, 'Can you give me a lung cancer pack instead of this impotence pack?'

Social sciences can help us explore and understand the reasons behind the way people behave and the choices they make. These include economics – the first social science to be applied systematically to explain behaviour in the agricultural sector, with farm management as a discipline built around the idea of the 'profit maximising' business. But other, 'softer', social sciences have much to offer, including sociology, with a branch of the discipline, rural sociology, developed to reflect the particularities of social life in rural, largely agricultural communities in $19^{th}$ and early $20^{th}$ century USA and Europe; anthropology, with its focus on the understanding of 'other' cultures, originally applied to studying peoples in other continents and countries, but with its methodologies increasingly applied to analysis of institutional, professional and work cultures closer to home; social psychology, which seeks to understand how other people's views and behaviour affect the way we behave; and communication science which draws on other social science disciplines to analyse how people's interaction with and through available means of communication influences their behaviour.

All these disciplines have been used to help understand how those in the field of animal health behave, and the choices they make and do not make. And policy makers have recently developed a new interest in the insights that social sciences can add to their evidence base. The paper reviews recent applications of social sciences, other than economics, in animal health before turning to reflections from a recent study of the attitudes and behaviour of livestock keepers in England towards practices to reduce risk of animal disease on farm.

## Social sciences and animal health

The idea that attitudes influence behaviour is widespread, leading to the view that if we can first understand, then try to influence attitudes we can influence behaviour. There are many studies in the animal health literature predicated on this idea, most often taking a quantitative approach to the measurement of attitudes. Fairly typical is a USA study of attitudes towards Johne's Disease (JD) control programme (Benjamin *et al.*, 2010). Attitudes were measured through farmers' and veterinarians' responses in a postal questionnaire to a series of statements; the results suggested that those who were better informed or had received training in JD control were more likely to have positive attitudes towards participating in control programmes. In France, Boivin *et al.* (2007) measured attitudes and beliefs about beef cattle, and knowledge of how to handle them, through postal questionnaires, again asking respondents to indicate the strength of their agreement or disagreement with a series of statements. While mean knowledge and attitude levels were generally positive, the authors concluded that variability between respondents and between the level of agreement with different statements (or 'items') indicated scope for improvement in attitudes and handling through training.

Another USA study illustrates the common idea that 'gaps' in knowledge can be identified and then addressed through the provision of information or training. This was a two stage study, in which ten in-depth interviews were conducted to inform the development of a self-completion questionnaire to assess the knowledge of veterinarians about antibiotic resistance, and their perceptions of farmers' use of antibiotics. Conclusions were drawn on the potential for improved use of antibiotics by farmers through filling identified gaps in veterinarians' knowledge about how bacteria acquire resistance and about transmission routes of resistant organisms to dairy cattle, as well as through improved flow of information between veterinarians and farmers (Cattaneo *et al.*, 2009). In another study, a questionnaire survey of beef farmers identified knowledge, attitudes and practices (KAP) in relation to antimicrobial use; the findings were used to make suggestions on development of education and training programmes (Green *et al.,* 2010). A questionnaire survey to explore Swedish pig farmers' information seeking behaviour in respect of contagious diseases found that proximity to an outbreak was an important factor in the likelihood that farmers would seek information, while printed information sent to all farmers was not particularly effective (Noremark *et al.*, 2009).

In the UK adaptive conjoint analysis, a quantitative methodology developed to identify attributes that influence consumers to buy products, was used to explore how farmers and veterinarians assess bluetongue control strategies, through a self-completion questionnaire (Cross *et al.*, 2009).They found uncertainty among both veterinary surgeons and farmers about the efficacy of current strategies, and suggested that dissemination of information to veterinary surgeons and farmers needs to be better coordinated.

In contrast to the above quantitative approaches, a study in Burkina Faso and Mali of attitudes towards cattle breeds used qualitative, ethnographic methods drawn from anthropological traditions. The authors identified cultural preferences for breeds that are susceptible to trypanosomiasis, which makes, they suggest, the seemingly 'rational' recommendation to keep trypanotolerant cattle unlikely to be followed; instead, participatory vector control strategies were designed and implemented (Clausen *et al.*, 2010). In Brazil cattle farmers' attitudes towards and knowledge of endoparasite control were assessed through face-to-face interviews, a lack of knowledge of recommended control practices suggesting the need for better communication strategies (Da Fonseca Delgado *et al.*, 2009). In Benin, goat farmers' objectives in keeping goats, and their perceived production constraints, were studied through participant observation and focus group discussions. The findings were used to suggest priorities for improved management practices (Dossa *et al.*, 2007).

Studies using a mixture of methods, often drawn from different social science traditions, are becoming more common. A study in the Netherlands used focus group discussions, personal interviews and an electronic questionnaire by email to identify factors affecting the reporting of possible CSF outbreaks. Six themes were identified, which suggested specific actions to encourage reporting (Elbers *et al.,* 2010). In the UK, a 'Pathway to disease control' framework, drawing on social psychology and epidemiology, was developed to explore, through thematic analysis of face-to-face interview transcripts followed by logistic regression, factors that influence farmers' behaviour in respect of zoonotic disease control. Among other findings was that a positive attitude towards control is not necessarily translated into specific action, particularly where farmers do not think their action will make any difference (Ellis-Iversen *et al.,* 2010). Other social psychology frameworks used include Theory of Reasoned Action (for example to explore the association between uptake of technology, livestock farmers' attitudes and subjective norms – Rehman *et al.*, 2007, Garforth *et al.*, 2005), and Theory of Planned Behaviour. Farmers' perceptions of the problem of cattle lameness were assessed through a questionnaire and compared with prevalence measured through observation. Lack of perception of lameness was a major barrier to reducing prevalence, suggesting implications for education and industry level action. The study also highlighted key motivators for taking action on lameness, dominant among which was pride in a healthy herd rather than concerns over what other people might think of them (Leach *et al.*, 2010a,b).

While several of these, and other, studies are predicated on the idea that we can identify and then fill gaps in knowledge of animal health issues and of specific measures that can improve health status or reduce disease risk, they also show that communication of information to address 'gaps' is not sufficient. Attitudes to animal disease, confidence in proposed measures, credibility of information sources, confidence in one's current understanding and competence all play a role – and can all be influenced through carefully planned communication. We now turn to a recent study in England to illustrate how these factors can be brought together in a flexible analytical framework that allows animal keepers' views to emerge in a way that can inform communication strategies. Underlying this approach is the notion that planned communication is not just about getting better, more and clearer information across to farmers and veterinarians, but also about influencing the environment in which they make, and addressing the factors that directly or indirectly influence, their decisions and choices.

## Attitudes and behaviour towards managing animal disease risk on farms in England

### *Research objectives and methods*

The British ministry of agriculture (Defra) has identified several ways in which animal keepers can reduce disease risk on their farms. These range from isolating incoming animals until it is clear that they are free of disease, through on-farm hygiene measures to avoid transfer of disease from one animal (or species) to another, to improving fencing to avoid contact with stock on neighbouring holdings. The aim of this research (Garforth *et al.*, 2011) was to improve our understanding of the factors that might motivate farmers to adopt these measures or discourage them from doing so, thus providing an evidence base for ways of encouraging the uptake of measures to reduce the risk of animal diseases taking hold on farms in England in the future.

Potential barriers and motivators, based on recent studies of behaviour and behaviour change relating to livestock management in general and disease control in particular (Jansen *et al.,* 2009, 2010a,b; Ellis-Iversen *et al.,* 2010; Garforth *et al.,* 2005, 2006), include lack of information and knowledge, particularly on how to adapt a particular suggestion or piece of advice to the circumstances of the individual holding or enterprise; perceived economic, social and other costs and benefits of implementing advice; particular characteristics of the individual holding or enterprise; credibility, of the advice itself, the perceived source of advice, or the person or institution giving the advice; attitudes towards science underpinning the advice; the views and actions of respected peers ('subjective norms'); and individuals' confidence in their ability to implement the advice effectively. Understanding which barriers and motivators are operative in relation to specific practices or measures shown by research and testing to improve disease control outcomes is an important step towards designing policies to encourage and incentivise positive behaviour by animal keepers. These were explored through semi-structured interviews with 40 farmed animal keepers in England, selected to represent the main livestock enterprise types (beef, dairy, sheep, poultry, pigs) conducted February-March 2011.

The interviews were audio-recorded and transcribed; transcripts were subject to thematic analysis, within an analytical framework illustrated in Figure 1. Drawing on previous research, we expected that farmers' behaviour in respect of animal disease risk management would be influenced by their:
- knowledge of specific practices;
- attitudes to specific practices, and to disease risk management in general;
- view on the efficacy of specific practices in reducing disease risk (which, in TpB terms, would be reflected in 'outcome beliefs' and hence attitudes) and of disease risk management in general;
- previous experience, and the experience they have heard from others, of specific practices;
- perception of their ability to put specific practices into effect, and their perception of factors that constrain their ability to put specific practices into effect (which, in TpB terms, relates to 'Perceived Behavioural Control'; and in the Health Belief Model, to 'self-efficacy') which may include current habitual behaviour;
- perception of what other farmers in similar situations are doing with respect to disease risk management;
- perception of what other people important to them would think about their doing or not doing specific practices ('subjective norms' in TpB terms).

### *Findings*

The prevailing attitude towards disease risk reduction among the 40 animal keepers is that they are doing all the things that make sense in the particular circumstances of their farm. There were very few instances where interviewees felt they should be doing more; and all had what seemed to them sound reasons for not complying with any practices they had not implemented. A typical response from a sheep farmer commented on the idea that animals

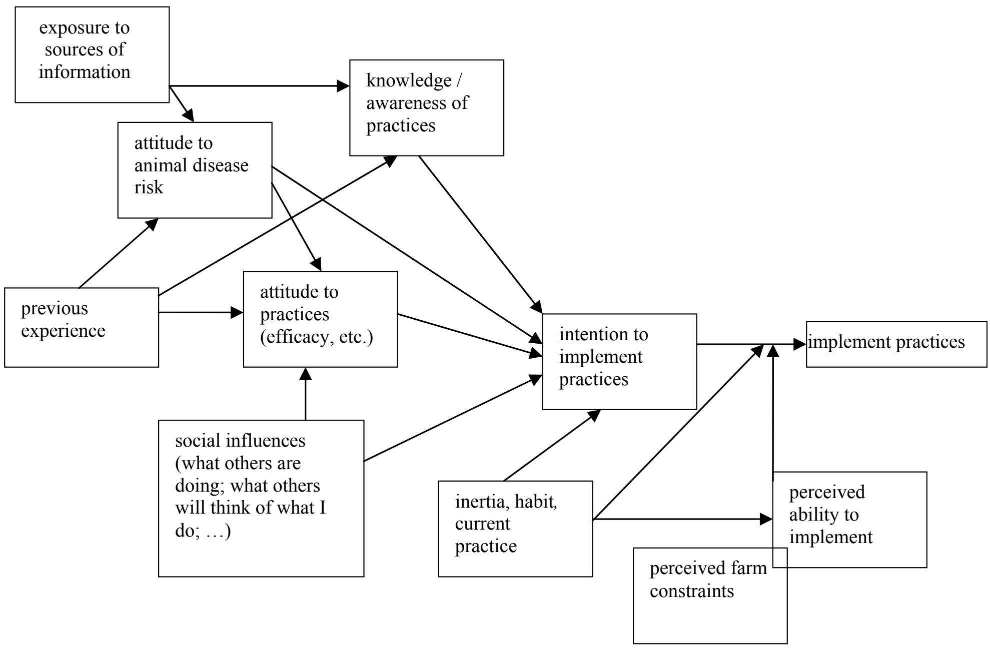


*Figure 1. Working hypotheses linking factors that influence farmers' disease risk management behaviour.*

bought in should be isolated for several weeks before joining the flock: 'in ideal circumstances we would try to and isolate them from the rest of the flock but obviously sometimes that's not practical if you haven't got much grass around and things like that'.

Regarding *knowledge and awareness of* practices, nearly all the interviewees felt they had a good understanding of disease risk control measures, with only one dairy and two pig enterprises saying they did not. For most, their understanding came from their long experience of working with animals rather than formal training, though many also acknowledged the importance of being able to check with their vet on appropriate action to take in the face of new threats to animal health. One larger dairy enterprise pointed out that understanding is not static: new experiences and challenges lead to the acquisition of new knowledge, a theme that was echoed by several other interviewees: 'I have some understanding but something might pop up that I don't know about. Five years ago I didn't know about Johnes disease. It was something that was there but I didn't know much about it. But generally, I am 90% sure of what I am doing because of experience'.

In terms of *attitude to disease risk*, there is widespread recognition that risks can be managed by good husbandry and reduced through implementing those measures that are practical for the individual farmer's situation. However, disease cannot be avoided entirely. This is not seen by livestock keepers as a fatalistic attitude, but as realistic: one can take sensible precautions to reduce some risks, but the nature of livestock keeping is that disease will occur. Furthermore, some risks cannot be managed or controlled by livestock keepers. Whatever they do on the farm, lack of effective control of risks by other people off the farm can undermine their efforts. One specific example was suggested by a poultry keeper: 'they supply plastic trays now and they reckon they disinfect them but they are all stuck together so I can't see how the disinfectant got in there. And that's why we got shut down because of that'. Attitudes to risk are informed by previous experience: in relation to scab, for example, one sheep enterprise volunteered: 'the times when we have had scab in the past, they always caught it on the moor from other sheep … if there is a problem there you are going to pick it up'. The overall picture from the interviews is that livestock keepers' compliance with the recommended practices is strongly influenced by their attitudes to disease risk. Those who feel a particular risk is both serious and manageable are more likely to take action to reduce it – provided they feel also that the costs are both feasible and justified.

It is also clear that many livestock keepers associate risk with the current disease status in the locality. For example several beef and sheep farmers had stopped vaccinating against certain diseases because the risk was low but would consider starting again (after consulting their vet) if disease prevalence increased in the area. A small poultry enterprise said that they take no specific action to stop visitors bringing disease onto the farm, but 'if there was an outbreak of something' they would not want people that have got their own poultry coming in.

*Attitudes to disease risk measures* seem strongly linked to attitudes to disease risk itself. Many interviewees base decisions whether or not to implement specific practices on perceived trade-offs between risk, efficacy and cost, not through any quantification of these factors but through a personal, qualitative assessment – which could also, perhaps, be interpreted as a post-hoc rationalisation of a decision taken on less rational grounds. Typical is this sheep enterprise's explanation of their decision not to vaccinate against bluetongue: 'vaccines are a very good thing, don't get me wrong, I couldn't manage without them but the less you can keep jabbing animals has got to be a good thing. You have to weigh up whether it's worth doing or whether you take a risk and probably this year, at the present time, I'm going to take the risk and not do it this year. If I was further east, I might probably do a bit more, going the other way if the truth were known'.

Another common theme is questioning the efficacy of practices, not because the theory does not make sense but because they cannot be fully implemented or because other risk factors will intervene. Although this was a theme with all enterprise types, it emerged particularly strongly with free range poultry (both smaller and larger enterprises) and seems to have an impact on the credibility of advice and, by association, the source: 'biosecurity between buildings, I think is just a waste of time on a free range farm as birds fly from one range to the next, and wild birds. Very difficult on a free range system as a sparrow can land in one field then flies up and lands in the next field'. The practices which are most commonly applied are those which farmers regard as common sense or simply part of good husbandry. They include vaccination, being selective over sources of new animals, keeping new animals separate from existing stock on arrival, and cleaning buildings between batches. These practices are adopted where the returns seem to justify it.

As for *social influences*, a strong theme coming through the interviews is that what other livestock keepers are doing and saying has relatively little influence on what the interviewees themselves do in respect of disease risk management. They rely very much on their experience and their own idea of what is sensible. The exception is the small number of less experienced interviewees who mentioned specific other people in the sector who they regard either as role models or with superior knowledge to their own. There were several references to carrying out measures because they represent good practice (for example, with reference to hygiene and animal welfare), but these seemed to be more related to personal values than a need to conform with others' views.

Interviewees' disease risk behaviour is strongly influenced by their *previous experience* – of practices that have worked or not worked, of diseases on farm, of working with animals for several years (often for decades), and of the organisations with which they have dealings. If a practice does not work, or is even seen to make things worse, livestock keepers are quick to change, even if the change is one that others might regard as an idiosyncratic choice. As the manager of a medium sized pig enterprises said, in respect of cleaning housing between batches: 'we found out very quickly that the worst thing you can do was to pressure wash and disinfect between batches because we found they built up a certain amount of immunity. So now we clean out and have foot dips going in and out of the farm but we don't pressure wash'.

On the other hand, a bad experience can provide the impetus to change practice: 'obviously because I buy a lot of calves in each year I never quite know what I'm bringing in. Last year, part of it was BVD, I know it stemmed to one farm. So I limit the farms now that I bring in animals from'.

As for *inertia and habit*, while there are frequent comments from interviewees about their having found a pattern of disease risk management practices that work for them, there is no strong indication that they are keeping to a pattern because of inertia. Indeed, most interviewees referred to occasions, often quite recent, where they had changed practice for various reasons. The continuation of habitual behaviour does not seem to be a strong driver of the use or non-use of specific measures. Farmers are willing to be convinced that they should use measures that they currently do not, but they need supporting evidence and advice from trusted sources, which for most is a vet whose opinion they have reason (from previous dealings) to trust.

*Exposure to sources of information* is clearly a necessary (though not sufficient) condition for effective communication. Most interviewees do not go out of their way to search for new information. Those that do, refer to keeping up to date through reading the general farming press, or through their interactions with vets. The international literature on farmer innovation and uptake of new technology often identifies 'other farmers' as a major source of new ideas. In this study, 'other livestock keepers' and neighbouring farmers do not figure prominently.

The dairy enterprises were the exception: three of them were members of discussion groups: although these were focused on issues other than animal health (grassland management, business performance), members do exchange information and ideas about disease risk measures and disease incidence at these meetings.

A consistent theme is the use of the vet to follow up on or check information and advice heard from other sources, whether these be in the local community, on the mass media and Internet, or from national organisations. Some vets are clearly being proactive in this field. One smaller sheep enterprise, when asked about their sources of advice, replied: 'My sister. Local vet practice. Phone them first. We go to regular health-based meetings for sheep and cattle, through the vets. On things like worms. We can pick up some interesting points'. Overall, those who are more exposed to sources of information are in a position to choose to adopt a particular measure. But the influence of that exposure is always mediated by farmers' own assessment of its relevance to their situation, an assessment which is often made after referring to the vet for further information and an opinion.

Many interviewees referred to some particular *constraint or feature of their farm* or enterprise when explaining why they had decided it was either unnecessary or impractical to adopt one of more the disease risk measures. Features making a measure unnecessary include geographical isolation and the protection from neighbouring stock afforded by roads and water courses at the farm boundary; those making a measure impractical include the construction or layout of farm buildings, lack of space, and fragmentation of the holding into several separate parcels. One of the pig enterprises felt that they could not do any more to prevent disease transmission from rodents and other wildlife without compromising their commitment to running an open system: 'if we starting boarding it up it would cause problems and is not the essence of what we are trying to do. It wouldn't cost much but it would compromise the welfare'. More general constraints are cost and time: 'there's a lot of advice in the health plan, things like keeping holes filled in fields so there's no water. It's just impossible, there's not enough hours in the day'; 'I'd like to vaccinate for BVD and I'd like to do quite a few other things but I can't, purely too expensive for the return'.

*Attitude to sources of advice* was not identified in the analytical framework, but it comes through as a strong theme for all enterprise types. Vets are seen as the most credible and reliable source of advice on disease and disease risk management, providing more farmer-focused advice than government sources: 'You've got to get to know your vet. They will come and talk to you. And they wouldn't give the advice that Defra give about washing down, they would know that it doesn't sound right. A vet will give an honest opinion. I would ask a vet first, before a government vet'; 'I think the thing is with Defra's information is that they don't know your farm or your situation so Defra tend, in my opinion, to work a lot more along generally established lines and ideas and they are not always practicable on your farm. Whereas a vet will come out to your farm, look at what you've got, look around and ask questions, and from that he or she will make a judgement on what is actually the best thing to do in your situation'.

## Conclusions and implications for effective communication

Most interviewees accept that action taken on farm and by farmers can reduce the risk of endemic disease breaking out and spreading among their animals. Most also feel they are doing all they reasonably can, within the constraints of their enterprise, to minimise such risks. However, the measures they implement and the rigour with which they do so are influenced by changes in perceived disease risk over time: as the perceived threat of disease increases, measures are applied more rigorously. This reinforces the importance of effective disease surveillance to provide early warning about current and possible future disease threats. Dissemination of credible early warning information through the farming press and vets will help to sharpen livestock keepers' assessment of risk and have both a direct and an indirect effect on the implementation of disease risk measures. Credibility is vital, though: the science on which recommended measures are based must be credible and clearly articulated, and the measures themselves must be seen to be realistic and cost-effective.

Most livestock keepers regard one or more of the measures that Defra would like to see adopted as unnecessary, ineffective or not appropriate to their situation, in part because of a perception that Defra recommend measures that are beyond what would be sensibly required. They see themselves as making rational decisions, based on the circumstances of their enterprise, on what measures to implement, irrespective of what other livestock keepers are doing. There is a high level of confidence in their own knowledge and expertise built up through years of experience. Information is more likely to be acted on if it is seen as relevant to the particular circumstances of the enterprise, and if there is opportunity for generic advice to be mediated through a trusted, local source of expertise. And the fact that most feel they are already have a good understanding of disease risk management suggests that generic information and advice is likely to be ignored as not relevant. One way of encouraging more, and more consistent, compliance with measures might be to focus on risk communication, encouraging livestock keepers to develop a more realistic assessment of risk to their own animals. This should be tailored to the different disease risk situations faced by different enterprises, which needs to involve local (public and private) vets who are widely regarded by livestock keepers as the main players in interpreting and filtering information emanating from national bodies. The farming press could also be used to enhance risk communication to animal keepers, given the wide use and credibility of these media.

Livestock keepers clearly place great importance on being able to access authoritative and trustworthy information relevant to their particular circumstances, which most of them see as available from their local veterinary practice. While they do not automatically act on the advice they receive, they are much more likely to act in response to information that is directed at their particular circumstances. Information and advice that is general and appears as if it is being sent out to all is more likely to be ignored at best, and at worst to reinforce attitudes that advice from central sources is not relevant or practical to the individual recipient. Farmers look to their vets to interpret and contextualise information and advice received from elsewhere.

## Acknowledgement

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# Part 1
# Udder health programs and campaigns

# Effects of health and welfare planning on the use of antibiotics and udder health in European dairy farms

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## Abstract

To improve the sustainability of dairy production it is essential to establish practices that reduce medicine use whilst safeguarding or improving herd health and productivity. Aiming at minimising medicine use through animal health and welfare planning (AHWP), 111 farms in 6 countries were monitored as part of the wider Core Organic ANIPLAN project. For this purpose, the number of udder treatments with antibiotics was recorded. Somatic cell score (SCS) served as an indicator of udder health, and milk yield and average lactation number were calculated at the farm level from milk recording data. Treatment and milk recording data were collected for a one year period before and after a first farm visit. AHWP was carried out either in stable schools or using one-to-one-advice. General linear models for repeated measures revealed a decrease in udder treatments with antibiotics over all farms ($P$=0.004). SCS improved significantly over all farms ($P$=0.025), whilst milk yield and average lactation number remained unchanged ($P$>0.05). Choosing 'udder health' as AHWP focus area (58% of the farmers) did not further improve the parameters investigated. The implementation of an

AHWP process can be regarded as a feasible approach to improve udder health and minimise medicine use without impairment of productivity.

**Keywords:** minimising medicine use, organic dairy cows, somatic cell score, treatments

## Introduction

To improve the sustainability of dairy production it is essential to establish practices to reduce medicine use whilst safeguarding or improving herd health and productivity. The majority of antimicrobial drugs are used for udder treatments (during lactation and combined with drying off; Menendez Gonzalez *et al.*, 2010). Hence, focussing on reduced antibiotic udder treatments may be an effective approach to minimise medicine use in general. Furthermore, mastitis is one of the most frequent health problems in dairy cattle, along with fertility disorders, and causes heavy economic losses (Aeberhardt *et al.*, 1997; Stärk *et al.*, 1997). For these reasons, several national projects have been focussed on reducing antimicrobial mastitis treatments and improving udder health (Bennedsgaard *et al.*, 2010; Ivemeyer *et al.*, 2008; Smolders, 2010; Vaarst *et al.*, 2007).

In the presented study (conducted as part of the Core Organic ANIPLAN project), the effects of a preventive health programme were investigated for the first time in parallel across several European countries. This involved participating farms using animal health and welfare planning (AHWP) with predefined principles (Vaarst *et al.*, 2010) and evaluating the impact on udder health, production and antimicrobial drug after one year.

## Material and methods

The project was conducted from 2008 to 2010 on 111 certified organic dairy farms in six European countries: 15 farms in Denmark (DK), six farms in Norway (NO), ten farms in the Netherlands (NL), 28 farms in Germany (DE), 37 farms in Austria (AT) and 15 farms in Switzerland (CH). The conceptual framework for the wider ANIPLAN project is previously (Vaarst and Roderick 2008). All farms participated voluntarily and agreed to take part in a herd health and welfare planning process. Additionally, 20 organic farms in the UK participated in the project, but are not included in the analysis described here as milk records were not available from these farms.

For the collection of health and welfare data, farms were visited twice with an interval of one year between visits. All on-farm assessments were conducted during the winter housing period. For treatment records and milk recording data two periods were defined for analysis: year 0 being the period of 365 days before the first visit, including the day of the first visit (Y0) and year 1 containing the 365 days following the first visit (Y1). In each country, one to four researchers had been trained in data collection and assessments of animals. The sources of treatment data differed between countries: Data from AT, DE, NL and CH were based on farm records and veterinary bills, respectively, whereas data from DK and NO originated from national central databases (Olsson *et al.*, 2001; Stege *et al.*, 2003). All treatments of udder diseases with antimicrobials (lactation and dry off therapies; AUT) were included in the analyses. A continuous application of drugs connected to the same diagnosis with a maximum of seven days of interruption was counted as one treatment. Treatments per farm were reported as total cases per cow and year. The number of cows per farm (NCOWS) was calculated as the mean over one year based on milk recording data (if there were 11 measurements per year with an average dry period of 6-8 weeks, it was the number of single measurements divided by 9). Information about udder health, average lactation number, herd size and milk yield were gained from milk recording data. In AT, CH, DE, DK and NL 11 milk recording measurements per year were conducted. In NO cow somatic cell count (CSCC) were measured five to six times a year, while milk yield was measured 10 to 12 times a year. Milk recording data were obtained from national central databases (DK, NO) or from private milk recording or breeding organizations (AT, CH, DE, NL). Mean daily milk yield (DMY) and lactation number (LN) were calculated at a farm level as means from all individual cows' test day measurements for Y0 and Y1, respectively. Udder health was described per herd and year as mean somatic cell score (SCS = mean of all ($\log_2$ (CSCC/100,000) + 3) per year; Wiggans and Shook, 1987).

Health and welfare data obtained during the first farm visit were fed back to the farmers by written reports. Based on these data all farms began an advisory process of an AHWP aimed at improving health and welfare and reducing medicine use (Vaarst *et al.*, 2010). The advisory methods differed between countries, but all methods agreed with the predefined principles; the AHWP process: (1) should aim at continuous development and improvement; and (2) should incorporate health promotion and disease handling based on a strategy including: (a) investigation of current status and indications (animal based and resource based parameters); (b) evaluation; (c) action; and (d) review. The process should (3) be farm specific; (4) guarantee farmer ownership; (5) involve external persons and external knowledge; (6) agree to organic principals; (7) acknowledge good aspects; and (8) include a written plan based on the farmer's conclusions or action points (Vaarst *et al.*, 2010). In DE and AT, a farm individual face-to-face process was conducted with at least one additional farm visit after the first assessment. In NL and NO farm advice was given on the day of the first visit and later via phone and/or e-mail. Most of the farms in DK (9; 60%) and CH (13; 87%) were participating in Stable Schools (Vaarst *et al.*, 2007). All farmers were encouraged to choose farm specific focus areas for improvement of their farms. All focus areas regarding udder health (FAUH) were included in the presented analyses.

Changes in production, udder health and treatment data from Y0 to Y1, as well as country-effects and advice-effects by chosen AHWP focus areas, were analysed at the farm level using general linear models for repeated measurements with year as within-subject effect. For production measures (DMY, LN) country was included as a between-subject effect. For SCS and AUT, the inclusion of the udder focus area was additionally considered as a between-subject effect. All interactions were maintained in the model calculations. Distribution of data and distribution of residuals in order to test model assumptions was evaluated graphically using normal-qq-plots. For all analyses, the level of significance was set at α=0.05. All statistical analyses were carried out using PASW Statistics 18 (IBM, SPSS, New York, USA, 2009).

## Results

Descriptive information about production, udder health and antibiotic udder treatments of all 111 investigated farms six European countries are shown in Table 1.

The development of herd production, udder health and antibiotic udder treatments on the investigated farms from Y0 to Y1 is shown in Table 2. Average LN and DMY did not change significantly over all countries. The level of all variables differed between countries significantly. SCS and AUT incidences per cow and year decreased significantly from Y0 to Y1. No specific effect of the focus area udder health (interaction year * FAUH) on development of SCS or AUT could be determined.

*Table 1. Herd size (NCOWS), daily milk yield (DMY), average lactation number (LN), average somatic cell score (SCS), antibiotic udder treatments per cow and year (AUT) and chosen focus area of udder health (FAUH) in the animal health and welfare plan of all 111 farms in the year before (Y0) and after (Y1) the first on-farm assessment.*

| Country (n farms) | NCOWS (n) (mean, range) | | DMY (kg) (mean, ± sd) | | LN (n) (mean, ± sd) | | SCS (mean, ± sd) | | AUT (median, range) | | FAUH (n, %) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Y0 | Y1 | Y0 | Y1 | Y0 | Y1 | Y0 | Y1 | Y0 | Y1 | Y1 |
| AT | 38 | 40 | 22.3 | 22.1 | 3.3 | 3.3 | 2.82 | 2.81 | 0.44 | 0.37 | 29 |
| (37) | 19-62 | 19-61 | 2.8 | 2.8 | 0.6 | 0.5 | 0.62 | 0.57 | 0.00-1.17 | 0.00-1.29 | 78% |
| CH | 29 | 29 | 19.3 | 18.9 | 3.7 | 3.6 | 2.75 | 2.63 | 0.10 | 0.10 | 5 |
| (15) | 12-73 | 10-73 | 3.2 | 2.9 | 0.5 | 0.6 | 0.53 | 0.57 | 0.00-0.30 | 0.00-0.22 | 33% |
| DE | 66 | 69 | 22.1 | 22.1 | 3.1 | 3.0 | 3.47 | 3.40 | 0.48 | 0.48 | 19 |
| (28) | 33-158 | 32-168 | 3.5 | 3.5 | 0.6 | 0.6 | 0.52 | 0.55 | 0.00-1.37 | 0.00-1.01 | 68% |
| DK | 119 | 125 | 24.1 | 24.1 | 2.5 | 2.6 | 3.35 | 3.33 | 0.18 | 0.16 | 4 |
| (15) | 56-184 | 56-182 | 3.5 | 5.1 | 0.3 | 0.3 | 0.16 | 0.26 | 0.06-0.64 | 0.03-0.64 | 27% |
| NL | 73 | 75 | 20.6 | 20.8 | 3.2 | 3.1 | 3.29 | 3.11 | 0.32 | 0.11 | 4 |
| (10) | 39-151 | 40-170 | 3.2 | 3.6 | 0.4 | 0.5 | 0.48 | 0.55 | 0.00-1.98 | 0.00-1.02 | 40% |
| NO | 21 | 22 | 21.3 | 20.6 | 2.3 | 2.3 | 2.42 | 2.41 | 0.08 | 0.17 | 3 |
| (6) | 13-27 | 13-29 | 2.8 | 1.5 | 0.2 | 0.3 | 0.36 | 0.26 | 0.00-0.37 | 0.00-0.21 | 50% |
| Total | 57 | 60 | 21.9 | 21.7 | 3.1 | 3.1 | 3.07 | 3.01 | 0.30 | 0.23 | 64 |
| (111) | 12-184 | 10-182 | 3.4 | 3.6 | 0.6 | 0.6 | 0.61 | 0.60 | 0.00-1.98 | 0.00-1.29 | 58% |

*Table 2. Effects of year and country on the production variables (average lactation number LN, average daily milk yield, DMY) as well as the effects of year, country and focus area udder health (FAUH, if chosen in the health and welfare plan) on somatic cell score (SCS) and udder treatment incidences (AUT) analysed in general linear models for repeated measurements (n=111 farms).*

| Variable | Factor | Effect level[1] | F | *P* | Effect direction for significant factors[2] |
|---|---|---|---|---|---|
| Production | | | | | |
| LN | intercept | | 2,831.96 | <0.001 | |
| | year | within | 0.14 | 0.709 | |
| | country | between | 12.06 | <0.001 | |
| | year * country | within | 0.49 | 0.783 | |
| DMY | intercept | | 3,397.60 | <0.001 | |
| | year | within | 1.04 | 0.309 | |
| | country | between | 4.20 | 0.002 | |
| | year * country | within | 0.40 | 0.845 | |
| Health | | | | | |
| SCS | intercept | | 2,667.56 | <0.001 | Y0 > Y1 |
| | year | within | 5.18 | 0.025 | |
| | country | between | 9.65 | <0.001 | |
| | FAUH | between | 3.29 | 0.073 | |
| | year * FAUH | within | 1.73 | 0.192 | |
| | year * country | within | 0.89 | 0.491 | |
| | country * FAUH | between | 0.68 | 0.636 | |
| | year * country * FAUH | within | 1.50 | 0.196 | |
| Treatment incidences | | | | | |
| AUT | intercept | | 91.21 | <0.001 | |
| | year | within | 8.85 | 0.004 | Y0 > Y1 |
| | country | between | 5.71 | <0.001 | |
| | FAUH | between | 3.00 | 0.086 | |
| | year * FAUH | within | 0.54 | 0.466 | |
| | year * country | within | 1.02 | 0.409 | |
| | country * FAUH | between | 1.50 | 0.196 | |
| | year * country * FAUH | within | 1.54 | 0.184 | |

[1] within = within subject effects; between = between subject effects.

[2] Y0 = period of 12 month before initial farm assessment, Y1 = period of 12 month after initial assessment.

## Discussion

Within the European project ANIPLAN, effects of animal health and welfare planning (AHWP) on udder health and antibiotic udder treatments were analysed on 111 farms in six countries. Regarding the implementation of the AHWP, these were not standardized across all countries, but the overall AHWP principles, as described by Vaarst *et al.* (2010) were fulfilled in all countries. Antibiotic udder treatments were performed in Y0 (year before the first farm visit) slightly less than in Danish and Swiss studies but more frequently than in a Norwegian study, which investigated incidences of antibiotic udder treatments in organic dairy farms (Bennedsgaard *et al.*, 2010; Ivemeyer *et al.*, 2008; Valle *et al.*, 2007). Regarding udder health, the project farms had a higher average herd somatic cell score (SCS) than average Swiss dairy farms (Bielfeldt *et al.*, 2004) but were similar to dairy farms in France (Gay *et al.*, 2007).

The incidence of antibiotic udder treatments (AUT) as well as the SCS decreased significantly within one project year. So, the AHWP may be generally regarded as a suitable approach to enhance udder health, but there was no specific effect of the chosen udder health focus area on the development of SCS and AUT. This may have been the consequence of the short monitoring duration of one year on each farm. Furthermore, the project year 1 started immediately after the first visit and yet the focus areas became evident during a period between 0 and 10 months after the initial visit. For some farms, this period to the end of the AHWP implementation period may have been too short to record any intervention effects. The more unspecific improvements in health and treatment situation consequent of overall planning effects may be due to general farmers' motivation in voluntarily joining a project aiming at reduction of medicine use and improving animal health.

As there were no control farms included in the study, it is unclear as to whether the general public discussion on the use of antimicrobials in farm animal production influenced the results in that some farms may have been reducing antimicrobial use as a response. In countries such as the Netherlands, with a substantial prevalence of MRSA (Methicillin-resistant *Staphylococcus aureus*) (Wagenaar and Van de Giessen, 2009), this could have been influential through increased farmers' awareness resulting in a reduced treatments. The Dutch MARAN-report (MARAN, 2009) and Smolders (2010) showed a decreasing use of antibiotics on Dutch conventional and organic dairy farms in 2009 compared to previous years. In contrast, in other European countries like Switzerland with a low prevalence of MRSA (Huber *et al.*, 2010) the amount of sold veterinary antimicrobials was relatively stable over recent years (Büttner *et al.*, 2009). Nevertheless, the results of the presented study support the findings of previous national udder health studies which determined a possible reduction in use of antibiotics through preventive extension concepts without impairment of health and productivity (Bennedsgaard *et al.*, 2010; Ivemeyer *et al.*, 2008).

In conclusion, the AHWP process which was implemented on the farms may be considered a feasible option to minimise the incidence of antibiotic udder treatments under different condition in European countries without impairment of health, longevity and productivity. However, further long-term studies are necessary to investigate effects of specific advice included in herd health and welfare plans.

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# The Danish udder health campaign: our milk – a pure pleasure

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## Abstract

The Danish milk quality campaign was launched in May 2010. It consists of four main objectives. Geometric bulk tank somatic cell count (BTSCC) should be lower than 150,000 cells/ml, geometric total bacteria count (TBC) should be lower than 5,000 bacteria/ml, no antibiotic residues in bulk tank milk (BTM) and a national reduction in therapy for mastitis with 50% together with an increase in the use of dry cow therapy. The campaign has been initiated by Team Raw Milk Quality of the Cattle Federation, and will continue for a number of years. The associated advisers working in various fields of the campaign will report by means of a hand out being published and delivered every fortnight to all dairy farmers, and in monthly journals. All dairy farms had a BTM sample tested by PCR for 11 mastitis pathogens in the fourth quarter in 2009 and 2010. This annual testing will be continued. In July 2010 the regulations on dry cow therapy were changed. Testing by PCR on samples of the milk production recordings was accepted as proof of infection. Farmers, who wanted to have all cows tested, were given the opportunity to apply for an automatic selection of a milk sample for testing from all cows prior to dry off. Since august 2010, the Danish geometric BTSCC has dropped to historically low value. For all 2010, the average BTSCC was 231,500. Since October 2010, the BTSCC has been lower than 220,000 for more than 5 months. The number of registered cases of mastitis has dropped by approx. 25% since October 2010. Use of intramammary tubes in lactation was reduced by 10% in all 2010, and by 27% in the first quarter of 2011. Use of tubes in dry cow therapy increased in 2010 by 9%. Use of intramammary tubes containing third and fourth generation cephalosporins dropped in 2009 by 33% and again in 2010 by 31% following a recommendation to avoid these antibiotics.

**Keywords:** milk, quality, scc, therapy, antibiotic

## Introduction

Milk quality is important to consumers' trust in milk as a healthy food product. Milk must be produced from healthy cows and contain no residues of antibiotics. For farmers, good milk quality is a way to increase production. (Bennedsgaard *et al.*, 2003).

The traditional way to express milk quality is by use of bulk tank somatic cell count (BTSCC) and total bacterial count (TBC). In Europe, it is usually expressed as geometric mean. In the recent decades, prudent use of antibiotics and the consumption of antibiotics in production animals have had increasingly political attention in many countries.

In recent years, the consumption of third and fourth generation cephalosporins and macrolides has had highly political attention. In May 2008, voluntary guidelines for antimicrobial use aimed to reduce the use of these drugs, were agreed upon between the industry, veterinarians and the authorities. Campaigns for better milk quality or national mastitis programmes are common in many countries. Some of the better known campaigns are Countdown Downunder in Australia, SAMM in New Zealand, The national mastitis control program in the Netherlands (Jansen *et al.*, 2010) and The Norwegian mastitis control programme (Osterås and Sølverød, 2009).

One of the major impacts on milk quality is the national regulations and payment system to farmers. The latest regulation of the borderline for BTSCC was effected on 1 July 1993, with a decrease of the geometric mean in three months to 400,000 cells/ml (Anonymous, 1993).

The previous milk quality campaign in Denmark was launched in January 2003, with a 2-year campaign having special focus on spreading knowledge on reduction of BTSCC through various fact sheets on milking hygiene, milking procedures, stall design, feeding and therapy. The campaign was followed by the dairy industry with a change in payment with additionally 2% payment for BTSCC ≤200,000 cells/ml, additionally 1% for >200,000 and ≤300,000, no addition for >300,000 and ≤400,000, and subtraction of 4% >400,000. The hope of that campaign was to reduce the BTSCC to a level lower than 200,000 cells/ml, but as can be seen from Figure 1, the campaign had only partial success. In December 2008, the largest dairy in Denmark started testing of SCC on every consignment..

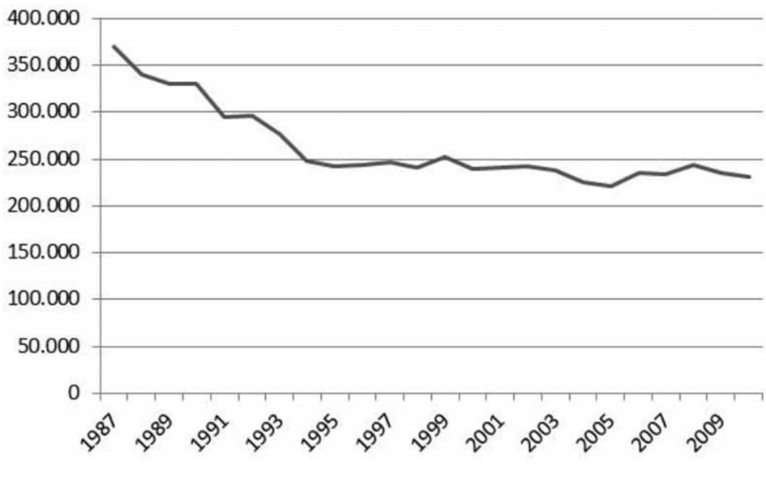


*Figure 1. Yearly geometric mean BTSCC in Denmark from 1987 to 2010.*

In this paper we will focus on BTSCC and the development in treatments for mastitis and the consumption of antibiotics as these are the first author's main advisory tasks.

## Materials and methods

Milk quality in Denmark is surveyed, and quality problems are handled by advisers at the Knowledge Centre for Agriculture, Cattle, Department of Meat Production, Animal Welfare and Raw Milk Quality. In May 2010, we decided to start a new milk quality campaign, with the main purpose to change farmers' attitude towards modern foodstuff producers. To put more emphasize on the campaign we designed a logo and a clear slogan 'Our milk – a pure pleasure' (Figure 2). We stated a few clear goals for good milk quality (Table 1) and did not set any deadline to fulfil these goals. All farmers were introduced to the campaign by letter of information on the goals, signed by the Director and Chairman of the Knowledge Centre for Agriculture, Cattle.

Every fortnight, all cattle producers in Denmark receive a 4 page A4 folder with news from the Knowledge Centre for Agriculture, Cattle, advisors on cattle and topics on crops. The campaign started with a special edition of this folder on Milk Quality.

*Figure 2. Danish milk quality campaign logo.*

*Table 1. Danish milk quality campaign goals.*

| Campain parameter | Goal |
|---|---|
| Bulk tank SCC | <150,000 |
| Total bacterial count | <5,000 |
| Antibiotic residues | 0 |
| Therapy for mastitis | 50% reduction |
| Dry cow therapy | Low increase |

After the introduction of the campaign, the traditional information from the advisers of the Raw Milk Quality team was intensified in the various journals and newspapers to dairy farmers. Also presentations at dairy meetings and meetings with farmer groups are highly focusing on the goals of the milk quality campaign. Advisers and veterinarians are being informed by e-mail with the information to focus on Milk Quality in the contact with the farms.

The campaign was launched concurrently with a major change in the veterinary advisory system in Denmark. Farmers have had the possibility of receiving antibiotic medicine for retreatments of cows in cases where the veterinarian had initiated the treatment, if the farmer had a monthly Herd Health visit by the veterinarian. The farmers have also had the possibility of initiating antibiotic therapy to adult cattle with certain actual diseases known in the farm if the veterinarian made a weekly Heard Health visit, with investigation of certain animals at risk, ex new calving cows, cows before drying off and newborn calves. In July 2010, Herd Health schemes were made mandatory to herds exceeding 100 cows. Farmers were able to continue without the possibility to retreat cows with antibiotics with two annual Heard Health visits by the veterinarian or they could choose a module with a monthly visit system with access to doing repeated treatments or a module with weekly visits with access to start treatments of more known diseases. For mastitis therapy, the July 2010 regulations stated that also veterinarians should take a milk sample if therapy for mastitis was initiated with other drugs than simple penicillin's. Since 2006, this was only a demand for farmers if they started therapy of mastitis without involvement of a veterinarian.

Since 1995, dry cow therapy with antibiotics in Denmark has only been allowed if a milk sample taken within the last 35 days has shown infection in at least one quarter. In the July 2010 order this infection could also be tested by use of PCR. In 2009 the Danish milk quality laboratory, Eurofins, Holstebro, Denmark, started to perform the Real-Time PCR test, Pathoproof®, Thermo Fischer Scientific, Espoo, Finland.

From July 2010, it was made possible for farmers to select cows for PCR investigation prior to drying off by PCR testing on the routine milk production recording samples. From the Danish Cattle Database farmers can select individual cows prior to a test day or make an automatic selection of all cows expected to be dried off within the next 35 days from milk production recording testing.

In accordance with the order of *Streptococcus agalactiae* surveillance in Denmark all farms have to have a bulk tank milk (BTM) sample tested for *S. agalactiae* on an annual basis. During the last three months of 2009 and 2010, all farms had the BTM tested by PCR, and we provided the results of the Ct-values for all 12 genes in the test by letter to all milk producers and made the results available in the Danish Cattle Database for producers, advisers and veterinarians.

BTSCC is tested per consignment and result is used in the payment system by the biggest dairy company Arla. Some of the minor dairies take only one BTSCC sample each week.

TBC is measured once every 2 weeks. BTM is tested once every week for antibiotic residues at the Laboratory Eurofins, by Delvotest® (Delvo SP-NT, DSM, Delft, The Netherlands). All trucks with milk for drinking and all silos at the dairy industry are tested by Betastar® (Chr. Hansen A/S, Hørsholm, Denmark) before milk is processed. If a Betastar® test is positive all farmer samples related to the truck or silo is tested by Delvotest® at the Laboratory Eurofins. If the initial Delvotest® is positive the samples is retested, if both test is positive the producer is orientated and the sample is send to verification. The farmer gets a penalty from the Dairy also in cases with antibiotics content lower than the maximum residue limit (MRL) values.

Data on mastitis therapy from both farmers and veterinarians is reported to the Danish Cattle Database, for mastitis treatment retreatments with 8 days is not calculated.

In Denmark, data on antibiotics distributed to the farmer from the drugstore, delivered from the veterinarian or used by the veterinarian is reported to Vetstat. Annual publications on the use of antibiotics and bacterial resistance in both humans and production animals are reported in DANMAP. More detailed calculations from different periods or different groups of antibiotics can be provided by Vetstat to the Knowledge Centre for Agriculture, Cattle.

## Results

### *BTSCC*

Since week 35 in 2010 there has been a sudden but constant decrease in BTSCC in Denmark at around 5,000 to 10,000 cells/ml (Figure 3). The actual figures and reduction in percentage for the BTSCC in 2009, 2010 and first half of 2011 can be seen in Table 2.

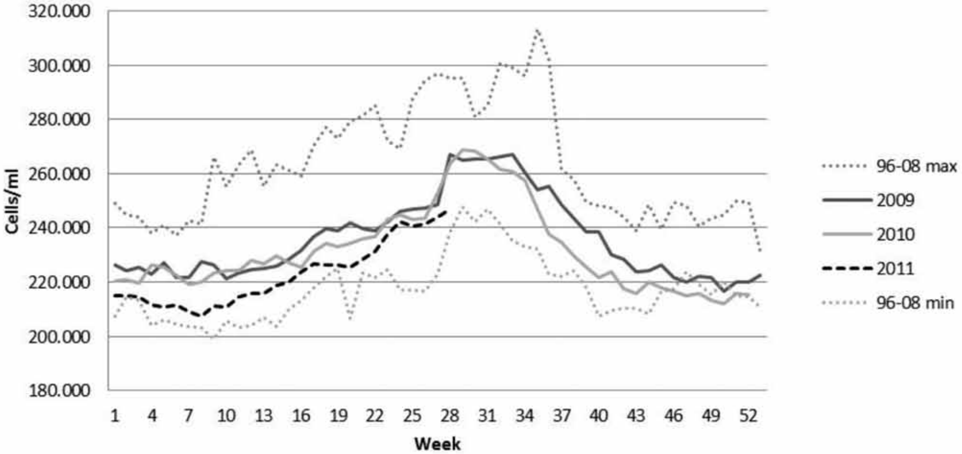


*Figure 3. Weekly geometric mean bulk tank somatic cell counts in Danish dairy herds 2009 to 2011. For the period 1996 to 2008 maximum and minimum values.*

*Table 2. Bulk tank milk quality parameters, use of antibiotics for mastitis and dry cow therapy, and number of BTM and individual cows tested by PCR in Danish dairy herds in 2009-2011.*

| | 2009 | 2010 | | First half 2011[1] | |
|---|---|---|---|---|---|
| Number of herds | 4,311 | 4,138 | -4% | 3,953 | |
| Number of cows | 574,000 | 573,000 | | 572,000 | |
| BTSCC | 235,300 | 231,500 | -1.6% | 221,000 | -3.6% |
| TBC | 8,090 | 9,530 | +18% | 9,300 | -2.1% |
| Positive BTM > MRL | 94 | 59 | -37% | 30 | 15% |
| Mastitis treatments | 235,488 | 215,669 | -8% | 90,331 | -18% |
| DCT | 61,015 | 68,204 | +12% | 36,813 | +21% |
| Imm tubes lactation | 956,266 | 864,583 | -10% | | |
| Imm tubes dry cow | 384,631 | 417,701 | +9% | | |
| Imm tubes $3^{rd}$+$4^{th}$ gen. cephalosporins | 79,416 | 48,802 | -31% | | |
| PCR - BTM | 7,096 | 7,047 | | 1,087 | |
| PCR Individual cow | 848 | 7,468 | | 15,294 | |

[1] Changes are calculated compared to first half 2010.

### *TBC*

The actual figures and variation in percentage for the TBC in 2009, 2010 and first half of 2011 can be seen in Table 2. Since 2003 there has been a constant increase in TBC in Denmark, so for the first time in many years there is a tendency of a beginning reduction in the 2011 first half of

### *Antibiotic residues in BTM*

The total number of Delvotest® positive BTM samples in 2010 decreased by15%. Around ten samples each year of the initial Delvotest® positive testing are not verified to contain antibiotics. The total number of positive BTM samples above MRL value is seen in Table 2. The number of cases above the MRL value was reduced with 37% in 2010 compared to 2009. This development is promising and related to a concentrated effort to reduce the positive samples in AMS systems where the percentage of herds with a positive sample in 2010 was reduced from 10% to 7%.

### *Mastitis and dry cow therapy*

From 2009 to 2010 the number of mastitis treatments was markedly reduced by 8%. In the quarters 1 (Q1) to 3 (Q3) of 2010 the reduction was 4% whereas in quarter 4 (Q4) the decrease was remarkably 20%. This reduction is continued in the first half of 2011 with a reduction of 18%. The number of cows getting dry cow therapy with antibiotics is continuously increasing month by month with 12% in 2010 compared to 2009 and with a further 21% increase in the first half of 2011.

### *Antibiotic consumption*

The total consumption of tubes for mastitis and dry cow therapy is seen in Table 2. For tubes used in the lactation for mastitis therapy the reduction in 2010 in Q1-Q3 was 2% whereas a markedly reduction in Q4 reached 33%. This reduction has continued in 2011 Q1 with a reduction of 27%. For tubes for dry cow therapy the increase is steady over the year, with a total increase in 2010 at 9%. $3^{rd}$+$4^{th}$ generation cephalosporin tubes is only used for therapy in the lactation and as such the numbers is included in the total number of tubes used in the lactation for mastitis therapy mentioned above. The number of $3^{rd}$+$4^{th}$ generation cephalosporin tubes used in Denmark was reduced by 33% from 2008 to 2009 with a further marked reduction of 31% from 2009 to 2010.

## Discussion

The results in this paper from 2010 especially in the last period and in the first half of 2011 shows a very positive development in milk quality. In accordance with the goals set in the milk quality campaign 'Our milk- a pure pleasure'. The geometric average BTSCC decreased with 5,000-10,000 cells/ml, the TBC is beginning to decrease, antibiotic residues in milk is decreasing, mastitis therapy is decreasing by up to 20% and the dry cow therapy is increasing. The use of tubes with third and fourth generation cephalosporins is again in 2010 decreasing with more than 30%.

Although the results is in accordance with goals set in the milk quality campaign we know for sure that a lot of other factors can have resulted in this positive development in milk quality.

After a period with big expansions the number of new buildings and expansions of dairy herds in Denmark have been influenced dramatically by the financial crisis in 2009. The autumn of 2010 was colder than normal without periods of hot weather. The change in Herd Health regulations in July 2010 with more farmers choosing a Herd Health scheme allowing them to start treatments without calling the veterinarian is a big change in the way the decision of treatment or no treatment at made. Also the possibility of not being obliged to report treatments to the Danish cattle database can have influenced the numbers of treatments. We have calculated that around 200 herds have stopped reporting regular numbers to the cattle database. On the other hand the numbers of tubes used follow the curves of treatments with the same reductions and these curves is not influenced by a possible change in reporting of treatments. Also the curves for dry cow treatments follows the number of dry cow tubes so this is also an indication of only minor changes in the reporting practices to the Danish Cattle Database.

The introduction of PCR test on BTM has been well accepted by Danish farmers and advisors.

The relatively low number in the first half of 2011 shall be seen in relation to the fact that around 4,000 samples for the yearly screening for *S. agalactiae* will be performed in Q4 of 2011

The PCR results from BTM are used on farm as an indicator of the dominating mastitis problems in the herd ex. *Streptococcus uberis*, *Staphylococcus aureus* or *S. agalactiae*. Actions can be taken towards prophylactic of the dominate pathogens and extra diagnostics on individual cows or follow up BTM samples can be initiated.

PCR on individual cows has been used in the follow up of *S. agalactiae* herds for eradication programs. To our knowledge this has occurred in 22 herds in 2010 with around 2,600 samples and 4 herds with around 600 samples the rest of the samples in 2010 and especially in 2011 indicates the use of PCR sampling from individual cows prior to dry of. The PCR testing was accepted by the authorities for these dry cow investigations in July 2010. Earlier these investigations had been handled by the local veterinarians in their laboratories. The number of testing's in the first half of 2011 indicates that in 2011 around 50% of the obligatory investigation prior to dry cow therapy in Denmark will be performed by the PCR testing.

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Østerås, O. and Sølverød, L., 2009. Norwegian mastitis control programme. Irish Veterinary Journal 62: 26-33.

# 'DEMO project udder health': a first step towards a better udder health and milk quality in Flanders (Belgium)

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## Abstract

Since 1999, the average bulk milk somatic cell count has increased 1 to 2% per year in Flanders. Inspired by this trend, Milk Control Centre Flanders and M-team$^{UGent}$, together with the farmers' organizations and the Flemish Cattle Breeding Association, decided to design a two-year program to work on udder health and milk quality. This so-called 'demonstration project' is primarily subsidized by the Flemish government and the European Union and purely emphasizes the transfer of existing knowledge towards the Flemish dairy farmers and its implementation in the farmers' daily practices through communication and education. Communication to dairy farmers and their advisors was established by general means such as an informative website (www.uiergezondheid.be), a digital newsletter, and roadshows (4 farmers' meetings and one advisors' meeting full of inspiring lectures). Additionally, 20 groups of 10 to 12 dairy farmers were brought together on farm of one of the participants to discuss udder health and milk quality. This paper describes the background, aims and structure of the project as well as some experiences gained throughout the project.

**Keywords:** communication, knowledge transfer, mastitis

## Introduction

Mastitis affects a high proportion of cows throughout the world and is without doubt still one of the most costly diseases for the dairy industry (Bradley, 2002). The financial losses associated with mastitis are mainly incurred by milk production losses, treatment costs, and culling (Huijps *et al.*, 2008). Additionally, farmers supplying milk with high bulk milk somatic cell count (BMSCC) may be losing out on bonus payments as well as incurring penalties. Mastitis also accounts for the largest proportion of antibiotic drug use in the dairy industry, strongly harming the image of milk as a high quality product. Indeed, herds with higher BMSCC have a higher risk of antibiotic residue violation because of their increased antibiotic usage (Ruegg and Tabone, 2000). Clinical mastitis has, in addition, its implications for animal welfare (Bradley, 2002). Treating infected cows also increases labor usage (e.g. time and efforts) and causes stress of which the consequences should not be underestimated as they are both perceived as the two most annoying aspects of mastitis by farmers (Jansen *et al*., 2009).

In many countries and regions including Flanders (Belgium), the average BMSCC has again increased over the years, indicating that an increasing proportion of lactating cows suffer from subclinical mastitis. In Flanders, the average BMSCC increased from 196.000 cells/ml in 1999 to 222.000 cells/ml in 2008 (Figure 1) and this trend was expected to continue if no action was undertaken. Still, several studies have shown that enough technical knowledge is currently available to be successful in improving and maintaining the udder health situation on a dairy farm. It is however very striking that still too many farmers, even though it would considerably improve their results, do not implement those effective mastitis management practices. This strongly suggests a lack of communication and transfer of the existing knowledge towards farmers (Jansen *et al*., 2010). In order to create some dynamism around udder health and milk quality in Flanders, between July 2009 and July 2011, a so called 'demonstration project' on udder health and milk quality was executed. This paper describes the objectives and structure of the project as well as the experiences gained in this project.

There obviously seems to be more to gain by presenting the current knowledge on mastitis prevention and control in a way that it can be readily implemented in practice rather than by increasing the amount of existing knowledge. Therefore, it was decided to purely emphasize on the transfer of knowledge towards the Flemish dairy farmers and its implementation in the farmers' daily practice through communication and education.

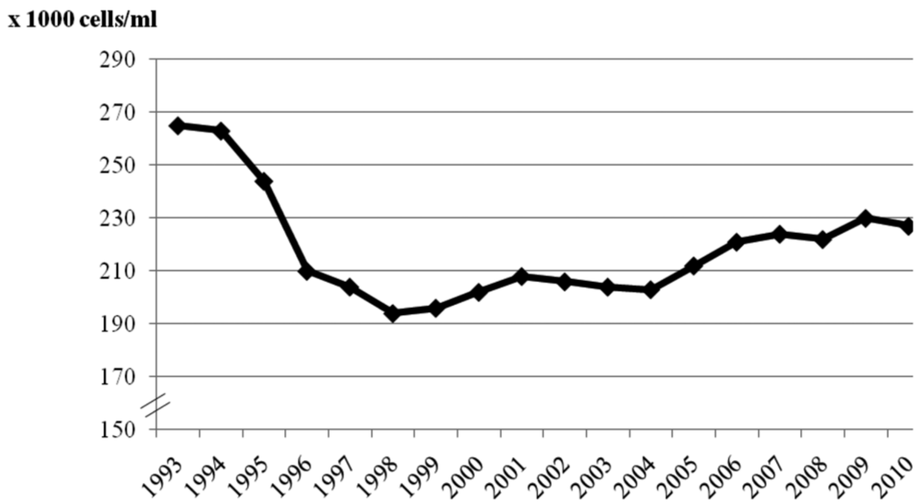


*Figure 1. Average bulk milk somatic cell count in Flanders (Belgium) between 1991 and 2010.*

The main objectives of the project were:
1. To disseminate information and relevant knowledge in the field of udder health and milk quality towards dairy farmers, veterinary practitioners, advisors active in the dairy industry, agro-business, and pharmaceutical industry.
2. To bring together dairy farmers to discuss udder health and milk quality issues.
3. To establish a knowledge center providing information on udder health and milk quality to dairy professionals including consultants, farmers, veterinarians.

This paper describes the Flemish udder health demonstration project.

## Structure and coordination

The 'DEMO project Udder Health and Milk Quality' was coordinated by Milk Control Centre Flanders and the M-team$^{UGent}$. Milk Control Centre Flanders is a non-profit organization that is responsible for the daily milk quality control (coli count, total bacterial count, somatic cell count) and composition (fat, protein, lactose and urea) of the milk produced in Flanders. In addition, it determines the composite milk SCC of milk samples collected as part of the voluntary Dairy Herd Improvement (DHI) program ran by the Flemish Cattle Breeding Association. Milk Control Centre Flanders also carries out farm visits primarily focussing on milking equipment and technical aspects of the milking procedure. The M-team$^{UGent}$ is part of the Faculty of Veterinary Medicine from Ghent University (Belgium) delivering extension services on udder health and milk quality to farmers throughout Flanders. All members of the M-team$^{UGent}$ are involved in scientific research as well. The members of both Milk Control Centre Flanders and M-team$^{UGent}$ give lectures and training to veterinarians, dairy farmers and their advisors on the basic principles of mastitis prevention and control and the economic profit of good udder health. Other partners that supported the project were the Flemish Cattle Breeding Association (CRV Delta, Oosterzele, Belgium) and the farmers' organizations Boerenbond and ABS. The project was fully subsidized by the Flemish Government and the European Union

## Website

An informative website (www.uiergezondheid.be) containing a modified version of the 10-point prevention and control program from the NMC (www.nmconline.org) was established. Via the website, farmers and their advisors were kept abreast of topical matters on mastitis and milk quality related to Flanders as well as other countries such as the Netherlands, France, Canada and United States. Time to time, an interesting topic was discussed more in depth. Topics that passed in review were related to bedding materials (e.g. advantages and disadvantages of sand bedding), different causes of mastitis (e.g. yeasts, *Klebsiella* spp, Mycoplasma, *Staphylococcus aureus)*, bacteriological culturing (e.g. importance, reasons for culture-negative results), treatment of clinical mastitis (e.g. use of anti-inflammatory drugs, how to check whether or not a cow is cured), approach of subclinical mastitis (e.g. overview of factors that influence the cure rate, why chronically infected cows should be culled), milking technique (e.g. udder preparation, teat disinfection after milking), milking equipment (e.g. when to replace teat liners, dynamic milk equipment testing). The website attracted on average 500 visitors per month.

## Roadshows

Four roadshows for farmers and one for dairy advisors' were organized throughout Flanders. The meetings took a variety of format. On the farmers' meetings short practical presentations were given by experts in the field of mastitis and milk quality as well as by a top dairy farmer willing to share his experiences with his colleagues. Topics that passed in review on these meetings were the prevalence of mastitis in Flanders, prevention and control of mastitis, heifer mastitis prevention and control, Mycoplasma mastitis, *Klebsiella* mastitis, coagulase-negative staphylococci as cause of mastitis, and improvement of udder health through genetic selection. Two of the four farmer meetings included an exhibition with different companies involved in several branches of the dairy industry Almost 1,200 dairy farmers attended at least one of the meetings. The advisors' meeting was more scientifically oriented and compiled newly gained insights in mastitis and milk quality research and extension services. The seminar was attended by approximately 120 veterinarians and representatives of the feeding, pharmaceutical and agro-business industry.

## Study groups

Based on the experiences from the five year program conducted in The Netherlands (www.UGCN.nl) between 2005 and 2010, it was decided to bring together small groups of farmers to discuss udder health and milk quality which was expected to be highly efficient and effective. Therefore, 20 study groups consisting of 10 to 12 dairy farmers were organized on farm of one of the participants. A couple of months before these on-farm meetings, all participating farmers were asked to complete an on-line questionnaire to get more insight in their attitude and behavior in relation to udder health. In total, 318 dairy farmers fully completed the questionnaire of which 51% (n=162) participated in this project's study groups. Each of the meetings started with a visit of the barn and cows, discussing the management practices. The concept of these on-farm meetings was overall highly appreciated. Sharing experiences and discussion among participants was considered to be of high value. Subjects dealt with during these meetings were: milking machine and milking technique, treatment of clinical mastitis, bacteriological culturing of milk, dry cow therapy, and the approach of subclinically infected cows based on the DHI-records. The results of the questionnaire were discussed as well.

Preliminary analysis of the data indicate that even the more basic principles in milking technique and treatment of clinical mastitis are not part of the daily routine of a large proportion of Flemish dairy farmers. It is, for instance, striking to see that only 13% of the farmers replaced the teat liners in time. Also, only a minority of the farmers seemed to be familiar with a standardized treatment protocol for clinical mastitis as could be deduced from the high within-farm variation in both treatment duration and route of application for cases of (mild) clinical mastitis. Still, most farmers (93%) used blanket-dry cow therapy and disinfected all teats after milking with dip or spray (85%). From the study groups, we learned that farmers do not always fully understand the importance and rationale behind some of the mastitis prevention and control which corresponds well to the experiences from the Dutch Udder Health Program. This most probably (partly) explains why they are not always implementing them in their daily routine (Jansen *et al.*, 2010).

## Future

In the upcoming months, the farmers that participated in one of the study groups will be asked to complete a short questionnaire on different aspects of mastitis prevention and control. This will allow us to evaluate whether or not and to what extent the study groups changed the farmers' attitude and knowledge regarding mastitis.

Additionally, as a kind of continuation to this project, a new project on the (mis)use of antimicrobials on dairy farms in relation to udder health will soon be launched. The goal of this project is to guide individual farmers and their advisors towards a more responsible use of antibiotics in the treatment and prevention of mastitis. In the final stage of that project, we hope to be able to conclude that regular monitoring of the udder health on a dairy farm and appropriate optimization of the farm management, results in a better udder health and better use of antimicrobials.

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# Improvement of udder health following implementation of herd health plans in organic dairy farms: results of a pilot study in Germany

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## Abstract

The present study aimed at assessing the effects of herd health plans (HHP) on animal health in 27 organic dairy farms over a period of up to three years; 13 other farms served as control farms. Farms were visited between 2006 and 2010 and herd health planning consisted of farm-individual intervention measures which were based on baseline recordings of health indicators and a weak-point analysis of the housing environment and the herd management. Mixed models for repeated measures were used to analyse the effect of the group (intervention vs. control group) and the year, as well as their interaction. Udder health significantly improved on 14 farms which implemented measures from their HHP promptly, compared to control farms (n=26). In intervention farms, the decrease in treatment incidence of clinical mastitis was more pronounced than in the control group (35.2 -> 16.1% vs. 22.8 -> 19.4%; interaction g*y: *P=0.01*) and also the somatic cell score (SCS) tended to improve (3.71 -> 3.42 vs. 3.25 -> 3.26). The percentage of cows in a herd with an somatic cell count higher than 100,000 cells/ml milk, as indicator for the incidence of subclinical mastitis, significantly improved in the intervention farms (*P=0.042*). When the difference from the baseline status in 2006 was analysed (with baseline situation as a covariate), there was a significant intervention effect on the change in SCS (Δ-LSMEANS; intervention: -0.200 vs. control: +0.016; *P=0.023*) and in the incidence of subclinical mastitis (Δ-LSMEANS; intervention: -4.43 vs. control: +0.98, *P=0.032*). Average herd age and average milk yield remained unchanged during the study. In conclusion, the results demonstrate beneficial effects of farm-individual herd health plans on several indicators of udder health.

**Keywords:** dairy cattle, animal health, intervention study, knowledge transfer

## Introduction

In organic livestock farming the prevention of animal health problems is of major importance. This can be achieved by choosing appropriate housing conditions as well as suitable breeds, offering high quality feedstuffs, allowing grazing or access to outdoor runs and considering proper stocking densities. Focusing on preventive measures, herd health plans (HHP) could be a helpful tool to optimize the health situation in organic dairy farms (Hovi *et al.*, 2003). The presented study aimed at evaluating the effects of farm-individual herd health plans on indicators of udder health.

## Material and methods

### *Study design and farms*

In total 40 farms were included in the study. The farms were located in different regions of (organic) milk production in Germany and fulfilled the following criteria: main breed Holstein Frisian, minimum herd size 30 cows, cubicle housing, participation in milk recording scheme and conversion to organic farming more than two years before the start of the study. Baseline health assessment took place in summer 2006 and in October 2006 all 40 organic dairy farms were revisited and herd health plans were implemented on 27 out of these farms; choice of a farm as intervention farm depended on the interest of the farmer in the concept of herd health plans. The study aimed at applying farm-individual intervention measures during repeated farm visits. This concept was adopted from a previous successful intervention study on lameness (March *et al.*, 2008). Udder health was an important topic in the HHP of 20 farms. Whether this concept was successful and effective was tested by comparing the development of selected indicators for udder health in intervention vs. control farms.

### *Data sampling – treatment data – milk recordings*

The on-farm assessments were conducted from summer 2006 to late winter 2009/10 and they included animal based parameters in the herd (e.g. lameness, body condition, cleanliness).

Information on housing conditions (e.g. dimensions and cleanliness of bedding) and management (health and feeding management) were collected using checklists and questionnaires. Based on milk recording data the number of cows per farm was calculated as the mean over all testing data in the milk recording year. The average age, milk yield, calving interval, age at first calving and information on udder health (somatic cell count (SCC), somatic cell score (SCS) and percentage of cows in the herd with an SCC larger than 100,000 cells/ml) were calculated as means from all individual cows' test day measurements in milk recording years. In order to obtain normally distributed data the mean SCS (=(log2 (SCC/100,000)+3) per year) was calculated (Wiggans and Shook, 1987). Incidences of treatments were calculated using farm records for the years 2006, 2007 and 2008 respectively as number of cases per cow and year. Repeated application of drugs connected to the same diagnosis with a maximum lag of seven days between treatments was counted as one.

***Health planning process***

Animal health problems were identified on the basis of the initial data collection and comparison with predefined target values. These health data were fed back to the farmers at the following farm visit using a benchmarking approach. Interventions measures regarding several categories of herd health improvement were defined in 27 farms, which agreed to participate as intervention farms. Farmers and stockmen were encouraged to choose farm specific topics and areas for improvement. In 20 farms HHP including measures to improve udder health were developed and written down. Herd health in these intervention farms as well as in the control herds was monitored for three years. During this period, four additional farm visits took place in six to twelve month intervals in order to evaluate the effectiveness of the intervention.

***Statistical analyses***

All analyses were performed at herd level. First, all farms with HHP focusing on udder health were considered as intervention group (n=20). In a second step, only those 14 farms were considered as belonging to the intervention group, which actually had implemented measures on the farms promptly until summer 2007, so effects within project duration were expectable. Mixed models for repeated measures were used in order to analyse the effect of the group (intervention vs. control group) and the year, as well as their interaction (group*year) on the chosen parameters of dairy health (PROC MIXED in SAS® 9.1). Similarly we analysed the change of the parameters as difference from the baseline status in 2006 and including the baseline values as covariate. 'Compound symmetry' or 'Autoregressive structure' were used as covariance structure depending on model fit criteria (AIC, AICC, BIC). For all analyses, the level of significance was set at $P=0.05$. All interactions were maintained in the model calculations. Distribution of residuals was evaluated graphically using normal-qq-plots.

## Results

***Characteristics of project farms***

Some characteristics of the project farms are shown in Table 1. Intervention and control farms did not differ significantly for all measures (all $P>0.1$; Mann-Whitney-U).

***Topics addressed in herd health plans and implementation of measures***

Udder health was an important topic in 20 of 27 intervention farms/HHP. 14 farms implemented measures from the HHP promptly (until summer 2007) and in total 17 out of these 20 farms implemented measures until the study's end in winter 2009/10. On average 43% of the measures focusing on udder health were implemented per farm within one year. This level of compliance increased during the next two years to 65%; on average 2 of 3.2 suggested

*Table 1. Characteristics of project farms at the beginning of the study (median, minimum, maximum).*

| | **Total (n=40)** | **Intervention (n=27)** | **Control (n=13)** |
|---|---|---|---|
| Agricultural area in use[1] (ha) | 104 (38-340) | 101 (38-340) | 110 (55-260) |
| Grassland area[1] (ha) | 52 (5-185) | 50 (5-150) | 57 (11-185) |
| Herd size[2] (cows) | 61 (30-158) | 60 (33-158) | 65 (30-135) |
| Age of cows[2] (years) | 5.0 (4.3-7.6) | 4.9 (4.3-7.6) | 5.1 (4.5-5.9) |
| Milk yield[2] (calculated standard-lactation yield, 305 days in milk) | 6,619 (4,667-9,211) | 6,649 (4,911-9,211) | 6,558 (4,667-7,564) |
| Intercalving period[2] (days) | 398 (374-461) | 399 (374-450) | 398 (376-461) |
| Age at first calving[2] (month) | 29.5 (24.3-34.7) | 29.0 (24.3-34.7) | 29.6 (25.5-34.0) |

[1] Data from initial interviews with project farmers.

[2] Analyses of monthly milk-recordings in milk-year 2006.

improvements of udder health management per farm were realised. The main intervention areas to improve udder health focussed on reducing transmission of cow associated pathogens (e.g. *Staphylococcus aureus)*, hygiene of cubicles/housing conditions and strategic drug use in udder health control.

### *Development of udder health in project farms*

When considering the farms with udder health as HHP topic independently from the actual implementation of measures, no significant differences between groups or within groups between years were found.

However, when focusing on farms, which promptly implemented recommendations from the HHP, udder health improved (Table 2). Treatment incidence of clinical mastitis in intervention farms significantly improved while it remained constant in the control farms (interaction group*year: *P=0.01).* Also SCS tended to improve and the percentage of cows in the herds with SCC >100,000/ml milk (as an indicator of subclinical mastitis) improved significantly in the intervention farms (group*year: *P=0.042*).

Change in treatment incidence of mastitis in the first project year (i.e. expressed as the difference from the baseline situation) was similar in intervention and control farms. However, in the second year the decrease was more pronounced in the intervention group than in the control group (Figure 1, interaction group*year: *P=0.016*; Table 3).

*Table 2. Development of incidence of mastitis treatments (mastitis), SCS and percentage of cows >100,000 cells/ml milk (class 100) during 3 years after implementation of the HHP (I=intervention farms in terms of actual implementation of measures[1]); mean (sd) and results of the analysis of variance of the effects: group (I vs. C), time in the project/year (y) and the year, as well as their interaction (g*y = group*year) on these indicators.*

| | **Group** | **n** | **Mean (sd)** | | | | **Group LSMean** | **(g) SE** | ***P*** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **2006** | **2007** | **2008** | **2009** | | | **g** | **year** | **g*y** |
| Mastitis (%) | I | 14 | 35.2 (17.4) | 25.3 (15.3) | 16.1 (9.6) | n.a.[2] | 25.53 | 3.50 | 0.244 | 0.0001 | 0.010 |
| | C | 26 | 22.8 (17.2) | 18.9 (14.9) | 19.4 (17.0) | n.a.[2] | 20.38 | 2.57 | | | |
| SCS (somatic cell score) | I | 14 | 3.71 (0.56) | 3.56 (0.57) | 3.42 (0.56) | 3.42 (0.51) | 3.53 | 0.13 | 0.120 | 0.218 | 0.068 |
| | C | 26 | 3.25 (0.47) | 3.32 (0.54) | 3.29 (0.49) | 3.26 (0.52) | 3.28 | 0.09 | | | |
| Class100 (%) | I | 14 | 64.8 (14.0) | 61.3 (14.3) | 58.1 (13.8) | 57.8 (13.6) | 60.48 | 3.23 | 0.111 | 0.155 | 0.042 |
| | C | 26 | 52.7 (12.5) | 55.5 (13.6) | 53.4 (12.2) | 54.2 (13.2) | 53.94 | 2.37 | | | |

[1] I=intervention, C=control group.
[2] Treatment incidences of clinical mastitis were only calculated until 2008.

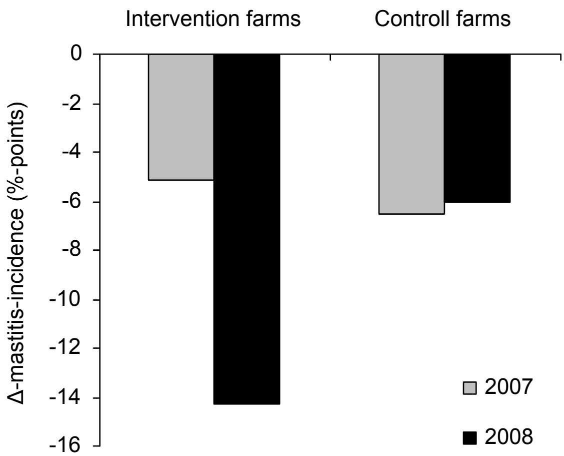


*Figure 1. Reduction in treatment-incidences of mastitis in the intervention vs. control farms 2007 and 2008 compared to the baseline 2006 (LS-Means); $n_I$=14, $n_C$=26).*

*Table 3. Results of the analysis of covariance of the effect group (I: intervention vs. C: control farms), time in the project/ year (y) and the year, as well as their interaction (g*y = group*year) on the difference of incidence of mastitis-treatments (Δ-mastitis), somatic cell score (Δ-SCS) and the percentage cows with more than 100,000 somatic cells per ml milk (Δ-class100) as difference to the situation at the beginning of the study and considering this situation as covariate (y0).*

| | | **n** | **group LSMean** | **(g) SE** | ***P*** | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | **g** | **year** | **g*y** | **y0** |
| Δ - | I | 14 | -9.71 | 3.36 | 0.420 | 0.030 | 0.016 | <0.001 |
| mastitis | C | 26 | -6.25 | 2.42 | | | | |
| Δ - | I | 14 | -0.200 | 0.07 | 0.023 | 0.175 | 0.501 | 0.102 |
| SCS | C | 26 | 0.016 | 0.05 | | | | |
| Δ - | I | 14 | -4.43 | 1.90 | 0.032 | 0.078 | 0.752 | 0.055 |
| class100 | C | 26 | +0.98 | 1.36 | | | | |

Considering the different situation during the start of the study in 2006 (year 0) between the groups, the estimated value (LSMeans) of reduction in mastitis-treatments was across the project clearly more pronounced in the intervention than the control farms (-9.7 vs. -6.3%-points; Table 3).

There were significant effects of intervention on the reduction of SCS (Δ- LSMeans; intervention: -0.200 vs. control: +0.016; *P=0.023*) and of the percentage cows with more than 100,000 somatic cells per ml milk (Δ- LSMeans; intervention: -4.43 vs. control: +0.98, *P=0.032*) when including the baseline status as covariate. Throughout the study the average age of the cows in the herd and the average milk yield remained unchanged.

## Discussion

### *Status quo in project farms and development of udder health*

In this study, levels of SCC and SCS were comparable with results from other European studies (Gay *et al.*, 2007; Brinkmann *et al.*, 2011). The assessment of disease incidence was based on farm records, although data quality may be limited. For example, the number of true cases of disease and of treated cases may not be the same, resulting in an underestimation of cases (Gonzalez *et al.*, 2010). Nationwide central databases of veterinary treatments exist in Scandinavian countries (Olsson *et al.*, 2001; Stege *et al.*, 2003).

They are regarded more reliable, but in many countries farm records are the only data source; particular in organic farming it is mandatory to record all allopathic treatments. The baseline incidence of mastitis treatments in this study was 27% and thus in accordance with data reported from organic dairy herds in the UK (Weller & Bowling, 2000). Antimicrobial drug use in 118 Danish organic dairy herds was 35 cases per 100 cow years for udder treatments in 2006, including treatments of dry cows (Bennedsgaard *et al.*, 2010). In Norway, Valle *et al.* (2007) found a similar treatment incidence in 159 conventional farms (31%), but it was markedly lower in organic dairy farms (17%; n=149).

In comparison with control farms, udder health was significantly improved on the farms that had implemented recommended measures from the farm individual HHP. The treatment incidence of mastitis in intervention farms decreased by on average 19 percentage points (control farms: 3 percentage points). There was an effect of interaction regarding the percentage of cows in a herd with an SCC more than 100,000 cells/ml as indicator of subclinical mastitis (*P=0.042*). By trend a major reduction of SCS on intervention farms was found, whereas the control group degraded or remained unchanged. Taking the situation in the beginning as covariate, there was an effect of intervention (group) on the SCS and the percentage of cows in the herd with more than 100,000 cells/ml. Comparable improvements have been reported on project farms attending in a study to improve udder health from Switzerland (Ivemeyer *et al.*, 2008). Green *et al.* (2007) found less cases of mastitis after one year using mastitis control plans, especially on farms with major udder health problems.

### *Study design, differences between the status quo in intervention and control farms*

In this study, parameters of udder health indicated more baseline udder health problems in intervention farms than in the control group; as the latter either did not agree to use a HHP or did not implement measures. This fact was foreseeable, as project farmers participated voluntarily. This is regarded as crucial also by Bell *et al.* (2006), who argue, that a herd health plan needs to be accepted by farmers in order to be effective. Also Vaarst *et al.* (2007) believe that the 'ownership' plays an important role in successful herd health planning processes. This fact could explain the low level of compliance during an intervention study on lameness in the UK, where farms were allocated randomly to the intervention or control group (Bell *et al.*, 2009).

### *Implementation of herd health plans and advised measures*

In this study, 14 out of 20 farms with a focus on udder health in the HHP actually implemented 43% of measures and the compliance still increased within the study duration (17 farms implemented 65% of measures). Therefore, the compliance of the project farms can be regarded as good. This is comparable to the compliance reported by Green *et al.* (2007) in a study on the implementation of mastitis control plans. In the same study udder health in participating farms improved and the success of the intervention plan was related to both, the correct identification of mastitis risk factors and the correct implementation of changes. The authors concluded that the application of existing information and knowledge to improve udder health is essential to achieve success. The farmers involved in the present study remarked at the end of the project, that the 'coaching' they experienced in the course of the project was very important to implement changes in farm routines. Furthermore the improvement in most of the indicators was more pronounced in the second year after implementation of the HHP, probably due to an increased compliance after a longer time of coaching and additionally due to long-term effects of implemented measures. It is crucial to involve all relevant people responsible for the daily work to achieve changes for improvement. This was obviously not the case in the intervention study on lameness in heifers of Bell *et al.* (2009), where veterinarians attributed poor compliance to lack of communication with stockmen and farmers.

## Conclusions

The results of the present longitudinal study demonstrate the benefits of farm individual herd health plans when focusing on udder health: SCS and incidence of subclinical mastitis successfully improved in dairy farms when recommended measures from the HHP were implemented. Our findings therefore confirm the effectiveness of herd health plans in connection with farmer compliance and show the feasibility of this management tool is. Communication with farmers and stockmen is crucial to implement recommendations successfully.

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# The effect of a national control program on mastitis occurrence in the Netherlands

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## Abstract

A 5-year national mastitis control program was initiated in the Netherlands in 2005. Knowledge transfer and improvements of dairy farmers' motivation towards udder health were used as means to decrease mastitis occurrence in Dutch dairy herds. The aim of this study was to determine the effect of the control program on (sub)clinical mastitis occurrence and on farmers' mindset and behaviour in relation to clinical mastitis. Two identical surveys were conducted in the same herds at the beginning and end of the control program to quantify the change in mastitis occurrence and farmers' mindset and behaviour. Prevalence of high composite somatic cell count (CSCC) and incidence rate of farmer-diagnosed clinical mastitis (IRCM) were compared between both surveys. The change in farmers' mindset and behaviour towards udder health was associated with the change in IRCM in 104 dairy herds using factor analyses and linear regression models. There was no significant decrease in high CSCC prevalence between both surveys. However, IRCM decreased from 33.5 in 2004/2005 to 28.1 quarter cases per 100 cow-years at risk in 2009. The variation in the change in IRCM was mainly explained by the 2004/2005 IRCM (29%) and factors describing the change in farmers' mindset (20%). These factors described a change in the perceived lack of control, a change in the perceived lack of influence on sources of mastitis, and a change in the worries about mastitis. This study indicated that udder health was improved in the Netherlands over the course of a mastitis control program. Changing dairy farmers' mindset seemed effective in decreasing clinical mastitis occurrence in dairy herds.

**Keywords:** udder health program, mastitis, prevalence, incidence rate, mindset

## Introduction

Since the 1970's, bulk milk somatic cell counts (BMSCC) have steadily decreased in the Netherlands. However, this improvement stagnated in the beginning of this century. Increasing

BMSCC levels were observed with higher peaks in the summer periods. Also, field reports indicated that more herds were experiencing problems with clinical mastitis (CM). In 2005, a national mastitis control program was therefore initiated by the Dutch dairy industry to decrease the absolute number of (sub)clinical mastitis cases with 10% (Van der Zwaag *et al.*, 2005).

The strategy of this national mastitis control program consisted of two main routes to transfer knowledge to as many farmers as possible: study groups were organized for internally motivated farmers and all Dutch farmers were targeted by an extensive multi-media campaign to trigger them to start improving udder health in their herds (Jansen *et al.*, 2010; Lam *et al.*, 2011). In a recent evaluation, this approach seemed to have changed the attitude, knowledge and behaviour of Dutch farmers towards udder health, but BMSCC did not decrease in these 5 years (Jansen *et al.*, 2010). However, BMSCC may not be an accurate indicator to objectively determine the subclinical mastitis (SCM) situation in dairy herds (Lievaart *et al.*, 2009). Also, BMSCC has a low correlation with the occurrence of CM in dairy herds (Van den Borne *et al.*, 2010).

The objectives of this study were 1. to determine the effectiveness of a mastitis control program on (sub)clinical mastitis occurrence in the Netherlands and 2. to quantify whether changes in farmers' mindset and behaviour explained changes in CM occurrence in these herds.

## Materials and methods

### *Herds*

The data analysed in this study were obtained from two surveys. Both were initiated to evaluate the effectiveness of the Dutch mastitis control program and are described in more detail elsewhere (Jansen *et al.*, 2009, 2010; Van den Borne *et al.*, 2010). In short, the first 1-year observational survey (defined as the 2004/2005 survey) was conducted from July 1, 2004 to June 30, 2005 to obtain test day recordings from 396 randomly selected Dutch dairy herds participating in the 4-weekly test day recording. Farmer-diagnosed CM cases, defined as cows with visual abnormalities on the udder and/or milk, were additionally obtained from 205 of the participating herds (Van den Borne *et al.*, 2010). The same herds that were still operative five years later (n=378) were subsequently asked to participate in a second, identical survey from January 1, 2009 until December 31, 2009 (defined as the 2009 survey). Test day recordings were obtained from 266 dairy herds in the second survey, while data on CM occurrence was obtained from 175 dairy herds. This approach resulted in a dataset of 266 and 116 dairy herds that participated in both surveys for SCM and CM, respectively. Reasons for dairy farmers not to participate were described elsewhere (Jansen *et al.*, 2010). Participating herds did not significantly differ in 2004/2005 BMSCC levels from herds that did not participate (Jansen *et al.*, 2010). An extensive questionnaire on farmers' attitude, knowledge and behaviour was conducted at the start of both surveys to obtain information about farmers' mindset in the Netherlands (Jansen *et al.*, 2009, 2010).

### *Statistical analyses*

Herd level prevalence of SCM, defined as the average annual proportion of cows with a CSCC ≥200,000 cells/ml, and herd level IRCM, defined as the number of quarter cases of CM in a herd divided by the number of cow days at risk, were estimated in each survey using negative binomial models, which are described in detail in Van den Borne *et al.* (2010).

The data from both surveys were merged to determine the change in prevalence of SCM and IRCM separately over the course of the national mastitis control program. A variable describing the year of the survey (2004/2005 vs. 2009) was added to the previously described models to determine whether the change was significant. The model for prevalence of SCM was adapted to correct for repeated test day recordings within survey within herds and the model for IRCM was adjusted for repeated surveys within herds using first order autoregressive correlation structures.

Continuous variables describing four herd characteristics (herd size, milk yield, age of the herd, and the farm's labour intensity) were determined using the available data. Variables describing farmers' attitudes, knowledge, and behaviour were binary coded or on a 5-point Likert score and were obtained from both questionnaires conducted at the start of both surveys (Jansen *et al.*, 2009, 2010). Gain scores were calculated for each of these variables by subtracting the 2004/2005 value from the 2009 value. A positive gain score indicated an increase in score.

The effect of the 2004/2005 IRCM, farmers' attitude, knowledge and behaviour, and herd characteristics on the change in IRCM was quantified in four steps: (1) a factor analysis was conducted on normal distributed gain scores to decrease the number of variables and multicolinearity; (2) a linear regression of selected gain factors on the change in IRCM was conducted; (3) a linear regression of all categorical gain scores on the change in IRCM was performed, and, subsequently; (4) the effect of selected gain scores and gain factors on the change in IRCM were further tested in multivariable linear regression analyses. In all models, a stepwise backward selection process was used until all variables were significantly contributing to the model ($P<0.05$). Four models were built to quantify the variation of the change in IRCM by the 2004/2005 IRCM, the change in farmers' attitude and knowledge, and the change in farmers' behaviour (Jansen *et al.*, 2009). The first model retained only the 2004/2005 IRCM. The second model consisted of the 2004/2005 IRCM and the significant farmers' attitude and knowledge gain scores and gain factors. The third model retained the 2004/2005 IRCM and the significant gain scores and gain factors describing the herd characteristics and farmers' behaviour. The gain scores and gain factors significantly contributing to the second and third models were further tested in the fourth multivariable linear regression model to quantify the between-herd variation in the change of IRCM for all gain scores and gain factors. The adjusted $R^2$ of each final model was determined to quantify its contribution to the between-herd variation in the change in IRCM, analogous to Jansen *et al.* (2009).

## Results

### *Mastitis occurrence*

In the 2004/2005 survey, DHI data of 45,322 cows in 396 herds were available for analysis of prevalence of SCM, while those were available from 35,099 cows in 266 dairy herds in the 2009 survey. The yearly average number of lactating cows per herd was 67.7 (SD=21.8) in 2004/2005 and 80.3 (SD=29.9) in 2009.

Occurrences of (sub)clinical mastitis in the Netherlands, according to the 2004/2005 – and 2009 surveys, are presented in Table 1. The IRCM decreased over the course of the 5-year mastitis control program. Mean herd level IRCM was estimated to be 33.5 (per 100 cow-years at risk) in 2004/2005 while it was significantly lower in 2009 (28.1; $P<0.01$). No significant change in the prevalence of SCM was observed between both surveys ($P=0.20$).

### *Farmers' mindset and clinical mastitis occurrence*

The final models investigating the change in IRCM (Table 2) were based on data from 104 dairy herds because of some missing values in the questionnaires conducted. The models determined that the 2004/2005 IRCM explained 29% of the variance in the change in IRCM, while farmers' attitude and knowledge and farmers' behaviour additionally explained 20% and 7% of the variance, respectively. The final linear regression model in which the 2004/2005 IRCM, the changes in farmers' attitude and knowledge, and the changes in farmers' behaviour on the variance in IRCM were investigated, did not contain any items on farmers' behaviour and was equal to the final model in which only farmers´ attitude and knowledge items were investigated. Attitude and knowledge factors that were associated with a change in IRCM were a perceived lack of control, a change in the perceived lack of influence on sources of mastitis, and a change in the worries about mastitis (Table 2). Variables loading to factors significantly contributing to one of the linear regression models are displayed in Table 3.

*Table 1. Estimated mean within-herd level occurrence of clinical and subclinical mastitis with 95% confidence intervals in 2 surveys conducted in the Netherlands.*

| Year | Prevalence of subclinical mastitis | Incidence rate of clinical mastitis | Reference |
|---|---|---|---|
| 2004/2005 | 23.0 (22.2-23.9) | 33.5 (31.3-35.8) | Van den Borne *et al.* (2010) |
| 2009 | 22.2 (21.4-23.2) | 28.1 (25.7-30.7) | this paper |

*Table 2. The change in incidence rate of clinical mastitis (IRCM) explained by the 2004/2005 IRCM (model 1), changes in farmers' attitude and knowledge (model 2) or changes in farmers' behaviour (model 3), according to three multivariable linear regression models. A positive gain score indicates an increase in this score.*

| **Variable** | **Model** | | |
|---|---|---|---|
| | **1** | **2** | **3** |
| 2004/2005 IRCM | 0.63*** | 0.70*** | 0.67*** |
| Attitudes and knowledge | | | |
| Factor 1 (perceived lack of control) | | 7.02** | |
| Factor 17 (sources of mastitis cannot be influenced) | | -3.99* | |
| Factor 18 (worries about costs) | | -4.30* | |
| 'The best way to decrease bulk milk SCC nationally is to have free visits from mastitis experts': a loss in attitude | | -4.67 | |
| 'The best way to decrease bulk milk SCC nationally is to have free visits from mastitis experts': no change in attitude | | Ref. | |
| 'The best way to decrease bulk milk SCC nationally is to have free visits from mastitis experts': a gain in attitude | | -17.79** | |
| Behaviour | | | |
| Factor 2 (longevity of dairy herd) | | | -4.81** |
| 'I have a standard treatment protocol': a loss in attitude | | | -15.03 |
| 'I have a standard treatment protocol': no change in attitude | | | Ref. |
| 'I have a standard treatment protocol': a gain in attitude | | | 8.61* |
| Adjusted $R^2$ | 0.29 | 0.49 | 0.36 |

Ref. = reference. *$P<0.05$; **$P<0.01$; ***$P<0.001$.

## Discussion

The aim of this study was to evaluate the effectiveness of the Dutch mastitis control program. The two conducted surveys identified that the IRCM decreased, while no effect was observed for the prevalence of SCM. The same herds were included in both surveys to avoid between-herd variability as much as possible. However, not all herds participated in both surveys and this may have resulted in biased information. The occurrences of mastitis between the 2004/2005 and 2009 surveys were therefore compared between herds participating in both surveys and herds that participated in only one survey. There was no difference in the prevalence of SCM and the 2004/2005 IRCM between those herds, but the 2009 IRCM of herds participating in both surveys was 1.4 fold higher compared with herds that only participated in the 2009 survey (results not shown). One possible explanation for this observation could be the knowledge

*Table 3. Sorted factor loadings ≥0.40 for factors significantly contributing to the multivariable linear regression models for the change in incidence rate of clinical mastitis (Table 2).*

| **Variable** | **Factor** | | | |
|---|---|---|---|---|
| | **1** | **17** | **18** | **2** |
| Attitude and knowledge variables | | | | |
| 'I generally have the mastitis situation on my farm under control' | 0.78 | | | |
| 'The last 2 yr I perceived serious mastitis problems' | -0.66 | | | |
| 'I know enough to prevent mastitis problems' | -0.58 | | | |
| 'Causes of mastitis are hard to influence' | | 0.83 | | |
| 'Bad luck plays an important role in a mastitis outbreak' | | 0.44 | | |
| 'Perceived knowledge about the influence of feeding on mastitis' | | -0.43 | | |
| 'I worry about the costs of mastitis' | | | 0.70 | |
| Important source of information: veterinarian | | | 0.44 | |
| Management and behaviour variables | | | | |
| Annual herd level mean parity | | | | 0.66 |
| 'When selecting bulls I take udder health traits into account' | | | | 0.66 |
| 'When I have problems filling my milk quota, I treat cows with subclinical mastitis less quickly' | | | | -0.52 |
| Frequency of cleaning the cubicles each day | | | | 0.45 |

transfer initiated by the Dutch Udder Health Centre. Farmers received a lot of information about how to detect CM and this may have resulted in an improved CM detection in the 2009 survey. Also, selection bias may have occurred because farmers that participated in both surveys may be more strict to diagnose cows with CM. However, both possible causes would have resulted in an over reporting of the number of CM cases in 2009, implying that the true decrease of CM occurrence might even have been larger.

Even if the herds in the survey are a good representation of all Dutch dairy herds, it remains difficult to truly evaluate the effectiveness of the Dutch mastitis control program. All dairy herds in the Netherlands were exposed to the activities of the Dutch Udder Health Centre because of the mass-media approach chosen. The results obtained from both surveys can therefore not be compared to a control group of herds that were not exposed to the activities. Hence, the observed decrease in CM occurrence might be because of year-to-year variation in, for instance, temperature, quality of the feed, or culling policies due to different market circumstances. However, we do believe that the estimates obtained from the surveys reflect the change in mastitis occurrence in the Netherlands. First, the program was evaluated by observing the change in mastitis occurrence within the same herds, thereby avoiding between-herd variability in, for instance, clinical mastitis diagnoses as much as possible. Also, it was shown that udder health improved in a selected cohort of dairy herds that actively implemented the mastitis control program compared with herds that did not actively implemented the program and to a control cohort of herds that were not offered the program (Lam *et al*., 2011). Moreover, attitudes, knowledge and behaviour of farmers changed over the course of the program (Jansen *et al.*, 2010). Finally, national BMSCC levels continued to increase in the first two years of the control program when it was not yet operational on a national scale. However, BMSCC started to decrease after 2007 when the program was offered to all Dutch dairy farmers and were at the same level again in 2009 as in 2004/2005 (Jansen *et al*., 2010). In 2010, the decrease in BMSCC continued (unpublished data).

The variance in the change in IRCM over the course of the mastitis control program was mainly explained by the 2004/2005 IRCM and changes in farmers' attitude and knowledge, but, surprisingly, not by the change in farmers' behaviour. The 2004/2005 IRCM was expected to explain a significant part of the variation because it was assumed that it is easier to decrease IRCM from initially high levels compared with initially lower levels. Also, the influence of farmers' attitude and knowledge was expected because similar conclusions were drawn before for BMSCC (Jansen *et al.*, 2010). However, it was not hypothesized that there was no association between behavioural changes and a change in IRCM because some behavioural changes were associated with a change in BMSCC previously (Jansen *et al*., 2010). This may be due to the relatively low number of herds in this analysis, a change in management that was not captured by the questionnaires, or by the complex multifactorial relationships between different variables in the dataset. This was confirmed by the high multicolinearity observed, although factor analyses were performed to identify underlying structures. Also, it may indicate that the quality of the behaviour improved (eg. better coverage of the teat disinfectant). This would then be reflected by changes in farmers' mindset, rather than in changes in farmers' behaviour. Future investigations should take these complex relationships into account.

## Conclusions

This study indicated that IRCM was significantly improved in the Netherlands over the course of a 5-year mastitis control program, although the overall aim of a 10% reduction was not achieved. Changing dairy farmers' mindset seemed effective in decreasing clinical mastitis occurrence in dairy herds.

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# €uroMilk mastitis control programme – a pilot study

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Despite the wealth of knowledge that exists in the industry, mastitis prevention and control continues to be a challenge for many farmers. Traditionally, Irish farmers may seek help and advice from individuals such as their farm advisor, veterinary surgeon or milking machine technician. However, communication between these groups of people in relation to farm issues remains limited. The €uroMilk pilot study centred on creating a communication network and a framework that facilitated service providers to work together as a team with the farmer. The objectives of this pilot study were to create multidisciplinary teams to develop farm-specific mastitis control programmes on twenty three Irish dairy farms, measure the impact and effectiveness of these teams in influencing change on participating farms and to determine if this model of delivery would be feasible in the Irish dairy industry. Each participating farmer invited team members of their own choice, such as their veterinary surgeon, milking machine technician, processor milk quality advisor and farm advisor. Team members were expected to use their existing skills and experience in the areas of communication, mastitis control and farming systems. Teams met at least 5 times over a period of fourteen months. Farmers were encouraged to set farm-specific milk quality targets. Farm specific losses associated with udder disease were communicated through the use of a cost-calculator. At each meeting, the teams drew up action plans, assigned responsibility for tasks, with review at subsequent meetings. The multidisciplinary teams were viewed positively, increasing awareness and providing focus as well as objective, independent advice. An active team leader, full team attendance, regularity of meetings and review were all important in maintaining momentum. Demands on professional availability of time, difficulties in coordinating meetings and conflicting professional advice were some of the obstacles to successful teamwork.

# CellCheck-a national initiative

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Animal Health Ireland (AHI) is a recently established, not-for-profit, partnership-based organisation. It provides benefits to livestock producers and processors by providing the knowledge, education and coordination required to establish effective control strategies, both on-farm and nationally. Initial AHI work identified seven disease priorities, one of which was udder health. Work programmes are being established, focusing on each of these priority areas. The udder health programme CellCheck, is based on the following principles: (1) building awareness-A comprehensive communication strategy is raising awareness of the factors contributing to mastitis, realistic and achievable solutions along with the benefits of improving mastitis control; (2) setting standards-CellCheck will provide a means for the industry to collectively set ambitious but achievable goals for national milk quality; (3) delivering best practice-CellCheck is developing evidence-based technical resources, subject to continual evaluation, including external peer review; (4) building capacity-CellCheck will develop the capacity of the various service provider groups, facilitate collaboration and also empower farmers to take responsibility for mastitis management on their own farms. At the core of all AHI work programmes is a Technical Working Group (TWG), or group of experts in the relevant field. The CellCheck TWG is currently working on reviewing and collating national and international research on mastitis control, in order to provide agreed, consistent messages for the Irish dairy industry. An Industry Consultation Group (ICG) provides industry support, guidance and expertise to assist the development and delivery of CellCheck. This structure also facilitates active engagement and communication with the key industry bodies. The ICG represents industry bodies with the ability to influence change at both farm and industry level.

# Preventive animal health concepts in organic dairy farming: results of an interdisciplinary intervention study on mastitis and metabolic disorders in Germany

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Between 2008 and 2010 in 106 German organic dairy farms a nationwide interdisciplinary intervention study was carried out in order to develop preventive animal health management strategies for mastitis and metabolic disorders, to validate this concept and to demonstrate its feasibility. During 4 visits per farm, health indicators and influencing factors such as housing, herd management, feeding and forage production were recorded. Following a thorough assessment, farm-individual evidence-based advice was provided by the project team. About two thirds of these farm-individual intervention measures were implemented within one year and their effectiveness in terms of health improvement was monitored for one respectively two years. Mixed models for repeated measures were used to analyse the outcome on farm level. In 102 farms measures regarding udder health improvement were implemented. In these intervention-farms treatment incidence for mastitis decreased significantly from 2008 to 2009 (17.7 -> 13.7%, $P$=0.002). SCC improved from 2008 to 2010 significantly (cows >100,000 SCC: 56.2 -> 53.2 -> 51.3%, $P$<0.001). Milk yield increased significantly (20.0 -> 20.7 -> 20.9 kg/ d, $P$<0.001), the average herd age did not change (5.4 years). Some health indicators regarding metabolic disorders (e.g. milk fever, ketosis) improved by trend. In conclusion, these findings provide evidence for improvements on the health situation in commercial organic dairy farms in response to farm-individual intervention measures. However, further data analysis is necessary in order to evaluate the effectiveness of the intervention approach, i.e. in terms of implementation of measures respectively according to the degree of implementation.

# Online mastitis survey in Flanders, Belgium: first descriptive results

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In 2010, an online questionnaire for Flemish dairy farmers focusing on udder health and milk quality management was conducted. The objective of the study was to get more insights in the implementation of the ten-point program in daily practice and to identify herd level risk factors associated with the bulk milk somatic cell count. The following topics were covered: incidence of several diseases such as clinical mastitis and metritis, …, milking equipment, milking technique, housing, nutrition, dry cow management, treatment of mastitis, and the farmer's long-term vision. Two hundred and eighty one farmers completed the questionnaire. Preliminary analysis of the data indicate, that even the more basic principles in milking technique, and the use of treatment protocols, are not part of the daily routine of a large proportion of the Flemish dairy farmer. This information has been discussed with small groups of farmers, via roadshows organized within a so called 'demonstration project' funded by the Flemish government, and is being used in online communication with the Flemish farmers and their advisors through an e-newsletter (M-news) issued by the M-team monthly. In a next step, the association between udder health management practices and bulk milk somatic cell count, total bacterial count and coliform count on Flemish dairy herds will be evaluated through statistical analyses of the data.

# Part 2
# New approaches in mastitis control

# Bulk milk quality: can it be improved by dairy farm audits?

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## Abstract

Udder health is important as it affects milk quality. This is reflected in somatic cell count and total bacterial count (TBC). One way to judge farm management, including udder health management, is the use of milk quality systems based on farm audits with checklists. Audits aim to ascertain and improve product quality. But the effect of audits on product quality is hard to demonstrate empirically as data are not easily available. In this study data on dairy farm audits and data about laboratory results of bulk milk deliveries of individual farms are studied to trace a putative relation between audits and product quality. The objective is to study whether the TBC of dairy bulk milk are reduced in the period around a farm audit and/or afterwards. The data set contained information about 13,006 audits performed on 12,855 farms as well as TBC counts of bi-monthly tested bulk milk of these farms. A record included: logTBC value, variables indicating the timing of the TBC test relative to the audit date, unique audit number, auditor, type of audit, outcome of the audit, audit checklist items, number of attention points and audit date. A random linear regression model was used to quantify the possible relation between LogTBC and the time before, during and after the dairy farm audits and other audit variables. A significant reduction in LogTBC levels were found around the date of the audit and in the period from 1.5 to at least 6 months after the audit. Additionally, LogTBC levels were found to depend on: season, total number of attention points given during an audit, audit type (standard, repeated or first audit), audit outcome (approved, rejected or temporary blocked), year of the audit (2006, 2007 or 2008), checklist items related to the maintenance of the milking equipment and/or utility room and tank and some interactions. Based on this study we can conclude that there is an improved milk quality (i.e. temporary decrease in logTBC) due to the audit.

## Introduction

Udder health is important at the dairy farm as it affects milk quality. This is reflected in somatic cell count and total bacterial count (TBC). Udder health and consequently milk quality can be improved by a continuous operation of good cattle management. The judgement and monitoring of good cattle management can be done using farm audits. These audits aim to (among others) indicate farm aspects that can be improved and to improve the milk quality in the end.

Moreover, quality and safety of dairy products have become an increasing issue of concern for both consumers and producers. This is in some part due to incidents such as dioxin contaminations of animal feed in Belgium and Germany, melamine contaminated powdered infant formula in China, and outbreaks of *Escherichia coli* O104:H4 infection in 16 countries in Europe and North America. Nowadays, the food industry is under the watchful eye of many. Consumers are concerned and demand information about the quality and safety of products and the way they are produced (Boor, 2001). Losses can be considerable for food business operators if the quality and safety of the product is insufficient or if the product is needed to be withdrawn or recalled, which makes the food processing industry set high standards for these criteria (Velthuis *et al*., 2009). Microbiological contamination of milk is an important issue since pathogens can affect food safety and spoilage microorganisms can limit shelf life and affect quality or yield of milk derivate products (Boor, 2001; Dogan and Boor, 2003).

In the Netherlands, each bulk milk delivery is routinely sampled, monitored and analysed for composition and quality in an independent monitoring station under the supervision of Netherlands Controlling Authority for Milk and Milk Products. Payment schemes include milk content or levels of fat, protein, lactose, urea, somatic cell count, total bacterial count (TBC), antimicrobial drug residues, butyric acid spores, freezing point depression, free fatty acid, and milk sediment. The testing frequency differs for different milk quality parameters, going from every delivery, twice per month, once per month to twice per year. Farmers whose milk does not meet all these requirements get a lower price for their milk and milk delivery can be rejected by the dairy processor, according to company or government regulations. On the other hand, farmers with a continuous supply of high quality milk are conferred a (small) bonus (Velthuis and Van Asseldonk, 2011).

Some widely used tools for improving the quality and safety of bulk milk are quality assurance and certification programs for dairy farms to reach the desired farm performance level by the dairy processing industries and communicate this to the stakeholders. These programs include farm audits that assess different criteria such as the use of veterinary drugs, animal health, equipment, facilities, personnel and farm hygiene, disinfection procedures, residues, feed and water management, among others.

The commercial or economic advantages of auditing have not always been measured or promoted and the industry is not always willing to put up with the costs that auditing implies (Dillon and Griffith, 2001). As farm audits and bulk milk analysis entail costs, it is important to know if they actually help improve quality and safety parameters in bulk milk and if this effect is temporary or has a more permanent effect. Bulk milk monitoring and certification schemes aim to improve the quality of bulk milk; nevertheless, the extent of how these are related is unknown. Therefore, the main goal of this research is to study whether the TBC values of bulk milk change during the period before and after the dairy farm audit.

## Material and methods

The data was provided by Qlip NV (an independent Dutch organization responsible for the certification and auditing of dairy farms and testing milk deliveries to the processors from farms). One data set contained bulk milk test results of all milk deliveries to processors and the other contained all dairy farm audits. The compound data set consisted of 325,150 records that included 13,006 audits conducted on 12,855 farms from February 2006 to April 2008 and all the corresponding TBC results within this period.

### *Farm audit data*

In this analysis the following farm audit variables were used as explanatory variables: *Auditor* (n=16, anonymous), *audit type* (n=3, standard audit, repeated audit, first audit), *audit result* (n=3, approved, rejected, blocked), m*ilking equipment maintenance* (*MEM*) (n=4, no remark, automatic-milking-system report missing, valid report missing, report misses a validation signature), and u*tility room tank maintenance* (*URTM*) (n=4, no remark, maintenance report is older than 15 months as a new tank is installed soon, new tank where the valid installation report is missing, the maintenance report is older than 15 months). A more detailed description of the complete farm audit data can be found in Velthuis and Van Asseldonk (2011).

### *Bulk milk lab result data*

TBC is analysed twice a month by automatic enumeration with BactoScan FC (Foss A/S) by flow cytometry (FCM). In this data set, the 'zero' was treated as a non-existing TBC value so that the minimum value is 1 (× 1000 cfu/ml). The maximum reported value is 999 (× 1000 cfu/ml) as the digital display only allow three numbers. So all TBC values higher than 999 × 1000 cfu/ml are record as 999.

*LogTBC* is the base 10 logarithm of TBC*1000 (cfu/ml), corresponding to a minimum of 3 and a maximum of 6.

### *Dummy variables for the timing of the TBC value in relation to the audit date*

To facilitate analysis, dummy variables (b60 to a60) that represent when the bulk milk sample was taken relative to the audit date were included. The letters 'b' and 'a' stand for 'before' and 'after' respectively and the following number represents the month. For example, a35 means 3.5 months after the audit and b10 means 1 month before the audit. The variable b00 corresponds to the audit date, although due to lack of information of when exactly the bulk milk sample was taken, it may not precisely match the audit date.

### *Statistical analysis*

A linear mixed model was used to test the relation between the depended variable and the predictor variables. TBC was assumed to be not normally distributed and TBC*1000 (cfu/ml) was the dependent variable. The data were analysed with Genstat version 13 for Windows (VSN International, Hemel Hempstead, UK), using the REML directive (Restricted or Residual Maximum Likelihood) with farm as the random model to reduce the variability that may exist among farms. REML estimates the treatment effects and variance components in a linear mixed model, which consists of a linear model with both fixed and random effects.

The general random mixed model is written as:

$$y = RANDOM(r_i) + \beta_0 + \beta_1 {}^* x_1 + \ldots + \beta_p {}^* x_p + e,$$

where $y = LogTBC$, $r_i$ = the random variable, $\beta_0$ = the constant, $\beta_1$ = the estimate of the corresponding variable $x_1$, $\beta_p$ = the estimate of the variable $x_p$, and $e$ = the error term.

Originally, all of the variables and interaction terms were included in the full model, and later on, each non-significant term ($P<0.05$, Wald's test) was excluded with a backward stepwise selection procedure. Therefore, the final model includes only significant factors and interactions.

## Results

The full fixed model is described as follows:

*LogTBC=RANDOM(farm)+C+(k11+k12)+AttentionPoints+AuditType+Outcome+AuditType*Outcome+Year+Auditor+AttentionPoints*Auditor+AuditType*Auditor+Outcome*Auditor+MEM+URTM+MEM*Auditor+MEM*Auditor+b00+a05+a10+a15+a20+a25+a30+a35+a40+a45+a50+a55+a60+Auditor*b00+Auditor*a05+Auditor*a10+Auditor*a15+Auditor*a20+Auditor*a25+Auditor*a30+Auditor*a35+Auditor*a40+Auditor*a45+Auditor*a50+Auditor*a55+Auditor*a60,*

where *C* is the intercept, $k11 = sin(2*\pi*Day/365)$ and $k12 = cos(2*\pi*Day/365)$, allowing for smooth seasonality effects.

The estimate and standard error for the variables can be found in Table 1. There is a statistically significant ($P<0.001$) decrease in the *LogTBC* level during the audit date (*b00*), but surprisingly there is no significant effect in the following month (*a05* and *a10*), though there is once more a significant decrease from 1.5 months to at least six months after the audit (*a15* to *a60*).

The *Standard Audit Type* has the lowest average *LogTBC* values. The *Audit Type* with the highest average *LogTBC* level is the *First Audit*. The *Repeated* and *First Audit* have a slightly

*Table 1. Estimates of random mixed model for LogTBC.*

| Variable | Levels | Estimate | SE |
|---|---|---|---|
| C | | 4.038** | 0.0089 |
| k11 | | -0.0086** | 0.0012 |
| k12 | | -0.0061 | 0.0012 |
| Audit Type | Standard[1] | 0 | 0.0053 |
| | Repeated | 0.0261** | |
| | First Audit | 0.0392** | |
| Auditor | Auditor[2] | -0.0415; 0.748* | 0.0129 |
| Attention Points | Attention Points | 0.0002** | 0.0001 |
| Outcome | Approved[1] | 0 | 0.0110 |
| | Rejected | 0.2403** | |
| | Blocked | 0.0812** | |
| Year | 2006[1] | 0 | 0.0029 |
| | 2007 | -0.0028** | |
| | 2008 | 0.0177** | |
| b00 | | -0.0066* | 0.0290 |
| a15 | | -0.0442* | 0.0116 |
| a20 | | -0.0512** | 0.0117 |
| a25 | | -0.0702** | 0.0116 |
| a30 | | -0.0408** | 0.0117 |
| a35 | | -0.0264** | 0.0116 |
| a40 | | -0.0396** | 0.0029 |
| a45 | | -0.0241** | 0.0116 |
| a50 | | -0.0162** | 0.0118 |
| a55 | | -0.0142** | 0.0117 |
| a60 | | -0.0113** | 0.0118 |
| MEM | No remark[1] | 0 | 0.0096 |
| | Missing AMS reports | 0.0426** | |
| | Valid report missing | 0.0102** | |
| | Report not with validation signature | 0.0490** | |
| URTM | No remark[1] | 0 | 0.0336 |
| | Maintenance company not certified | 0.0179** | |
| | New tank, valid installation report missing | 0.0175** | |
| | Report older than 15 months | -0.0122** | |
| Audit Type*Outcome[2] | | -0.3146 ; 1983** | 0.0420 |
| Attention Points*Auditor[2] | | -0.0009 ; 0.0025** | 0.0010 |
| Audit Type*Auditor[2] | | -0.1461 ; 0.3331** | 0.0717 |
| Outcome*Auditor[2] | | -0.5359 ; 0.4457** | 0.0832 |

*Table 1. Continued.*

| Variable | Levels | Estimate | SE |
|---|---|---|---|
| Auditor*b00[2] | | -0.0883 ; 0.0880* | 0.0330 |
| Auditor*a15[2] | | -0.0848 ; 0.1026* | 0.0330 |
| Auditor*a20[2] | | -0.0725 ; 0.0469* | 0.0331 |
| Auditor*a25[2] | | -0.0721 ; 0.0760** | 0.0329 |
| Auditor*a30[2] | | -0.0752 ; 0.0722** | 0.0331 |
| Auditor*a35[2] | | -0.1759 ; 0.0193** | 0.0329 |
| Auditor*a40[2] | | -0.1295 ; 0.0372** | 0.0333 |
| Auditor*a45[2] | | -0.1550 ; 0.0412** | 0.0330 |
| Auditor*a50[2] | | -0.1142 ; 0.0153** | 0.0333 |
| Auditor*a55[2] | | -0.1069 ; 0.0239** | 0.0331 |
| Auditor*a60[2] | | -0.1160 ; 0.0294** | 0.0333 |

**P<0.05, **P<0.001.*

[1] Reference level.

[2] The variable includes more varieties. To restrict the size of the table, the minimum and maximum estimates are given, respectively.

lower average and not significantly different (*P*>0.05) from each other, although both are significantly different (*P*<0.05) from the *Standard Audit Type.*

The *Outcome* of the audit has a significant (*P*<0.001) effect on the *LogTBC* levels. Figure 1 shows that the *Rejected* farms have the highest average levels. As would be expected, the *Approved* farms have the lowest average *LogTBC* values whereas the *Blocked* farms have slightly increasing effect on *LogTBC*. All three *Outcome* variables are significantly different from each other (*P*<0.05).

The influence of the *Auditor* is not straightforward as there are interaction effects with the months before and after the audit, with the *Audit Type* and *Attention Points*. The combination with other variables determines the overall effect of an auditor.

The effect of the *Attention Points* on the *LogTBC* level is 0.00017 by every given audit point, implying that as the number of *Attention Points* a farm gets is higher, the *LogTBC* value increase as well.

Throughout the years, on a longer term, the foreseen behaviour was for *LogTBC* levels to decrease over time, however, the results of this analysis show the contrary. The years *2006* and

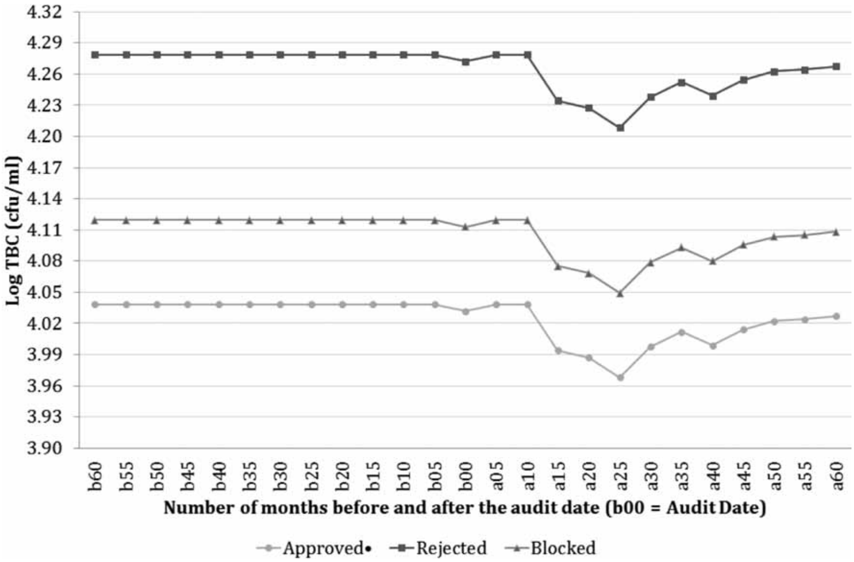


*Figure 1. Effect of the audit* Outcome *on the average* LogTBC *throughout the year. Base attributes:* Standard Audit Type, Year 2006, Auditor1, MilkingEquipmentMaintenance – No remark, UtilityRoomTankMaintenance – No remark.

*2007* have a lower average *LogTBC* than the year *2008*. The *LogTBC* values from the years *2006* and *2008* are not significantly different from each other ($P$>0.05), though they are from *2008*.

## Discussion

In this study data on dairy farm audits and data about laboratory results of bulk milk deliveries of individual farms are studied to trace a putative relation between audits and product quality. The objective is to study whether the TBC of dairy bulk milk are reduced in the period around a farm audit and/or afterwards. It can be concluded that there is an improved milk quality (i.e. temporary decrease in logTBC) due to the audit. This effect starts 1.5 months after the audit and continues until at least 6 months after the audit.

There are payment schemes related to bulk milk TBC. Carrying on with such schemes is supported by the presented results as there is a relation between audit results and TBC values and consequently dairy farm hygiene practices (Gonzalo *et al.*, 2006). It is important to mention that even the farms with high average LogTBC values are well below the established maximum limit of Log 5 (100,000 cfu/ml) for bulk milk delivery in the EU (EEC, 1992). The magnitude of the estimates may not have a noticeable impact on a single farm level from the point of view of Food Microbiology. Nonetheless, when the data set is taken as a whole, the impact of dairy farm auditing on TBC levels is evident. It may be possible to perceive a bigger impact if a study comparing farms with extreme TBC levels is conducted.

Further research on auditing and related topics is interesting as information is scarce on this subject. It would be helpful to include data from non-audited farms, if available, to compare those to farms that are already in an auditing scheme.

The focus of this investigation was on the temporary effect of auditing on milk quality parameter, a long-term effect should furthermore be considered. As the auditing scheme has changed since 2009, a study comparing both schemes may give further indication of how auditing affects bulk milk quality parameters. The company has moreover suggested that there may be an effect of the maintenance date on bulk milk TBC values. Although this information was not available for this research, it would be useful to compare the outcome of here the presented results.

According to literature, there is a correlation between TBC and SCC; therefore, an additional suggestion would be to conduct a similar study including as an alternative SCC. There are many bulk milk quality parameters that may be affected by different variables such as animal health, hygiene practices and environmental and farming conditions that have not been taken into consideration for this study. Further research that take other variables into consideration may give additional insight into the relation between auditing and bulk milk quality.

## Acknowledgements

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# Internet data services from maritime quality milk: tools for tracking milk quality

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## Abstract

Milk quality monitoring has been an important aspect of public health programs for more than 50 years. Bulk tank milk samples are typically collected on dairy farms at every tanker truck pickup. Information generated from samples is not fully exploited to aid the producer in managing their herds. There is often a gap between generation of the data and communication of the information to make decisions and improvements on dairy farms. In a recent project, consumer complaints were decreased by half when milk was sourced from farms meeting a higher bacteriologic and bulk tank somatic cell count standard. During that project we determined that dairy producers were not efficiently using milk quality data generated through the regulatory system. This may be because the data was not in a format that could be quickly and easily understood. Subsequently, Maritime Quality Milk began providing value-added graphical analysis of milk quality and component parameters for producers in the Eastern Canadian provinces of Prince Edward Island, Nova Scotia and New Brunswick. Producers are able to look at quality results in real time or they can control the level of monitoring effort expended by setting email device notification filters. Using these systems, farmers are alerted only when test performance have gone outside the parameters that they have set. More recently, one processor has begun using the system to provide real-time alerts to producers regarding quality targets they must achieve on a monthly basis to qualify for quarterly bonuses. In 2011, focus groups were conducted to understand the industry needs, barriers to use and set development priorities.

**Keywords:** bulk tank milk, graphing, email notification, quality bonus

## Introduction

Milk is in a very competitive beverage market. Consistent quality is extremely important to retain and advance market share, particularly among young consumers. Monitoring of milk quality through bulk milk testing has been an important vehicle for improving quality and advancing public health for more than five decades. Bulk tank milk samples are typically collected on dairy farms at every tanker truck pickup, which is usually every second day. The volume of data available on these raw milk samples has expanded rapidly in the last two decades.

Historically, bulk tank quality data has been limited to infrequent somatic cell count (SCC) and bacteria levels using the procedures described by both the International Dairy Federation (International Dairy Federation, 1991) and the American Public Health Association (Wehr and Frank, 2004). For many years, rapid and accurate SCC information has been available through flow cytometry-based instrumentation. Additionally, highly automated testing systems, such as the Bactoscan® system (FOSS, Denmark) and the BactoCount® system (Bentley Instruments, USA) have become widely used in the industry for total bacteria counts in raw milk. These bacteria counting systems provide very high throughput (up to 150 samples per hour) testing. As this technology matures, costs decline on a per sample basis and the opportunity arises for cost-effective increased testing frequency. When the value additional milk quality information for management purposes and the costs of sorting samples required for regulatory regimes is considered, testing every sample rather than the minimum for regulatory purposes may become an attractive option. This option has been taken by one province in Canada (Ontario), which has begun to test all bulk tank samples taken on the farm for composition and bulk tank somatic cell count (BTSCC; Anonymous, 2011).

Intensive systems, such as the Ontario program, lead to greater availability of these data for management purposes but require more sophisticated information technology applications to convert the data into meaningful information. Seamless transfer of these data to quality monitoring systems, provide a significant opportunity for milk quality improvement. In this paper, the value of expanded testing and the Maritime quality milk graphical analysis program are being described.

## Value of expanded testing

Raw milk quality can influence post-pasteurization milk quality through a variety of mechanisms. Some bacteria found in raw milk may survive pasteurization (heat resistant spore formers) and could have a direct influence on shelf-life through post-pasteurization bacterial growth (Boor *et al.*, 1998). Additionally, lipolytic and proteolytic enzymes, which alter milk flavor post-pasteurization, may be liberated by these spore forming bacteria (Elmoslemany *et al.*, 2007) or from bacteria destroyed in pasteurization (heat labile bacteria) (Barbano *et al.*, 2006). Finally, milk with high SCC, has a higher level of inflammatory compounds, including plasmin, which survive pasteurization and can influence shelf life. As a result, many dairy processors offer premium payments for milk of lower bacteria and somatic cell count (Ma *et al.*, 2000).

Beginning in 2005, our research group conducted a large project focused on establishing the farm management practices that were the key determinants of milk quality (Elmoslemany *et al.*, 2010). In concert with that research program, Amalgamated Dairies Limited, a Prince Edward Island producer-owned processor, began to identify milk sources for fluid consumption meeting more stringent raw milk quality criteria. The criteria for use in the fluid processing line were total bacteria count <15,000 cfu/ml, laboratory pasteurization count <100 cfu/ml, preliminary incubation count <25,000 cfu/ml, coliform count <25 cfu/ml and SCC <200,000. Approximately 50% of herds consistently met the criteria. Consumer complaint data related to fluid milk quality was tracked before and after the institution of the quality sourcing program. There was a 58% reduction in the relative number of consumer complaints related to all aspects of fluid milk quality after the changes to milk sourcing compared to historical values. Similarly, there was a 48% reduction in the relative number of consumer complaints related to shelf-life (Keefe and Elmoslemany, 2007).

## The maritime quality milk graphical analysis program

From these data on the affect of raw milk quality on consumer acceptance, it was apparent that substantial gains could be made if producers had the tools to improve farm practices. In addition to knowledge about the key farm management practices, producers identified lack of real-time information on milk quality as a deterrent to change. In response, the Maritime Quality Milk Graphical Analysis Program was developed. MQM - GAP is a internet based system that allows producer and their advisors to view bulk tank milk quality data as it is produced in the laboratory. The system operates in a secure web environment and features a number of generic and individual user driven functions.

Figure 1 shows a screen shot of one of 16 options for graphical display. Within the system the most recent test day information is displayed in table form on the left. Drop down windows

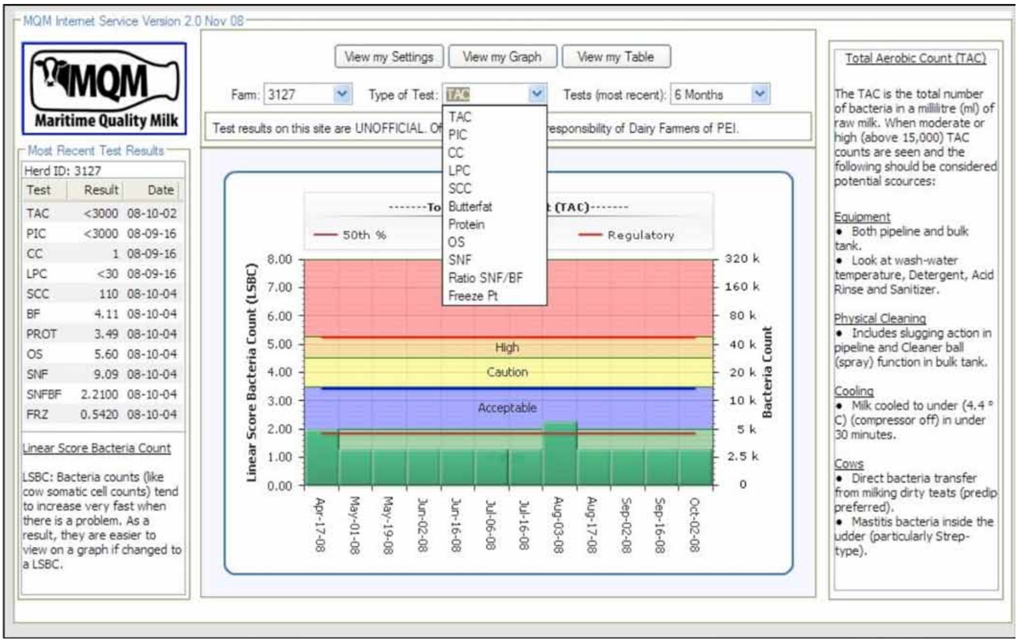


*Figure 1. Graph of total aerobic bacteria count with benchmarks and education information.*

allow the user to choose the parameter and the time period of interest. The left of the screen displays extension education information related to the parameter under view. In the centre of the screen is the historical display of the parameter of interest, with suggested herd goals and both the 50$^{th}$ percentile and regulatory benchmarks for comparison.

Having access to the laboratory milk quality and productivity data in graphical format allows for evaluation of data trends. For example, in Canada milk quota utilization is based on butterfat shipments and butterfat and other component levels must be kept within strict ratios to avoid penalty. Evaluation of trends in butterfat level related to feed and other management alterations and monitoring of component ratios have proven to be very popular utilities within the system.

Early feedback on the system indicated that, while today's managers are interested in additional information, many are also suffering from an overload of information and a lack of time to filter through it. As a result, MQM GAP has developed an email notification system, under the control of the producer, which allows each individual to set alerts based on recent test results. Figure 2 demonstrates the screen used by producers to adjust email notifications.

Users set upper limits or ranges for the data that they consider normal fluctuation within the farm. If the results stay within this range, no notification is sent when new data is retrieved from the laboratory. If, however, data falls outside the prescribed range the producer is immediately notified via email and can link directly to the system to get details. Email notifications can be set for four bacteria count criteria, SCC and six other measures of productivity and quality. In addition to producers, advisors such as veterinarians, herd nutritionists and udder health

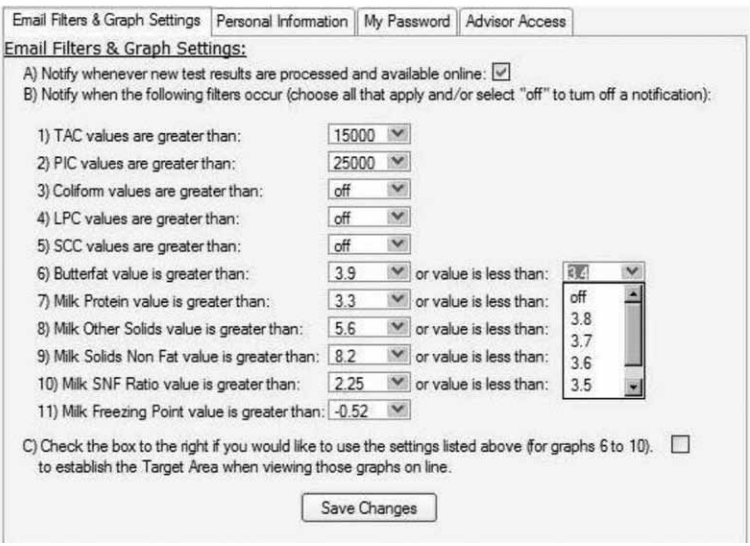


*Figure 2. Notification settings for email alerts related to productivity and milk quality.*

technologists utilize the notification system as a alert mechanism for monitoring their client herds.

More recently, we have again partnered with Amalgamated Dairies Limited to communicate herd eligibility for bonus payments. Within the system data is tracked for the 4 parameters that are used in the bonus scheme; SCC, total bacteria count, coliform count and laboratory asteurization count. Bonuses are paid quarterly based on the three month geometric mean of monthly values for the parameters (Figure 3). MQM GAP displays the monthly test result data (dot), as well as the geometric mean for that quarter's bonus pay period (bar). The month the actual bonus is paid (third month of quarter) is identified, as well as the status with respect to the bonus eligibility. When not all 3 months of the quarter have data yet, the system projects the target that the producer must achieve in order to meet the bonus criteria in that quarter.

Uptake of the system within the regional dairy community has been strong. Within one year of launch approximately 50% of producers were accessing the system regularly. In Nova Scotia, where the laboratory was not previously providing any electronic access to data, uptake was highest with 60% of farms regularly visiting the website was an average frequency of access of more than once per week.

In 2011, producer focus groups were held to get feedback on the system and to set direction for future development. The focus groups consisted of both user and non-user dairy producers, with participants suggested by the provincial dairy marketing boards. The main reasons given by non-users for not utilizing MQM GAP was a lack of knowledge about availability and

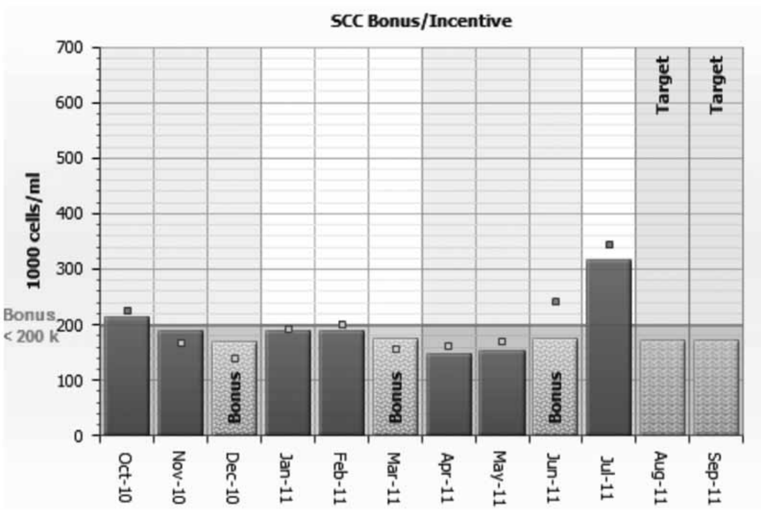


*Figure 3. Display for quarterly bonus eligibility based on 3 month geometric mean SCC.*

understanding of the capability of the system. Users indicated that, as comfort grew with the system, they relied increasingly on the email alert system, rather than going to the website directly. At the request of one provincial dairy board, tracking of quota credits (utilization) had recently been made available in that province only. Producers from other provinces felt this was a useful tool for all users. The appearance and usability of the site were favorably reviewed and the producers suggested that presentation was not as important as function. For the future, producers suggested that applications that are better adapted for mobile devices should be a high priority for development.

## Conclusion

As per unit costs for milk testing decrease over time, more frequent testing for management as opposed to regulatory purposes are likely to take place. These data represent both a challenge and opportunity to increase communication with end user dairy producers and their advisors.

In a short period of time the MQM GAP system has become widely used in the regional dairy industry of Atlantic Canada. The frequent access of the site by producers provides an excellent vehicle for transfer of extension education material related to milk quality.

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# Systems analysis of high somatic cell counts on dairy farms

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Many milk quality programs are focusing on somatic cell counts or other milk quality parameters in their communication strategies with dairy farmers. However, it is critical to acknowledge that farms are complex systems, regardless of their size. Biological, economic, and social/behavioral aspects jointly impact the ultimate efficiency of the farm. To successfully address such a complex system a comprehensive, coordinated and fully integrated systems approach is essential. Focusing on a single component of performance of a dairy farm may have unintentional side effects or may ignore the full picture of a complex farm system. To understand better the impact of our efforts to improve milk quality, we have developed an initial systems analysis model to show the complexity and feedback loops involved in reducing bulk milk SCC. The model shown in Figure 1 was developed by our research and extension team with input from stakeholders and it is currently being fed by real life data and stakeholder

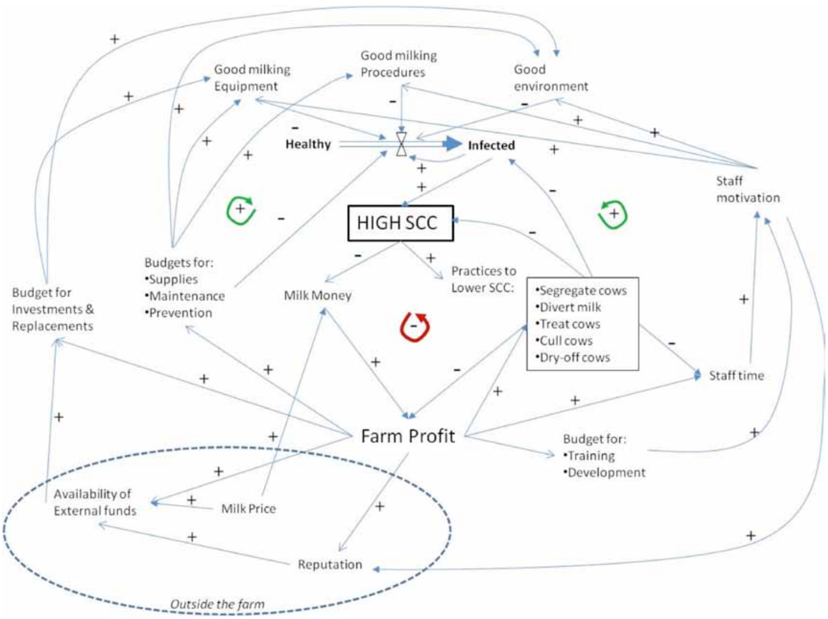


*Figure 1. Initial systems approach model of high bulk milk somatic cell count (SCC) on a dairy farm. The key stock that we model here is the number of healthy and infected cows; the flow as it relates to high SCC is generally from healthy to infected. The arrows indicate expected causal relationships. The circles with a '-' or '+' indicate negative or positive re-enforcing feedback loops.*

input. The model provides an example of our initial perception of SCC complexity when considered in the complex dairy farm system. Following the causal arrows in the model allows the identification of positive and negative feedback loops. One important negative feedback loop is directly associated with a continuous increase in SCC. The importance of such negative feedback loops and strategies to come out of negative feedback loops will be presented.

# Part 3 Motivation and communication strategies

# A Bayesian approach demonstrating that incorporation of practitioners' clinical beliefs into research design is crucial for effective knowledge transfer

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## Abstract

New knowledge will only be used on farm if the underpinning research has an impact by changing the clinical beliefs held by veterinarians in practice. If practitioners currently hold very strong clinical beliefs, stronger future evidence will be required to alter those pre-existing beliefs and forge a new prevailing opinion amongst the veterinary community. This study aimed to investigate within a Bayesian framework, the beliefs of veterinarians regarding the efficacy of systemic antibiotics as an adjunct to intra-mammary dry cow therapy and the consequences for knowledge transfer. The beliefs of 24 veterinarians from five practices in England were quantified as probability density functions ('prior beliefs') using probabilistic elicitation. Classic multidimensional scaling revealed *major* variations in beliefs both within and between veterinary practices which included: confident optimism, confident pessimism and considerable uncertainty. Of the nine veterinarians interviewed holding further cattle qualifications, six shared a confidently pessimistic belief in the efficacy of systemic therapy and whilst two were more optimistic, they were also more uncertain. The prior beliefs were incorporated into Bayesian models that used a synthetic dataset from a randomized clinical trial (showing no benefit with systemic therapy) to *predict* how the veterinarians' prior beliefs would alter as the size of the clinical trial increased. This study demonstrated the usefulness of probabilistic elicitation for evaluating practitioners' beliefs. The major variation observed raises interest in the veterinary profession's approach to prescribing essential medicines and has important implications for knowledge transfer; determining practitioners' pre-existing beliefs is crucial as they fundamentally affect the strength of evidence necessary for knowledge to be transferred effectively from research into clinical practice. As in human medicine, an important reason why veterinary research has failed in the past to evoke change may concern the strength of the research produced relative to the strength of practitioners' beliefs.

**Keywords:** probabilistic elicitation, dry cow therapy, systemic antibiotics

## Introduction

Quantifying the diversity and strength of practitioners' clinical beliefs is important for designing clinical trials. Conducting a randomised clinical trial (RCT) requires considerable effort and expense and thus researchers who conduct clinical trials are almost invariably enthusiastic about the outcome at the outset. Their enthusiasm may be markedly different to the end consumers of the data (e.g. veterinary practitioners), who may hold very different beliefs, even extreme scepticism. However RCTs that have been designed in a classical statistical framework using traditional frequentist sample size calculations do not (and indeed cannot) take into account the current beliefs of the end consumers of the data. Thus in the event the trial does yield a positive result, this may prove sufficient evidence to convince the researchers themselves, but be of insufficient strength to alter the clinical beliefs held by practitioners and hence fail to alter the decisions actually taken on farm.

Within the framework of Bayesian statistics, a RCT can be formally designed to take into account the pre-existing beliefs of practitioners, such that if the trial finds a positive effect it is likely to be taken seriously by practitioners, given their current beliefs. This paper illustrates how practitioners' beliefs can be quantified mathematically using a statistical technique called 'probabilistic elicitation' and used within a Bayesian statistical framework to investigate the strength of evidence needed (in theory) to convince practitioners that systemic antibiotics *do not* offer a clinically worthwhile benefit over intra-mammary dry cow therapy (IDCT) alone. This objective stemmed from the fact that, despite the current common use of systemic therapy, there is a lack of solid evidence supporting its efficacy and it is not an unreasonable proposition that such use may not be clinically worthwhile. Moreover systemic antibiotics in this context are off-licence and may contribute to antimicrobial resistance. The two key aims of this research were therefore: (1) to conduct a probabilistic elicitation to quantify the variation in veterinarians' beliefs regarding systemic therapy; (2) to investigate (using statistical modelling) the strength of future evidence required to change those beliefs.

## Materials and methods

### *Identification and recruitment of veterinarians*

The study population comprised all veterinarians treating dairy cattle within an area 100 miles in radius, centred on the University of Nottingham. The on-line database (http://www.rcvs.org.uk/) provided a sampling frame of veterinary practices. Only practices that treated cattle and contained at least one veterinarian holding the R.C.V.S post-graduate Certificate in Cattle Health and Production ('CertCHP') were selected. A two-stage 'cluster' sampling design was used and 5 veterinary practices selected with probability proportional to their size and then 5 veterinarians selected randomly from within chosen practices (Kalton, 1983). This produced a sample of 24 veterinary surgeons (one practice only contained 4 veterinarians). Data were collected on 5 days from 23$^{rd}$ June to 7$^{th}$ July 2010.

### *Definition of variables and task structure*

The question of interest was 'do systemic antibiotics in combination with IDCT (treatment 2) offer a clinically worthwhile benefit over IDCT alone (treatment 1)'? Thus it concerned a contrast between two variables; the cure rate achievable with treatment 1 (denoted $\theta_1$) and the cure rate with treatment 2 (denoted $\theta_2$). These variables are probably regarded as *dependent*; given knowledge that $\theta_1$ is lower than expected, many may believe that $\theta_2$ will also be lower. To quantify beliefs relating to two variables requires their joint probability distribution which is considerably more complicated to elicit for dependent variables (O'Hagan *et al.*, 2006). To avoid this complexity the task was re-structured by defining another variable, $\theta_3$, the cure rate achievable with treatment 2 given treatment 1 has failed. With this definition for $\theta_3$, $\theta_2$ is given by $\theta_2 = \theta_1 + (1 - \theta_1)\theta_3$. The assumption of independence between $\theta_1$ and $\theta_3$ was considered acceptable to veterinarians and hence the joint distribution of $\theta_1$, $\theta_3$ is given by $f(\theta_1, \theta_3) = f(\theta_1)\, f(\theta_3)$. Since T: $(\theta_1, \theta_3) \rightarrow (\theta_1, \theta_2)$ is a one-to-one transformation of continuous variables, the joint distribution of $\theta_1$ and $\theta_2$ involved a standard calculation to derive an explicit equation for the joint distribution of $\theta_1$, $\theta_2$ in closed form.

### *Probabilistic elicitation method*

Probabilistic elicitation is a statistical technique that usually involves eliciting a small number of summaries of the expert's belief, fitting parametric distributions to them and assessing the adequacy of the fit (Garthwaite *et al.*, 2005). Specifically designed software was used (SHELF, O'Hagan and Oakley http://www.tonyohagan.co.uk/shelf/) and best practice followed with an interview between the first named author and each practitioner lasting up to 40 minutes. Practitioners were paid £100 per hour. Two pilot interviews with academics from the University of Nottingham tested the method. For each variable ($\theta_1$ and $\theta_3$) five values were elicited to allow a beta distribution to be fitted; the plausible range (minimum to maximum), median and two further judgements (lower and upper quartiles).

The task itself considered commercial dairy cows at the point of drying-off which had a 'chronic' intra-mammary infection (in one or more quarters) with unknown but major pathogens; 'chronic' was defined as a somatic cell count greater than 400,000 cells/ml at both of the two monthly milk recordings prior to drying off. Cows received either treatment 1 or treatment 2 and it was assumed that no other treatments were given until calving. Cows were 'cured' if they were free from any major intra-mammary pathogens at calving. Actual product choice for both treatment 1 and 2 was left to the discretion of the veterinarian; interest resided in the generic use of antibiotics administered by the systemic route for dry cow therapy. Information was also gathered concerning key features of the individual veterinary surgeons and their practices. Raw data were entered into Microsoft Excel (Version 2007, Microsoft Corp). All analyses used the R programming environment; version 2.10.1 (R Development Core Team, 2009).

### *Classical multidimensional scaling*

For this analysis the elicited values from the two pilot interviews were included. If the vector of 10 elicited values for each veterinarian is denoted $x_i$ ($i$ = 1 ... 26) then the squared Euclidean distance between the vectors for veterinarian *i* and veterinarian *j* is given by

$(x_i - x_j)^T (x_i - x_j)$ and this was used as a measure of the dissimilarity in veterinary beliefs. The standard 'goodness of fit' statistic was calculated (Mardia *et al.*, 1979) and was used to determine the number of dimensions in conjunction with a scree plot.

### *Bayesian analysis*

Bayes' theorem mathematically describes the rational way to update an initial state of knowledge (belief) to a new state of knowledge in the light of new data. For a single continuous unknown variable $\theta$, Bayes' theorem can be written as:

$$\pi(\theta \mid x) \infty \pi(\theta \mid x)\pi(\theta), \tag{1}$$

where $\pi(\theta)$ is the prior probability density function (or prior belief), $\pi(x \mid \theta)$ is the likelihood (based on new data $x$) and $\pi(\theta \mid x)$ is the posterior probability density function containing all available information about $\theta$ after the prior belief has been updated with information contained in the data. Equation (1) says that the extent of any logical change in belief depends on *both* the prior belief, $\pi(\theta)$, *and* the strength of the new evidence, $\pi(x \mid \theta)$.

Bayesian models were used whereby the 24 prior beliefs obtained during the interviews were combined (individually) using Equation (1) and *synthetic* data from clinical trials of different size (30, 50, 250, 500, 750 and 1000 infected cows in each treatment arm) in order to produce 24 posterior distributions, $\pi(\theta \mid x)$. The posterior distributions can be considered to represent what each veterinarian *would* believe if they were shown the synthetic data and they updated their prior beliefs *rationally* and hence are subsequently referred to as '*predicted beliefs*'. For this analysis a threshold was used; a 'clinically worthwhile benefit' was taken to be a minimum of a 5-10% improvement in the probability of cure with treatment 2 over treatment 1 (equivalent to an odds ratio ≥1.5). For each trial size, $\theta_1$ and $\theta_2$ were set equal so that $\theta_3 = 0$ i.e. the synthetic data suggested there was no difference between the two treatments. Software developed by the 'BUGS' project (Bayesian inference Using Gibbs Sampling) was used in a form embedded within R, library 'BRugs' (Thomas *et al.*, 2006) to run the model which uses Markov chain Monte Carlo (MCMC) stochastic simulation.

## Results

### *Descriptive statistics*

Non-response rate was zero. Seven of the veterinarians held extra (cattle-related) qualifications; five held the CertCHP, two held the Diploma in Bovine Reproduction, one held both. Number of years qualified varied from 9 months to 26 years (median 7 years). The 'percentage of current time spent working with dairy cattle' ranged from 15-100% (median 80%). The joint distribution $f(\theta_1, \theta_2)$ was plotted for each veterinarian. There were major variations in beliefs, both between individuals within a practice and between practices. Both confident optimism and confident pessimism for the combined use of systemic and intra-mammary antibiotics were observed, alongside several veterinarians who had considerable uncertainty. To illustrate, Figure 1(A) shows the joint distributions of 5 veterinarians (from the same practice) and reveals the wide diversity in beliefs observed within a single practice.

### *Classical multidimensional scaling*

The first three (of 10 possible) dimensions accounted for 95.3% of the variation. The first principal coordinate axis was interpreted as an 'overall measure' of the veterinarians' belief for $\theta_3$ Hence it contained information related to all five elicited judgements for this variable. Similarly, the second principal coordinate axis was interpreted as an 'overall measure' of the veterinarians' belief for $\theta_1$. The third principal coordinate axis reflected the veterinarians *uncertainty alone* in $\theta_3$.

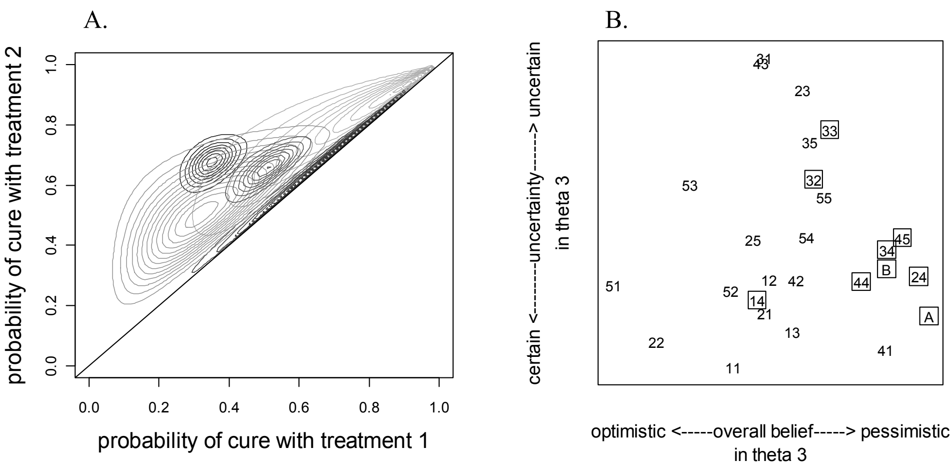


*Figure 1. A. Joint probability distributions for $\theta_1$, $\theta_2$ for 5 veterinarians working for the same practice, diagonal line denotes $\theta_1 = \theta_2$. B. Classical scaling of the data.*

The two-dimensional map for one of the three planes is presented in Figure 1(B). Each number represents an individual veterinarian, with those from the same practice sharing the same first digit (e.g. 11,12,13,14 all worked for the same practice, labelled '1'). A square box highlights veterinarians holding extra-qualifications (denote 'expert'). 'A' and 'B' represent the clinical academics from the University of Nottingham. Figure 1(B) reveals that six of the nine 'expert' veterinarians (clustered in the lower right corner of the map) shared the same 'confident pessimism' for $\theta_3$ and whilst two experts (32 and 33 from the same practice) are slightly more optimistic, they are also much more uncertain. Only one expert (14) had 'confident optimism' in $\theta_3$. Inspection of the other two planes (not shown) revealed that seven of the experts shared their optimism for $\theta_1$ (the success of IDCT alone), whilst the other two experts (32, 14) were more pessimistic. It can be seen from Figure 1(B) that the veterinarians in practice 1 are located closest together, suggesting that they held the most similar beliefs (and with a similar level of certainty) of any practice. In particular, the raw data showed that they all believed systemic antibiotics would cure a minimum of 20% more cows (given IDCT had failed). In contrast, the raw data showed that everyone in practice 3 agreed that using systemic antibiotics may not improve cure rates at all.

### *Bayesian analysis*

MCMC simulation was used with three chains, a total sample size of 30,000 and a 'burn-in' of 1000 iterations. The chains visually converged almost immediately; Gelman-Rubin statistic convergence to one. Figure 2 (first column) shows the 95% credible intervals for the prior distributions of the odds ratio for the 24 veterinarians (note: the choice of x-axis scale truncates eight of the prior credible intervals at their upper range, but this choice facilitates comparison with the posterior predicted beliefs).

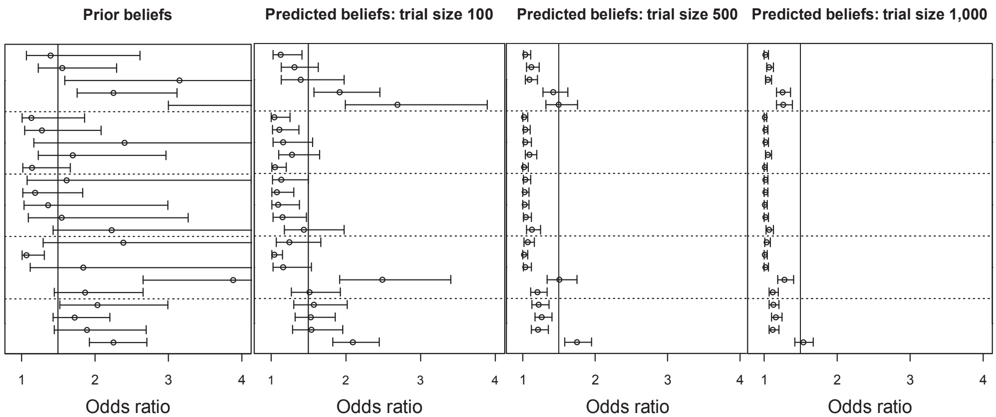


*Figure 2. The prior beliefs (column 1) and posterior predicted beliefs (columns 2-4) as 95% credible intervals for the odds ratio for the 24 veterinarians.*

Only one veterinarian had their entire 95% prior credible odds ratio interval *below* 1.5, whilst six veterinarians had their entire 95% intervals *above* 1.5 (recall that an odds ratio ≥1.5 was taken to indicate that systemic antibiotics *do* provide a clinically worthwhile adjunct to intra-mammary dry cow therapy). Figure 2 (second to fourth columns) shows the 24 posterior distributions (i.e. the 'predicted beliefs') derived from combining the priors from the 24 veterinarians with synthetic data from clinical trials of varying size (50, 250 and 500 cows in each treatment group) each of which shows no difference between treatments. Figure 2 reveals that only with a trial size of 1000 cows are 23 of the 24 predicted beliefs such that the entire 95% posterior credible odds ratio intervals are less than 1.5.

## Discussion

The wide diversity in beliefs observed is likely to result in very different decisions being taken on farm, with considerable discrepancies in the treatments received by dairy cows at drying-off. This raises concern over whether antibiotics are being prescribed consistently in practice and also more generally about the heterogeneity in veterinarians' beliefs and decision-making. Whilst it is undesirable for veterinarians to be completely unified in their clinical approaches, broad agreement is important for the credibility of the veterinary profession and to ensure a consistent delivery of healthcare to dairy cattle.

Explanation of the variation is likely to be multi-factorial. Reasons could include; cost of products/marketing, differences in how veterinarians source and appraise information, lack of data, education and farmer perceptions. Interestingly, the majority of 'expert' veterinarians in this sample shared a 'confidently pessimistic' belief in systemic therapy. The beliefs of 'expert' veterinarians are not fact but are important, especially in the absence of robust data. Given the escalating global threat of bacterial resistance to antibiotics, justification for the off-licence use of systemic antibiotics for dry cow therapy becomes difficult.

A major advantage of adopting a Bayesian approach is that by eliciting clinicians' beliefs at the design stage of clinical trials, sample size calculations are greatly facilitated by placing the proposed trial in the context of current clinical opinion. Despite increasing use of this approach in human medicine over the last decade (Spiegelhalter *et al.*, 2004), the authors are not aware of any veterinary research trials that have been designed in this way. Yet research efforts will be targeted more effectively if trials destined never to sway clinical opinion from the outset are avoided. Similar to human medicine, an important reason why veterinary research may have failed in the past to evoke change on farm could be due to the strength of the research produced relative to the strength of practitioners' beliefs.

Possible reasons why probabilistic elicitation has not been used more widely in the veterinary field include the complexity of the task, cost and time considerations (Berry and Stangl, 1996). Indeed, as Spiegelhalter *et al.* (2004) commented 'turning informally expressed opinions into a mathematical prior distribution is perhaps the most difficult aspect of Bayesian analysis'.

However it is hoped that the development of freely available software along with the major benefits to be derived from conducting productive research, will provide motivation.

## Acknowledgements

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# Enhancing udder health with clinical communication skills: evidence based communication frameworks for the 22nd century

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## Abstract

Communication is a core clinical skill of veterinary medicine and it must be taught and learned to the same extent as other clinical skills. Veterinary schools across North America, UK, EU, Australia and the Caribbean have developed or commenced development of communication skills programs and assessment strategies. These initiatives are fuelled by overwhelming evidence in favour of communication skills training required for practice success. More recently communication skills education is taking place on site in veterinary practices resulting in significantly improved relationship-centered communication which includes moving beyond traditional history taking to include questions pertaining to the client's beliefs and values. Humanistic oriented research in production animal medicine also reveals that the farmer's attitude (i.e their unique perspective) rather than behaviour is predictive of the incidence of mastitis. To date much of the focus in production animal/communication research has been on developing global communication strategies. This research has been highly informative, and we must move beyond broad based strategies and understanding of our audience. This paper describes the frameworks, based on 40 years of combined research in human and veterinary medicine, currently being used in veterinary education and practice settings, and review what is necessary for teaching, learning and utilizing communication to a mastery level of competence.

**Keywords:** communication skills, veterinary training

## Introduction

Research in production animal medicine has found farmer's attitude (i.e. perspective) rather than behaviour predicts the incidence of mastitis on a farm (Jansen *et al.*, 2009; Coe *et al.*, 2011). This is supported by research from other healthcare fields which would suggest that when a producer has a pre-established viewpoint regarding an issue that is not consistent with their veterinarian's, the producer is likely to reject the veterinarian's viewpoint in favour of their own (Tuckett, 1985). These findings reinforce the importance of not only gathering a traditional medical history but also the importance of gathering information specific to the producer's perspective (e.g. their beliefs, their expectations, etc). In other areas of veterinary medicine it has been found that 30% of clients who did not follow through with their veterinarian's recommendation did not do so because they felt it was unnecessary, suggesting that these clients did not receive information that was relevant to their perspective (Lue *et al.,* 2008). A foundation has been laid in the production animal literature that is starting to make connections between communication and the uptake of medical issues that are essential for udder health (Potter, 2007). It has also been identified that some of the more 'hard-to-reach farmers' are not homogenous in their desire and type of information, and each one of them requires a different approach to communication and information on udder health rather than a uniform approach to interacting(Steuten *et al.,* 2008). Understanding the producer's unique perspective provides the groundwork for a food-animal practitioner to work with and educate the producer to a mastitis recommendation in a way that the individual producer will see value.

## Communication skills for veterinarians

Communication is a core clinical skill and one that needs to be taught, learned and assessed to the same degree as any other clinical skill in veterinary medicine (Adams and Kurtz, 2006). Over a decade worth of studies have been done in an effort to determine competencies that are necessary for success in the veterinary profession. The American Veterinary Medical Association's market study (Brown and Silverman, 1999) identified a gap in essential communication and management skills for successful practitioners. Lloyd and Walsh (2002) developed a recommended veterinary curriculum including outcomes pertaining to communication, and a personnel decisions study recommended communication skills training amongst other skills as being essential to practice success (Lewis and Klausner, 2003). These recommendations have been critical in moving the communication agenda forward, and they pertain primarily to 'what' to teach rather than 'how' to teach. There is 40 years of research in human health linking communication to outcomes including diagnostic accuracy, satisfaction, understanding and recall, compliance, and reduction in malpractice. These relationships have been well documented and are succinctly summarized in the books Skills for Communicating with Patients (Silverman *et al.,* 2005) and Teaching and Learning Communication Skills in Medicine. In veterinary medicine there is close to 10 years of research building on this evidence from human medicine within the veterinary context. Interpersonal communication research in veterinary medicine furthers the understanding of the relationship between communication skills and increasing client understanding, uptake and ultimately decision making thereby effecting animal health and well-being (Shaw, 2004; Shaw *et al.,* 2004, 2006; Borden *et al.,* 2010; Coe, 2008; Coe *et al.,* 2007, 2009; Nogueira, 2007; ). While beyond the scope and length of this paper, there are a number of veterinary schools now using evidence based approaches to teach and assess communication in preparing our next generation of veterinarians (Adams and Ladner, 2004; Adams and Kurtz, 2006; Shaw and Ihle, 2006; Abood, 2007).

In addition to the research that has begun to frame communication teaching and learning approaches, there are also significant societal changes and some very specific to udder health communication including culture and diversity (Roman-Muniz *et al.,* 2004; Saha *et al.,* 2005; Jansen *et al.,* 2009). While communication practices necessary for cross-cultural communication and sensitivity are the same as communication skills anywhere else in veterinary practice, the level of intensity or intentionality may vary. Cultural communication does not require a 'new' set of communication skills rather a level of 'cultural sensitivity', meaning communication skills and capacities that enable veterinarians to coordinate their work across a number of potential cultural divides including race, ethnicity, and the divides that exist in veterinary medicine itself (Kurtz and Adams, 2009). For the remainder of this manuscript we will discuss frameworks and strategies for teaching and learning communication skills, including skills specific to effective udder health communication.

## Teaching and learning communication skills

The development of communication skills training in practice and academic settings must be guided by the evidence base, which we've alluded to above. While we have referred to a select number of studies from medicine and veterinary medicine, it's important to note that the vast evidence base supporting the importance of clinical communication in achieving outcomes such as accuracy, efficiency and productivity is far too compelling to refute. The evidence also informs the types of communication skills that are needed to achieve the outcomes defined by the veterinarian and client, and in turn the directions for teaching and learning communication. For example, a recent veterinary study (Dysart *et al.,* 2011) identified that the odds of a new concern arising during the final few minutes of a veterinarian-client interaction was 4 times more likely if the veterinarian had not intentionally explored the client's concerns (i.e. perspective) at the beginning of the interaction. This evidence provides a basis for teaching veterinarians and veterinary students communication skills to solicit and screen for additional client concerns at an early point in any interaction.

There are a number of established frameworks for teaching skill-based communication including the Patient Centered Model (Stewart *et al.*, 2003), 4-habits (Frankel and Stein 1999), Segue framework (Makoul, 2001b), Bayer-Fetzer Essential Elements (Makoul, 2001a), AAPP 3-Function Model (Lipkin *et al.*, 1995), MAAS-Global (Van Thiel *et al.*, 2000) and the Calgary Cambridge Guide (Silverman *et al.*, 2005). The framework most widely used in healthcare communication is the Calgary-Cambridge Guide (CCG) (Kurtz and Silverman, 1996; Adams and Kurtz, 2006; Kurtz, 2006). This evidence based framework was initially developed by a team of physicians and communication experts; since it's origin it has been successfully translated into 12 languages and applied to multiple other healthcare fields including veterinary medicine. The guide consists of 72 communication skills organized around an expanded framework including initiating an interaction, gathering information conducting a physical exam, building a relationship, structuring the conversation, explaining and planning with the client(s), and closing and making plans for follow up (Box 1). Veterinary educators in the US, Canada, Caribbean, UK, and Australia have been using this framework for 15 or more combined years. An example of important communication skills, applicable to a variety of issues including udder health, is noted in Box 2.

Regardless of context of the communication (i.e veterinarian-producer; communicating with other professionals, community and so on), or the issues that one is dealing with (i.e mastitis, respiratory disease, herd health, reportable disease, conflict, risk/benefit communication, culture and so on) communication always involves three overlapping skills that need to be taught and learned. First there are content skills or what the veterinarian communicates. Content skills are the substance of what the veterinarian asks about and talks about. Second,

*Box 1. Calgary-Cambridge guide: communication process skill.*

Initiating the session
- establishing initial rapport;
- identifying the reason(s) for the appointment.

Gathering information
- exploration of patient's problems;
- additional skills for understanding the client's perspective.

Providing structure to the consultation
- making organization overt;
- attending to flow.

Building the relationship
- using appropriate nonverbal behaviour;
- developing rapport;
- involving the client.

Explanation and planning
- providing the correct amount and type of information;
- aiding accurate recall and understanding;
- achieving a shared understanding: incorporating the client's perspective;
- planning: shared decision making;
- options in explanation and planning:
  - if discussing opinion and significance of problems;
  - if negotiating mutual plan of action;
  - if discussing investigations and procedures.;

Closing the session
- forward planning;
- ensuring appropriate point to end the visit.

*Box 2. Skill sets to emphasize in udder health communication.*

- relationship building (skills for developing and maintaining relationship);
- establishing mutually understood common ground (the basis for trust);
- accurate information exchange-checking for understanding;
- eliciting and acknowledging the other person's perspectives, especially when they differ from our own;
- demonstrating empathy;
- attentive listening;
- engaging in shared decision making;
- identifying our own intentions and assumptions;
- nonverbal communication (appropriate for culture/context);
- relational coordination (skills for coordinating efforts with others);
- dealing with conflict and defensiveness;
- putting together well-conceived, concise messages and delivering them well.

process skills have to do with how the veterinarian communicates. Process skills include how the veterinarian:

- structures and organizes what s/he says;
- asks questions (open versus closed ended questions);
- develops and maintains relationships;
- listens, and acknowledges others;
- non-verbal communication;
- expresses compassion, caring or understanding.

Finally, there are a range of perceptual skills that must be addressed. These have to do with the thoughts, feelings and capacities that underlie the WHAT and HOW the veterinarian is communicating. These include: clinical reasoning, problem solving, internal decision making, assumptions, biases, prejudices, attitudes, values, intentions, beliefs, emotional intelligence, feelings about other or the topic at hand, and cultural awareness, sensitivity, flexibility and compassion.

Beyond content, process and perceptual skills and the capacities necessary to teach and learn communication, we also need to set up a situation where we are observed by others and given feedback-constructive/balanced feedback. Veterinary medical education has adopted the use of simulated clinical encounters using actors and community people trained to portray a real life interaction (Adams and Ladner, 2004; Borden *et al.*, 2008). The importance of learning to give and receive feedback cannot be overlooked. Communication skill development is unlike other skills training in that it's tightly tied to sense of self or self concept, and we are all starting with different levels of experience-some good and some not so good! Finally, opportunities must be made for people to practice and integrate the feedback they have received. Communication skills training at the practice level have been conducted and significant improvements have been reported (Latham and Morris, 2007; Shaw *et al.,* 2010).

## Conclusions

There is increased evidence supporting the importance of communication skills for achieving outcomes that are essential for dairy health, and rationale for treating communication skills training and mastery level competence as important as all other clinical skills and knowledge development. Udder health at the individual and herd level requires ongoing attention and a sharpened focus on communication skills teaching, learning and research in the field.

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# Udder health management improvement: Insights from agent-based modelling

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## Abstract

Food processors and governments aim to motivate dairy farmers to improve udder health management. Such farmers' decisions are driven not only by economic considerations, but also by other motivations, cognitions and professional and personal networks. Little is known about integrated influence of such aspects on adoption of improved udder health management. The effect of these aspects on success of the current tools used to motivate farmers to improve udder health is also unknown. An agent-based model that simulates the simultaneous decisions to adopt udder health measures of multiple heterogeneous dairy farmers (agents) interacting with each other has been developed. The model reveals emerging macro-level patterns of system behaviour, when individual behaviour of each farmer is defined by economic considerations, cognitions and farmers' networks. The collective behaviour is presented by the total number of farmers adopting certain udder health improvement measures over time. The integrated analysis of farmers' behaviour with regard to adoption of udder health measures indicates that stimulation of adoption of different measures require different approaches to designs of incentive system and communication campaigns. Intensive communication campaigns seem to be better designed per individual measure, since intensive communication might be not needed for all the measures available. For the measures, adoption of which could be more difficult due to extra expenditures involved, communication campaign and interacting with other farmers alone are not very effective. Stimulation of adoption of such measures requires putting an economic incentive system in place. Farmers' personal motivation and network are also shown to reinforce the adoption of udder health; though network is really effective only for low motivated farmers.

**Keywords:** economics, farmer behaviour, farmer network, simulation model, complex system

## Introduction

Food processors and governments aim to motivate dairy farmers to improve udder health management. Udder health improvement mainly involves implementation of various measures on the farm. Such farmers' decisions are driven not only by economic considerations, but also by other motivations (Valeeva *et al.*, 2007), cognitions (Ajzen and Fishbein, 1980) and professional and personal networks. Little is known about integrated influence of such aspects on adoption of improved udder health management. The effect of these aspects on success of the current tools used to motivate farmers to improve udder health is also unknown. The challenge is to find out the extent of adoption of desirable udder health measures over time and the influence of internal aspects of farmers' decision making and external tools on this process.

This paper presents an agent-based model that simulates the simultaneous decisions to adopt udder health measures of multiple heterogeneous dairy farmers (agents) interacting with each other. The model aims to model actual human behaviour (which can be sub-optimal) of Dutch dairy farmers in decision making regarding measures to improve udder health. The model does not aim to define an optimal strategy but to find out what collective behaviour emerges from behaviors of the individual farmers.

## Materials and methods

### *An agent-based model as integration of available tools*

An agent-based model has been developed to examine the simultaneous farmers' decisions to adopt behaviour regarding udder health measures. The model includes multiple dairy farmers (agents) with simple behavioural rules of action and interaction, so as to elicit complex emerging outcomes (collective adoption behaviour). The behavioural part of this model is inspired by the theory of planned behaviour (Ajzen and Fishbein, 1980). For an introduction to the agent-based modelling, see Epstein and Axtell (1996). Agent-based models do not rely on the assumption that the system will move towards a predetermined equilibrium state, as conventional economic equilibrium models do. Instead, at any given time, each agent acts according to its current situation, the state of the world around it and the rules governing its behaviour. The model keeps track of the many agent interactions with other agents and environment, to see what happens over time and to reveal emerging macro-level patterns of system behaviour (Farmer and Foley, 2009).

Behavioural rules in this study were defined for each farmer to govern his own internal process along with his interactions with other farmers (networks) and environment. Farmers are characterized as bounded rational and acting in what they perceive as their own interests.

The model behavioural rules were based on three key elements:
1. Information types available to the agents to found their decisions on (a) farmers are informed by the dairy processing company about penalties based on the actual bulk milk somatic cell count (BMSCC) level, i.e. economic incentive; (b) farmers are informed by dairy processing companies, government or other professional extension services about the specific udder health measure, i.e. communication campaign on effectiveness, costs and savings/net benefits due to implementing the measure; (c) farmers inform each other whether they have adopted a particular measure, i.e. farmer's network.
2. Agent's information processing and decision-making mechanism to adopt measures based on the above information types.

3. Generation of the change in the BMSCC level.

The model was built and solved using the multi-agent programming language and integrated modelling environment NetLogo 4.1.2 (Wilensky, 1999). A complete model specification and formal description of behavioural rules can be found in Verwaart and Valeeva (2011). An improved model as used in this study is available from the following site http://www.verwaart.nl/FoodSafety.

As described below, under different parameter settings, model runs result in the emerging numbers of farmers adopting and not adopting udder health measures over time. given a certain incentive scheme and communication campaign. The measures considered in this study are 'wearing milkers' gloves' and 'milking cows with clinical mastitis last'. These measures entail different types of variable costs. The measures are examples of possibilities to improve the udder health, but not necessary the most important ones (Huijps *et al.*, 2010a).

#### *Model parameters*

The parameters used to formulate the behavioural rules of farmers decision to adopt udder health measures are outlined in Table 1. The model parameters are grouped into three categories. The agent parameters are used to model a heterogeneous population of dairy farmers with respect to their internal behavioural process of taking decision on adoption of udder health measures as well as their interactions with other farmers. The information type parameters reflect the influence of environment on farmers behaviour. The parameters of generation of bulk milk SCC are employed to model the change in bulk milk SCC due to implementing the measure.

#### *Data*

Most parameter estimations are based on data from published Dutch studies (Jansen *et al.*, 2009, 2010a,b; Hogeveen *et al.*, 2011; Huijps *et al.*, 2008, 2010b; Valeeva *et al.*, 2007). For estimation of economic and risk attitude parameters the base farm is considered. It is characterized by 65 milking cows with an average 305 day milk production of 8,500 kg/year, and milking parlour with 12 places, an average bulk milk SCC of 200,000 cells/ml, an incidence of clinical mastitis of 30% per year.

## Results

The model was run for different scenarios as indicated in Table 1. In each run, results include the average percentage of farmers who adopted a certain measure in total farmer population (2,809 in this model). Depending on the intensity of communication and farmers' openness to it, it takes from 10 to 30 two-week time periods to reach the situation where adoption fluctuates in a stable range.

*Table 1. Input parameters for running simulations on adoption of two udder health measures.*

| Category and symbol | Content | Parameter value | |
|---|---|---|---|
| | | **Wearing milkers' gloves** | **Milking cows with clinical mastitis last** |
| Agents (dairy farmers) | | | |
| l | Constant absolute risk aversion | 0.011 | |
| n | Motivation type as preference for operational excellence[2] | 0; 1.0 | |
| g | Openness to communication | Random 0.0 ... 0.5 | |
| b | Persistence of attitude | 0.5 | |
| d | Network degree | 4 | |
| $m_i$ | Motivation to follow *i* (equal for all *i*) | Random 0.0 ... 0.5 | |
| $w_A$ | Weight of attitude in intention forming[2] | 0; 0.5; 1.0 | |
| $w_{SN}$ | Weight of social norm in intention forming[2] | 0; 0.5; 1.0 | |
| $w_{PBC}$ | Weight of PBC in intention forming[1] | 0 | |
| $PBC_{threshold}$ | PBC threshold[1] | 0 | |
| Information type | | | |
| Economic incentives | Penalty-based system: | | |
| $\alpha_1$ | – Bulk milk SCC threshold for penalty, cells/ml | 250,000 | |
| $\alpha_2$ | – Penalty for first non-compliance[2], eurocent/kg | 0 ... 4.0 | |
| $\alpha_3$ | – Increase factor for repeated non-compliance | 1 | |
| $\alpha_4$ | – Maximum penalty, eurocent/kg | 20 | |
| Communication campaign | | | |
| $\iota a$ | Intensity of communication[2] | 0.1; 0.2; 0.5; 0.8; 1.0 | |
| | Measure-specific information[2]: | | |
| prev_reduction | – Decrease in bulk milk SCC, % | 6 | 17 |
| add_cost | – Costs, eurocent/kg | 0.013 | 0.430 |
| E_saving | – Saving, eurocent/kg | 0.106 | 0.190 |
| Generation of bulk milk SCC | | | |
| E(BMSCC) | Mean bulk milk SCC, cells/ml | 210,000 | |
| cv | Coefficient of variation | 0.3 | |
| d | Persistence parameter | 0.5 | |

[1] PBC = Perceived behavioral control (Ajzen and Fishbein 1980).

[2] Parameters changed in simulation scenarios.

### *Adoption scenarios under different influences of environment*

Table 2 reports the adoption of the measure 'milking cows with clinical mastitis last' under different influences of information types available to farmers to found their decisions on such as described above certain incentive schemes, communication campaigns and interaction with other farmers (network). In terms of the model parameters the analysed scenarios consider different levels of intensity communication, different penalty levels for the first non-compliance and different weights of social norms in intention forming, respectively (Table 2). Results are also differentiated for two extreme level of farmer's motivation described as preference for operational excellence. Note that implementing 'milking cows with clinical mastitis last' causes negative savings. This could imply extra difficulty in getting farmers to adopt this measure despite its' rather high effectiveness (Table 1).

Table 2 shows that all the three information sources have influence on adoption of 'milking cows with clinical mastitis last' among dairy farmers. However, the extent of their influence is rather different.

*Table 2. Adoption 'milking cows with clinical mastitis last' under various levels of information available to differently motivated farmers (% in the total farmer population).*

| **Intensity of communication ($\iota a$)** | **Penalty for first non-compliance, eurocent/kg ($\alpha_2$)** | **No network effects of social norms ($w_A$ = 1; $w_{SN}$ = 0)** | | **Network effect of social norms ($w_A$ = 0.5; $w_{SN}$ = 0.5)** | |
|---|---|---|---|---|---|
| | | **No preference for operational excellence (n = 0)** | **High preference for operational excellence (n = 1)** | **No preference for operational excellence (n = 0)** | **High preference for operational excellence (n = 1)** |
| 0.5 | 0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2 | 27.4 | 58.0 | 58.7 | 58.0 |
| | 4 | 39.5 | 78.3 | 77.6 | 79.4 |
| | 6 | 43.8 | 85.8 | 85.8 | 86.9 |
| | 8 | 48.1 | 89.0 | 89.4 | 90.1 |
| 0.8 | 0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2 | 34.9 | 77.3 | 98.6 | 78.0 |
| | 4 | 43.8 | 89.0 | 91.8 | 92.2 |
| | 6 | 46.3 | 95.4 | 94.7 | 95.1 |
| | 8 | 49.8 | 96.1 | 96.5 | 96.5 |

The only increase in intensity of communication results in no change of adoption (0%), given that the penalty-based incentive system is not introduced. The same is true for the effect from network with other farmers.

The level of penalty for non-compliance and network with other farmers have high influence for farmers having no preference for operational excellence (without personal motivation). The only introduction of the penalty system (change from 0 to 2 eurocent/kg) and the first step of penalty increase (change from 2 to 4 eurocent/kg) lead to increase of adoption rate up to 27.4% and 39.5%, respectively. Interaction with other farmers increases theses rates up to 58.7% and 77.6%, respectively. However, there is almost no such a network effect observed for farmers having high preference for operational excellence (with personal motivation), the initial effect of penalty does not differ between both network scenarios, resulting in the adoption of about 58.0% and 78.0-79.0%, respectively.

Increase in intensity of communication also strengthens the effect of the penalty-based incentive system for farmers with different level of motivation; though for farmers having high preference for operational excellence (with personal motivation) the observed increase of adoption due to more intensive communication is somewhat larger. For example, for the penalty change from 0 to 2 eurocent/kg, adoption increase from 58.0% to 77.3% and from 27.4% to 34.9% for personally motivated and not motivated farmers, respectively. This increase in adoption is even larger in combination with the network effect, in particular, for farmers having no personal motivation.

### *Adoption scenarios for two udder health measures*

Figure 1 compares the simulated adoption of two measures, namely 'milking cows with clinical mastitis last' and 'wearing milkers' gloves'. under different designs of incentive schemes and communication campaigns. In contrast to 'milking cows with clinical mastitis last', implementation of 'wearing milkers' gloves' results in saving (Table 1).

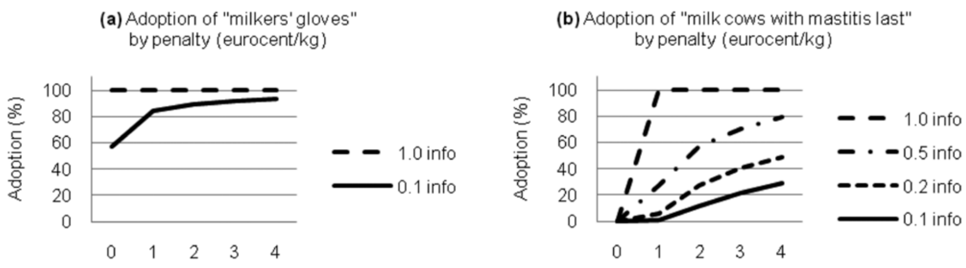


*Figure 1. Percentage of farmers who adopted two udder health measures under different incentive schemes (penalty for first non-compliance, eurocent/kg: $\alpha_2$ = 0; 1; 2; 3; 4) and communication campaigns (intensities of communication: $\iota_a$ = 0.1; 0.2; 0.5; 1.0).*

Figure 1 shows that 'wearing milkers' gloves' is being highly adopted even at low levels of penalties for non-compliance and intensities of communication. This indicates a rather low effect of these two information types on adoption of this measure. This measure itself initially provides a rather sufficient level of incentives (savings). Additionally, its' implementation requires no substantial change in working routine. Under current parameter settings to generate bulk milk SCC and to calculate the penalty, full adoption of 'wearing milkers' gloves' would lead to a 25% reduction in the number of penalties (not shown in Figure 1).

For 'milking cows with clinical mastitis last', Figure 1 also shows that both an adequate level of penalty and a high level of communication intensity are needed in stimulating farmers to change their adoption behaviour. Full adoption of this measure would reduce the number of penalties by approximately 65% (not shown in Figure 1).

## Discussion and conclusions

The integrated analysis of farmers' behaviour with regard to adoption of udder health measures indicates that stimulation of adoption of different measures require different approaches to designs of incentive system and communication campaigns. Intensive communication campaigns seem to be better designed per individual measure, since intensive communication might be not needed for all the measures available.

For the measures, adoption of which could be more difficult due to extra expenditures involved, communication campaign and interacting with other farmers alone are not very effective. Stimulation of adoption of such measures requires putting an economic incentive system in place. An optimal design of such an incentive system can be the first priority in increasing the level of adoption of these measures. Farmers' personal motivation and network are also shown to reinforce the adoption of udder health measures; though network is really effective only for low motivated farmers.

The study provides valuable insights into the farmer' decisions to improve udder health in a contemporary environment. More research would be however needed to find out the better estimates of the model parameters, in particularly to model communication campaigns and farmers' network. Existing diversity of individual farmers and their social networks is also rather limitedly modelled in this study. For example, autocorrelation is currently used to adapt the data per individual farm in accordance with the measures implemented. Having individual data on dynamics of bulk milk SSC per each farm would allow to count for measures' effect in a more realistic way. A further development of the model would be to include a possibility of exploring the adoption of a set of measures.

In conclusion, the presented approach models udder health management as a complex dynamic and more realistic system, taking human adaptation and learning (perceptions and behaviour) into account next to traditional economic considerations (cost-effectiveness and economic incentives). The study helps better understand interrelation of these aspects and their effect on success of the different tools used to stimulate farmers to improve udder health such as economic incentives and communication campaigns.

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# Usage of milking gloves and teat sealer on German dairy farms

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## Abstract

Thirty-three fourth year veterinary medicine students visited dairy farms, to fill in a questionnaire, and to provide advice in two subject matters, i.e. wearing milking gloves and using teat sealer in combination with antibiotic dry cow treatment. Two communication strategies (i.e. argument-based vs. emotion-based) were randomly applied to communicate background information related to the two subject matters. Four weeks after the visit the farmers were interviewed by telephone to evaluate the effectiveness of the two strategies using a follow up questionnaire. In total 366 German dairy farms were visited between September and November 2010. 278 follow up questionnaires were filled in after 33±8 days. Wearing gloves improved from 72.0% to 78.8% (n=250). Only 25.9% and 21.3% (n =108) at follow up farmers cleaned gloves after every cow. However, cleaning gloves at least after every milking group increased from 76.9% at the first visit to 88.0% (n= 108) at the second interview. The attitude towards using gloves during milking improved significantly. 69.6% (90.9% at follow up, n=263) of the farmers thought gloves were hygienic; 81.7% (86.7% at follow up) found them protective for the skin, and 63.5%(86.7% at follow up) believed gloves were effective for mastitis prevention. Only 18.7% (n=273) (22.7% at follow up) of the participants always used internal teat sealer for drying cows off; 11.0% (12.8% at follow up n=273) used teat sealer sometimes. 58% (n=231) of the farmers did not have an opinion about the efficacy of teat sealer. At the follow up survey 42.4% farmers were still not convinced. Efficancy of the two communication strategies was similar.

**Keywords:** communication strategies, milking gloves, teat sealer

## Introduction

Udder health is one of the greatest concerns in dairy industry. Plenty of udder health programs to improve and control mastitis have been invented (LeBlanc, 2006). The success of these programs is highly dependent on the compliance of the farmer and their personnel (Kristensen and Jakobsen, 2011). Effective communication from the advisory veterinarian towards the farmer is essential to implement strategies for mastitis prevention on farm (Lam *et al.*, 2011).

But training in communication skills is rare for veterinary practitioners. Only few veterinary schools offer courses in communication skills.

Some veterinarians blame 'hard-minded' farmers to be resistant against suggestions for improving herd health, but they are not aware of the different attitudes, learning styles and level of knowledge of the farmers (Lam *et al.*, 2011). Others do not trust their advisory capabilities (Jansen, 2010a).

Various theories how to change human behaviour have been discussed (Hogeveen *et al.*, 2011, Ellis-Iversen *et al.*, 2010). For example in the rational choice theory it is assumed that behaviour will change only through scientific based arguments, calculation of financial benefits or technical analysis of consequences. This theory neglects both social and environmental influences. The belief-system theory includes the social state and the personal felt identity of the farmer (Grube *et al.*, 1994). The social pressure due to perception of the farmer by his environment can be highly motivating to change behaviour.

Not only the type of arguments used for an advice is important, but the way they are presented. First the advisor has to find out about the mind-set of the respondent (Lam *et al.*, 2011). How do they perceive the risk of mastitis? What is their knowledge in this area? How are they motivated and what kind of learning mode do they prefer? It is important the advisor does not argue from his point of view but from the viewpoint of his respondent.

Jansen *et al.* (2010b) evaluated two communication strategies in the Netherlands, one to improve udder health management on a broad scale and the other to implement a specific management tool, wearing milking gloves. For the first issue they used a 'central route'. This

followed the rational choice theory with scientific based arguments, study groups and educational tools. To convince farmers to wear milking gloves they used a 'peripheral' route. This followed more the belief-system theory with media campaign and persuasion techniques.

In our study we wanted to compare directly the efficiency of these communication strategies for usage of milking gloves and drying of cows with internal teat sealer on German farms. Furthermore we wanted to introduce 4$^{th}$ year students into the role as an advisor on dairy farms.

## Material and methods

### *Students*

Thirty-three fourth year veterinary students from all five German universities were acquired through social student networks within the scope of Pfizer Animal Health 'Milchinitiative 2010'. In August 2010 they were invited to a two-day workshop in Berlin. The workshop included lessons in mastitis therapy, especially in drying cows with internal teat sealer, as well as an introduction into the two communication strategies. On the second day the students visited a dairy farm milking 1000 cows.

### *Farms*

Farmers were acquired in a campaign on a large agricultural fair and through agricultural magazines.

### *Questionnaire*

The first questionnaire included 48 questions on farm structure, barns, milking technique, milking routines including use of milking gloves, udder health, mastitis prevention and therapy as well as on the farmers mind- set toward veterinary advices on udder health.

The follow up questionnaire investigated the experience the farmer made with the counselling interview and his change of behaviour in terms of milking gloves and teat sealer. It was filled in 33±8 days after the farm visit.

### *Farm visits*

From September to November 2010 the students contacted dairy farmers and their local vets to make an appointment for a counselling interview. On the farm visit they tried to convince the farmer to use milking gloves and teat sealer. In addition they filled in a questionnaire. The farm visit did not last more than one hour. After four weeks the students made a follow up telephone call and filled in a second questionnaire.

For the consultancy they used, computer randomized, either the 'central route' or 'peripheral route'. Information material for the 'central route' enclosed a scientific based poster and tables based on Godden *et al.* (2003) for the teat sealer and Rodrigues *et al.* (2005) for the milking gloves. For the 'peripheral route' the students showed a magazine with a report on a positive experience with internal teat sealer or/and left a free sample of milking gloves. Furthermore they discussed that most of the successful farmers use milking gloves. It was possible that a student had to use both communication strategies on one farm, e.g.'central route' for milking gloves and 'peripheral route' for internal teat sealer.

### *Statistics*

Data were analysed using PASW Statistics (Version 19, SPSS). Descriptive analyses were used to describe the distribution of answers within a questionnaire. The McNemar Test was applied to test differences between the two surveys. Significance level was set at 0.05.

## Results

### *Descriptive analysis*

The 366 dairy farms visited, were in all parts of Germany. The average herd size was 124 cows, with a minimum of 11 and a maximum of 1,200 cows. The average 305 d milk yield was 8,620 kg with a minimum of 4,000 kg and a maximum of 12,000 kg. Up to 12 milkers were employed at the farms, and one milker was milking an average of 63 cows. Men and women were equally distributed. In total 278 sets of questionnaires were included in the analysis, of which 88 questionnaires were excluded because information was insufficient or the first and second questionnaire could not be allocated. For the analysis only farmers were considered that answered the questions in the first and second questionnaire.

On the first visit 72.0% (n=250) farmers used milking gloves. Only 25.9% (n=108) cleaned gloves after every cow. 50.9% (n=108) cleaned the gloves at least between two milking groups. 23.1% milkers did not clean gloves at all. Most of the farmers had a positive attitude towards using milking gloves. 69.6% (n=263) believed that wearing gloves is hygienic; they are skin protective (81.7%) and a good preventive tool against mastitis (63.5%). Only 7.6% farmers did not see any advantage in using milking gloves.

Internal teat sealers were not used commonly on the study farms. Only 18.7% farmer always used internal teat sealers for drying off cows and 11.0% (n=273) sometimes. 58.0% (n=231) were unsure if teat sealers are effective in preventing mastitis.

In the second questionnaire 78.8% (n=250) were using milking gloves regularly, whereas only 21.3% were cleaning or disinfecting gloves after every cow, 88.0% (n=108) were doing so at least after every milking group.

### *Efficiency of consultation*

The usage of milking gloves increased significantly (n=250, $P<0.05$) during the survey. Whereas cleaning gloves after every cow did not improve (25.9% versus 21.3%, n=108, $P=0.359$), more farmers cleaned gloves at least after every group (76.9% to 88.0%, n=108. $P<0.05$).

The attitude towards using gloves improved in some aspects. 21.3% (n=263) more farmers believed milking gloves to be hygienic ($P<0.05$) and an additional 23.2% (n=263) farmers found milking gloves can prevent mastitis ($P<0.05$). The skin protective attribute did not change significantly (n=263, $P=0.11$).

The consultancy for the internal teat sealers was successful. Additional 5.8% farmer (n=273, $P<0.05$) used internal teat sealer after the students visit. Also the attitude towards internal teat sealers was improving 30.7% (n=231, *P*<0.05) changed into a positive opinion about internal teat sealers.

#### *Communication strategy*

The advice to use milking gloves was presented 128 (46.5%, n=275) times with the 'central route' and 147 times (53.5% n=275) with the 'peripheral route'. For the internal teat sealer information 51.4% (n=278) 'central route' and 48.6% (n=278) 'peripheral route' was used. There was no difference in efficiency between the communication strategies.

## Discussion

Effective communication strategies are essential to convince anyone to change his behaviour. Jansen *et al.* (2010b) found a rational based strategy as well as a peripheral strategy effective to implement mastitis prevention tools on Dutch dairy farms, but they evaluated each strategy for a different aim. The central route (rational based) was effective for a complex goal, a long lasting management program. Farmers with a specific motivation to improve heard health took part in this study. The peripheral route was tested on a specific management tool that is wearing milking gloves. This campaign reached a wide range of farmer through mass media and agricultural fairs. In our study we wanted to compare these two communication strategies for the same targets. These were to motivate dairy farmers to use milking gloves and internal teat sealer for drying of cows. We found both strategies were equally effective.

For the milking glove campaign already 72% of the participants used milking gloves regularly. This is in contrast to the Dutch situation, where only 20.9% used gloves from the start. So the potential for an improvement was smaller. Nevertheless the attitude toward using milking gloves improved significantly in some aspects. The conviction that wearing gloves was good, because they are hygienic and good mastitis prevention internalized in the farmers. So the motivation to continue to use of milking gloves will be quite high. Motivation to change behaviour is associated with the perception that the change of behaviour is necessary, and it is effective in term of animal health and economics (Janz and Becker, 1984). So the educational tools should create such an awareness and knowledge. The material the students presented to the farmer in the 'central' route gave evidence proofed information of the benefits of milking gloves. For little step by step behavioural changes the 'peripheral' route is supposed to be effective as well (Sheeran, 2002). So we could not find any difference in effect in our study.

The use of internal teat sealers were not very common (29.7%) on the farms visited by the students. The students attempt to convince the farmer could create a significant difference. Also the attitude towards internal teat sealers changed in a positive direction. The communication strategy had no influence. So again implementing a specific management tool seems to be quite effective by either communication strategies.

## Conclusions

In our study we could not proof any differences in efficiency between two communication strategies. After a short training fourth year veterinary students were able to successfully advice dairy farmers to implement two management tools to improve udder health.

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# Communication research from other healthcare disciplines and its application to udder-health management

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Research to date in production-animal medicine has primarily focused on developing global communication strategies to address issues relating to udder-health management. Research in other areas of veterinary medicine and other healthcare professions has found interpersonal communication to be an important factor in effecting clinical outcomes such as satisfaction, adherence, recall, understanding, and patient health. Research into the implementation of udder-health management programs has identified farmer's attitude (i.e. perspective) rather than behaviour predicts the incidence of mastitis on a farm. Building on these findings, research in human medicine would suggest when a producer has a pre-established viewpoint regarding an issue that is not consistent with their veterinarian, the producer is likely to reject the veterinarian's viewpoint in favour of their own. Other areas of veterinary medicine have found that 30% of clients who did not follow through with their veterinarian's recommendation did not do so because they felt it was unnecessary, suggesting that these clients did not receive information relevant to their perspective. Recent research in small-animal veterinary medicine, conducted by the authors, demonstrates increased client involvement in an interaction leads to greater adherence. In this study veterinarian-client interactions leading to client adherence were scored significantly higher ($P<0.05$) for relationship-centered care (i.e. client involvement) than interactions leading to non-adherence. This presentation will summarize recent empirical communication research from other areas of veterinary medicine as well as human medicine, link these findings to the role of veterinarian-producer communication in maximizing udder health and discuss directions for future research into the role of interpersonal communication in udder-health management

# Attitudes with regard to animal management of farmers with an automatic milking system and their relationship with udder health

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Farmers with an automatic milking system (AMS) might have a different attitude with regard to animal management than other farmers. Data were collected on 151 dairy farms, varying in herd size from 30 to 420 cows. The farmers reflected on 75 propositions divided in 4 general topics, being business and goals, working style, AMS and mastitis. The answers of the farmers were analysed to get insight in their attitude with regard to animal management. Using multivariate regression analysis, the farmers attitude with regard to animal management was related to the udder health on those farms. The udder health of the farms was described, based on data from milk production registration and the incidence of clinical mastitis, as reported by the farmers. The geometric mean of the annual average herd somatic cell count (SCC) was 258,000 cells/ml, the annual average percentage of cows with a new high SCC ranged was 10% and the average incidence rate of clinical mastitis was 27 cases per 100 cows per year. Farmers with an AMS were very interested in management aspects directly related to cows. Reducing labour was also important for these farmers. The working style of the farmers with regard to flexibility varied greatly between farmers. Almost all the farmers claimed that mastitis is problematic. A division in the farmers could be made with regard to their perception of their knowledge about mastitis. Factors that were found to have a relation with udder health on farms with an AMS were, amongst others, the farmers' belief that a high milk production per cow is important and the working procedures farmers handled.

# Farmer-veterinarian communication in the new Danish herd health program: changing responsibilities in relation to mastitis treatment and udder health promotion

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In November 2006, a new herd health program (NHHP) was launched in Denmark, based on weekly farm visits by the herd veterinarian performing systematic clinical examinations (SCE) at each visits. In the framework of NHHP, farmers are allowed to initiate treatment of cows with mastitis. Before NHHP, only veterinarians could diagnose and initiate treatments and leave the post-treatment to the farmer, given that he had monthly veterinary advisory visits. In NHHP, consensus and common understanding on diagnosis, and how antibiotics can be administered, changes the requirements to the skills and capacities of both farmer and veterinarian, and in particular, also how they collaborate and communicate. Veterinarians are now more 'supervisors', and farmers take responsibilities for appropriate treatments. This study is based on thirteen semi-structured qualitative research interviews (taped, transcribed and analyzed) of farmers and their veterinarians, with focus on communication and use of NHHP, including how they perceive the changes since entering the program. The importance of the veterinarian's capacity to understand, interpret and explain data on herd level to farmers was demonstrated to be crucial to make the analyses valuable for the farmer. The large variation in farmers' and veterinarians' attitude towards SCEs and milk samples influence how data analyses are used in decision making and herd monitoring. Frequent communication was described as motivating and stimulating. The changed roles were generally perceived positive both by farmers and veterinarians, giving professional challenges and potentials to use knowledge and skills and more equal communication. Dilemmas were identified, e.g. routine milk samples at a certain stage seemed to provide very little additional information. A major challenge is how to involve farm staff members in the communication with the vet, as well as sharing of knowledge and responsibilities.

# Dairy farmers' knowledge, attitude and behaviour towards udder health in Switzerland

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Recent studies determined the influence of farmers' motivation towards bovine udder health but were conducted in countries with relatively large dairy herds. Milk production in Switzerland is characterised by small scale dairy herds with a relatively high milk quality. This study explored dairy farmers' motivation and behaviour towards udder health in Swiss dairy herds. An online questionnaire on farmers' attitude, knowledge and behaviour was sent to a stratified random selection of 2,285 Swiss dairy farms milking >10 dairy cows, of which 1,003 (44%) responded. The median bulk milk somatic cell count (BMSCC) level at which Swiss dairy farmers' were satisfied was 100,000 cells/ml, while the median BMSCC problem level was 150,000 cells/ml. Only 16% of the farmers indicated that they were able to further decrease their BMSCC. Ninety percent of the farmers regularly diagnosed (sub)clinical mastitis using bacteriological culturing, 13% wore gloves during milking, and post-milking teat disinfection was applied on 79% of the dairy herds. Half of the farmers worried about mastitis and the majority (60%) indicated that they had sufficient time to improve udder health in their herds. Udder health data will be obtained from Swiss milk quality and test day recording schemes to identify associations between farmers' motivation and behaviour and the udder health status in these herds. The initial results from this study determined Swiss dairy farmers' motivation towards udder health and will be used as a starting point for further studies to improve udder health in Switzerland.

# Impact of communication strategies for milkers on udder health program

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The aim of this study was to evaluate the impact of communication strategies for milkers on udder health program. During 4 years a dairy enterprise with 16 dairy farms, 6,000 milking cows and 62 milkers was included in the study. A team integrated by 6 veterinarians and a consultant on mastitis control and milk quality, developed the communication strategies for milkers. The practical tools included training sessions for milkers in mastitis control and milk quality, technical bulletins, a written standard operating procedure for milking routine and clinical mastitis therapy and supervision on a regular and frequent basis. After the implementation of communication strategies for milkers, the dairy farms had a significant reduction in the bulk tank somatic cell counts and incidence rate of clinical mastitis. Communication between veterinarians and the milkers was the key for successfully implementing an udder health program.

# Part 4
# The effective advisor

# Potentials and limitations of systematic clinical examinations in farmer-veterinarian collaboration for improved udder health in the new Danish herd health program

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## Abstract

In November 2006 a new herd health program (NHHP) was introduced in Denmark. Important elements of NHHP are weekly farm visits by the veterinarian, systematic clinical examinations (SCEs) of freshly calved cows and cows at drying off, and the authorization of farmers to initiate mastitis and other treatments. Our aim was to evaluate the application and implementation of SCE in the herds using quantitative data analysis and qualitative semi-structured interviews with 13 farmers and their veterinarians. Data from these farms with NHHP including SCEs with the mandatory variables CMT, metritis score, vaginal score, udder score, body condition score and general condition were available. The quantitative analysis showed a large variation in data quality and application of some score values especially for udder score. This was confirmed in qualitative interviews. The farmers' and veterinarians' attitude towards SCEs varied greatly and influenced data quality and implementation in the herd. The frequent contact between farmer and veterinarian was perceived as beneficial in itself, the SCE helped to focus the dialogue and basis for short-term decisions. Long-term planning and monitoring of udder health using SCE was limited and revealed further demands to the veterinarian for competencies in data handling, analysis and interpretation. In conclusion, SCE are perceived as beneficial tools in udder health management. Distinct knowledge of the farmers' and veterinarians' application and attitudes towards SCE is necessary to explain the variation in the data and increase data validity.

**Keywords:** herd health management, systematic clinical examinations, mastitis treatments, veterinary advisory service

## Introduction

In November 2006 a new herd health program (NHHP) was introduced in Denmark as a result of a negotiation between authorities and the stakeholders involved in the agricultural and veterinary sectors. The intention of the program was to improve herd health and advisory service. The farmers obtained the right to initiate medical treatments of mastitis and other diseases if they enrolled to the program, which involved weekly or bi-weekly regular veterinary visits. At each herd visit the veterinarian conducts systematic clinical examinations (SCEs) of all animals at risk, i.e. freshly calved cows, cows at dry off and newborn calves and follows up on animals treated since the last visit. Furthermore veterinarians monitor herd health, welfare and medicine usage and are obliged to prepare quarter annually reports including all data and information on the herd's health status, disease incidence, system, management, feeding and production.

Mandatory variables for SCE in newly calved cows from day 5-19 are CMT, metritis score, vaginal score, udder score, body condition score and score for general condition.

Other variables can be chosen, e.g. ketosis scores or manure scores, ph of the urine and others. In cows 100-40 days prior to expected calving (i.e. before dry off), the SCE includes CMT, body condition score, general condition and udder score. Manual and electronic recording schemes are available and the results are transferred to the Danish central cattle database (DCCD), where all information on disease treatments, results from milk sampling and other laboratory tests, milk recording, breeding, milking system, slaughtering, culling and veterinary reports are stored and available for herd health analysis. In the spring of 2010 more than 800 farms had signed a contract for NHHP. A huge amount of data is collected, but little is known about the application of different types of information in day-to-day as well as long term herd health management.

The aim of this study was to evaluate the application and implementation of SCE in the herds using quantitative data analysis and qualitative semi-structured interviews with 13 farmers and their veterinarians. In this paper we will focus on udder health management and how different sources of information are applied in the advisory process, e.g. the udder health specific parameters CMT and udder score from the SCEs. Since dry cow therapy is only allowed in cows with a positive culturing result of a milk sample, we were especially interested in criteria for choosing cows for antibiotic dry cow treatments.

## Material and methods

### *Research approach*

The research team took a mixed method approach in this part of the project. Quantitative and qualitative data (quarter annually reports, qualitative interview of farmer and veterinarian) from 13 farms was collected and analysed, and the results of the analyses were combined to give an in-depth understanding of the process of herd health management in collaboration with the farmer, the farm employees and the veterinarian.

### *Quantitative analysis*

Data from 11 herds with NHHP was retrieved from the Danish Cattle Data Base (DCDB) from 1st June 2009 to 31st May 2010 and analysed using descriptive statistical methods on cow and herd level with focus on variables related to udder health and cow and herd characteristics (Table 1). Distribution of udder scores and CMT values were examined and the relation between the scores and having a sample taken for bacteriology, somatic cell count from closest milk recording, and dry cow treatment was examined with chi-square tests. A logistic regression model with herd as a random effect was fitted with backwards elimination using the glimmix procedure (SAS 2009).

### *Qualitative analysis*

The mandatory quarter annually reports from the veterinarians were retrieved from the DCDB and an overall document analysis focusing on ways and modes of communication was conducted.

*Table 1. Characteristics of 13 herds with new herd health management program.*

| Herd | Breed | Months with HHM | Herd size in cow years | Kg ECM305days per cow | Avg. SCC from milk recording x 1000 | Avg. SCC from bulk tank x 1000 | Cases of treated mastitis per 100 cow years[b] |
|---|---|---|---|---|---|---|---|
| 1 | DH | 42 | 90 | 9,249 | 362 | 348 | 59 |
| 2 | JER | 41 | 360 | 9,555 | 187 | 186 | 41 |
| 3 | DH | 8 | 491 | 11,509 | 204 | 203 | 18 |
| 4 [a] | DH | 25 | 254 | 9,267 | 388 | 385 | 20 |
| 6 | DH | 16 | 107 | 10,384 | 211 | 205 | 50 |
| 6 | DH | 15 | 144 | 11,005 | 187 | 185 | 59 |
| 7 | Cross | 33 | 169 | 8,500 | 214 | 202 | 40 |
| 8 | Cross | 38 | 143 | 8,834 | 307 | 305 | 166 |
| 9 | DH | 41 | 211 | 11,400 | 152 | 150 | 36 |
| 10 | Cross | 7 | 163 | 9,483 | 118 | 115 | 20 |
| 11[a] | DH | 19 | 213 | 11,043 | 173 | 164 | 23 |
| 12[a] | Cross | 9 | 179 | 8,713 | 304 | 301 | 39 |
| 13 | JER | 39 | 351 | 8,468 | 290 | 288 | 86 |

[a] Automatic milking system. All other herds have conventional milking parlour.

[b] All cases including dry cow treatments. Treatments occurring >7 days were regarded as new cases.

Among all herds with NHHP, two times 15 farmers were approached by letter and phone. We deliberately selected for the largest possible diversity between herds in terms of herd size, length of duration of the NHHP, mastitis treatment levels and breed, in order to explore how the herd health advisory service could work in a broad spectrum of different types of herds. Thirteen farmer + veterinarian teams were interviewed on the respective farm, beginning with an half hour farm walk and one and a half hour interview. Most rejections were based on lack of time, and some were without reasons. Four farmers never responded. The interview was a qualitative semi-structured research interview with focus on collaboration between veterinarians and farmers, and their routines and experiences connected to the herd health visits and communication.

### *The herds*

The participating 13 herds represented a broad spectrum of main breeds, with varying herd sizes, levels of milking production and udder health parameters (Table 1).

## Results

### *Quantitative analysis*

Screening of all cows with a completed lactation and subsequent calving showed that on average 76% of the cows within a herd, which were dried off, had a registered SCE, ranging from 35 to 99%. In the subsequent lactation, 94% of the freshly calved cows were examined, ranging from 87-99% within the herds. Results from SCEs at drying off and after calving were available from 1,281 cows from 11 herds. Udder scores from 0-9 describe changes in the udder beginning from changes in secretion, changes in the udder tissue and including chronic effects on production (Table 2). The application between farms varied greatly; on average 13% of scorings within a herd were missing for dry cows, ranging from 0 to 67%. The median number of different scores given within herd was 3 for both cows at dry off and after calving, ranging from 2 to 9 scores. All herds had reported score 0 (no changes), 8 herds score 1 (slightly change in secretion), 7 herds had reported score 8 (cows with three teats). Only 2 herds used the full scale of the udder score, while most herds applied few scores. The uneven distribution of number of different scores applied within herds and the high proportion of missing values indicates that the parameter is not applied similar in different herds and is most likely not regarded as important for evaluation of udder health. This was confirmed in the interviews. Veterinarians and farmers generally were very aware of the benefit of profound udder examinations, but they did not use the udder score or the results on herd level in decisions or in long term planning.

In contrast to udder score, the CMT scores at drying off were used as decision support for taking milk samples at dry off as well as for selecting cows for dry cow treatment in all parity groups. SCC from milk recording increased the odds of dry cow treatment, but cows with

*Table 2. Overview over the scores used in relation to systematic clinical udder examinations.*

| Score clinical udder examination | |
|---|---|
| 0 | No changes in secretion, no gland changes. |
| 1 | A small secretion changes, no signs of swelling or induration. |
| 2 | Clearly secretion change, milk is still the main component, no signs of swelling or induration. |
| 3 | Clearly secretion change, signs of swelling. |
| 4 | Clearly secretion change with clearly swelling. |
| 5 | Signs of gland atrophy, undoubtedly signs of yield reduction, no secretion change. |
| 6 | Clearly signs of gland atrophy, no secretion changes – moderate yield reduction. |
| 7 | Clearly signs of induration in teat and/or gland, profound yield reduction. |
| 8 | Clearly signs of induration in gland, no production. ***'3-teat-cow'.*** |
| 9 | Clearly signs of induration in several glands, no production. |

high CMT were more likely to being treated in comparison to cows with low CMT and high SCC. We found the lowest odds for cows with both values low, which indicates that CMT was more important than SCC results from milk recording. Older cows had a higher probability of getting treated. Differences between herds accounted for 25-28% of the variation in the data.

### *Available material for decision making in the herds*

The veterinarian of a dairy herd has access to all production and treatment data in the Central Cattle Data Base, as a part of the NHHP. This enables the veterinarian to make analyses of the herd data and in this way contribute to the discussion with overviews over the development with regard to diseases, production and the condition of the animals. In addition to this, they have the huge amount of clinical evaluation data which they have collected during their biweekly herd health visits. The farmer has access to his own data in the Cattle Data Base and daily observations from working with the herd. Registration, selection and optimal use of relevant data is a challenge in many large Danish dairy herds today, because the work and responsibilities are divided between more people. This requires a good flow of communication, which can be difficult because of time and language barriers (many farm workers are foreigners from e.g. Eastern European countries).

### *Use of data by farmers and veterinarians*

A document analysis of the quarter-annual reports showed a huge variation between the style, length and contents of the reports. The length of reports from second or third quarter of 2010 varied from 4-28 pages per herd. The style varied from purely narrative reports to almost purely compiling of tables, graphs and figures showing e.g. developments over the last year or compare the last 3 months to the last year. The use language ('professional language' versus 'small-talk language') varied much. Some veterinarians had employed another person to retrieve and present the herd specific statistics (tables other types of overviews) for the report using templates. When receiving the herd overview, the veterinarian would then comment and conclude based on the tables and graphs. Generally, the reports contained the veterinarian's evaluation of the situation and recommendations, and did not contain any reference to what had been commonly agreed or understood between the farmer and the veterinarian. In some reports, there was an 'action plan' but often it was the veterinarian's recommendations more than agreed action. Very few reports contained follow-up on previous actions. Based on the interviews we conclude that the length and style of the reports in particular reflect the veterinarian's interest (or lack of) for data analyses and presentation of data. In the interviews, farmers were asked how they included the reports in their decision making. This varied very much between farmers, and partly depended on the veterinarian's attitude, presentation and use of the reports in the discussions. Some veterinarian-farmer couples held particular meetings to discuss the results of the quarter-annual reports, and agreed on common actions, eventually with appointment of responsibilities. Others only took discussions on the weekly/biweekly visits and in a more ad-hoc manner, and the reports were mailed or emailed to the farmers and only discussed if there were major changes or developments in the herd or 'strange results'.

### *The value of frequent meetings*

Many farmers expressed that the frequent meetings were valuable and justified the relatively high costs for participating in NHHP. The weekly veterinary visits helped them focus on the cows which needed special attention. The weekly visit where 'other professional eyes looking at the herd and cows' assured many farmers that things were all right or taken care of in herd situations where overview could sometimes be difficult because of the herd size, structure of labor (many foreign farm workers) and production pressure. Additionally, the frequent contact with the veterinarian gave them the opportunity to bring up questions to which they needed inputs. Many veterinarians expressed that they benefitted from the closer collaboration with the farmer and gained better understanding of herd specific conditions. They also felt professionally stimulated taking this approach to looking at herds and cows and getting closer into the herd management.

## Discussion

Establishing a herd health management program which includes collection of SCE data enables the decision makers in the herd to take more informed decisions. In this study, this information was rarely included in the strategic planning of actions and changes of management practices, although it had great value in and made the frequent dialogue concrete and focused towards the actual condition of the newly calved cows. If the rationale for SCEs should be revisited, this has to be taken into consideration, because they seem to help the farmer and veterinarian focus on certain groups of cows in the actual situation, but seems to be less useful in the overall and long-term planning, where they to a larger extent base their discussions and argumentations on 'well known' production and disease data. The quantitative analysis supported the results from the qualitative interviews that CMT was an important tool for treatment decisions, but rarely presented and discussed in the reports. The varying usage of udder scores emphasizes the need for a revision of the parameter in order to reach a common understanding of the levels and to use the results for monitoring purposes within herds and between herds. It also indicates that examples and exchange of experiences on how concretely to use SCE data in health advisory service could maybe stimulate more farmer-veterinarian teams to use it more actively. One pitfall of the existing SCE scheme could be that the focus is kept exclusively on these groups of cows and there is less time and focus on completely different issues in the herd, which the farmer or some of the herd staff may wish to focus on.

The reports rarely reflected the dialogue between farmer and veterinarian in terms of agreed future action, and rarely contained information about the management of the herd and actions. One reason for this may be that the legal purpose of the reports is to document the actual disease status as background information for judging whether the herd's medicine use is justified. Nevertheless, this should not exclude that agreed actions and changes in management practices are included, and we suggest that it will make the report more useful on long-term basis in order to follow-up on the development in the herd and as reference point for the following reports.

## Conclusion

Frequent contact between a farmers and his veterinarian seems beneficial in itself, because of immediate discussions of the farmers' pressing questions, and because the frequent contact contributes to a common understanding of the current herd condition. Data from SCE were collected with varying quality, mainly used for day-to-day decisions and only to a limited extent when analysing the herd situation and planning long-term strategies.

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# Veterinary on-farm counselling on dairy farms: the veterinarians' vision

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## Abstract

At present most Dutch veterinary practices offer on-farm counseling to dairy farmers. Goal of this study was to determine how Dutch veterinary practices defined on-farm counseling and what problems they experienced interacting with dairy farmers. In January 2011 ten randomly selected Dutch veterinary practices involved in on-farm counseling within the scope of herd health programs on dairy farms were asked to participate in this study. Upon agreement an appointment was made at the veterinary practice where one veterinarian, providing on-farm counseling in practice, was interviewed. During the interview a list of questions were asked in a semi-structured fashion. The interviews were recorded with a voice recorder and later transcribed in full. The definition of on-farm counseling differed between practices. Some practices defined it as fertility checks, while others included structural advice on aspects of dairy farming such as animal health, housing and prevention. According to the veterinarians, the way on-farm counseling was executed was fully dependent on the farmers' wishes. However, farmers were not actively asked for their wishes. During on-farm counseling goal setting and evaluation were used only by two veterinarians. Three veterinarians provided a written advice afterwards. Most veterinarians experienced difficulties communicating advices to dairy farmers; they indicated they found it difficult to change farmers' behavior and experienced difficulties explaining the value of the advice. Most advices were followed only partially. An important observation in this study was that veterinarians who were enthusiastic about the concept of on-farm counseling saw possibilities to expand it in their practice and experienced less communication problems. Problems with udder health and production level were detected earlier and dealt with in a more preventive and structural way. Veterinarians also had fewer difficulties selling their advice to farmers, and perceived their farmers as motivated more often.

**Keywords:** on-farm counselling, veterinarian, herd health management, interviewf

## Introduction

Veterinary on-farm counselling within the framework of veterinary herd health management is becoming increasingly important in Dutch dairy practice. At present most Dutch veterinary practices offer it to their dairy farmers. The definition and execution of veterinary on-farm counselling, however, differs between practices, and sometimes even within one practice.

In literature, veterinary on-farm counselling is defined as the analysis of and advice on animal health, productivity and prevention of disease, in which (farm) economics, animal welfare, public health, food safety and the environment are taken into account. Regular checks of the farm and farm specific data play a key role therein (Brand *et al.*, 1995; De Kruif and Opsomer, 2004; LeBlanc *et al.*, 2006). Since udder health has great impact on production levels, farm economics and animal welfare (Halasa *et al.*, 2007, 2009), it is considered to be a spearhead in herd health management programs and therefore in on-farm counselling. On-farm counselling is expected to play an important role in reducing the level of mastitis on a farm.

In practice, however, the performance of on-farm counselling is not as uniform as suggested by the definition. It is expected that not every veterinarian involved in dairy cattle is an expert on all aspects. Especially small practices may have problems filling the knowledge gaps and may offer narrower counselling. At the same time, not every dairy farmer will be interested in integrating all of the different aspects of on-farm counselling on his or her farm. Considering these areas of attention, it is expected that the definition of on-farm counselling in practice is not uniform. There is, however, little data available to support this expectation.

The aim of this study was to observe how veterinarians defined on-farm counselling and which problems they experienced implementing this definition in practice.

## Material and methods

For the interviews a topic list was created, based on a literature study. Three main themes, existing execution, communication and ideal execution, were used as a starting point. A list of eight topics was created (Table 1).

All veterinary practices, registered in the yearbook of the KNMvD (Royal Dutch Society for Veterinarians), were assigned a number. Randomly, veterinary practices were picked from this list and checked whether they were involved in dairy cattle. If so, it was contacted by telephone and asked to participate in our study. The first ten practices that agreed were visited. In total eleven practices were contacted; one practice declined participation because they did not offer on-farm counselling to their dairy farmers. The respondents were selected by the practice.

Eight interviews were held on the practice, two at the veterinarian's home. All interviews were with the respondent only. Five practices had a separate room where the interview could take place, at three practices a table behind the reception was used. The duration of the interviews varied from 28 to 47 minutes. All interviews were recorded with a voice recorder and later transcribed in full.

*Table 1. Interview topics, head themes and example questions from the interview.*

| Topic | Main theme | Example question |
|---|---|---|
| General practice information | - | How many farms do you visit for on-farm counselling?<br>How many full time veterinarians are working in dairy? |
| Content on-farm counselling | Existing execution | How would you define on-farm counselling?<br>Since when does this practice offer on-farm counselling? |
| Protocol on-farm counselling | Existing execution | Do farms have their own counselling veterinarian?<br>Do you, as a practice, have a protocol for on-farm counselling? |
| Finances | Existing execution | Is on-farm counselling profitable for your practice?<br>How do you charge for on-farm counselling? |
| Experience on-farm counselling | Existing execution | Do you enjoy giving on-farm counselling?<br>What do you like less about on-farm counselling? |
| Communication of advice | Communication | How is the communication of advice to the farmer?<br>Do farmers follow the given advice? |
| Optimizing on-farm counselling | Ideal execution | Where are points of improvement of on-farm counselling?<br>Is there room to expand on-farm counselling in this practice? |
| Future of on-farm counselling | Ideal execution | How do you see the future of Dutch dairy farming?<br>What role will the veterinarian have in this vision? |

## Results

In total four veterinarians in employment, five partners of a large practice and one veterinarian running a one-man business were interviewed. General practice information is given in Table 2. All interviewed veterinarians were working in dairy and provided on-farm counselling to dairy farmers. Four of the interviewees were female, six were male. Both female and male respondents are referred to as him in this paper.

All veterinarians indicated that the basis for on-farm counselling was the regular herd fertility checks. In all practices fertility counselling was offered to dairy farmers. Most practices expanded this with other topics, like udder health, data-analysis, or feed. Two practices took blood samples to measure mineral status and fatty acids in order to prevent (metabolic) disease (Table 3).

Nine of the interviewed practices charged for on-farm counselling per time unit. One practice charged a fixed price per cow per year. The practices that charged per time unit charged between 115 and 130 euro per hour.

*Table 2. Size, % dairy and number of dairy farms receiving on-farm counselling per practice.*

| Practice number | Full time veterinarians | % of vets working in dairy | Total number of dairy farms | Counselled dairy farms | Structurally counselled farms per full time dairy vet |
|---|---|---|---|---|---|
| 1 | 4 | 25 | 25 | 20 | 20 |
| 2 | 1 | 100 | 45 | 43 | |
| 3 | 4 | 20 | 50 | 15 | 19 |
| 4 | 4 | 70 | 160 | 40 | 14 |
| 5 | 3 | 35 | 45 | 27 | 27 |
| 6 | 5 | 60 | 195 | 58 | 19 |
| 7 | 4 | 25 | 36 | 20 | 20 |
| 8 | 13 | 15 | 140 | 70 | 36 |
| 9 | 10 | 45 | 185 | 130 | 29 |
| 10 | 5 | 20 | 38 | 23 | 23 |

*Table 3. Overview of the different topics discussed during on-farm counselling per practice. 'Other' stands for topics other than named here (e.g. claw health, grass management or housing).*

| Practice number | Fertility | Data-analysis at the kitchen table | Udder health | Feed | Other | Blood samples |
|---|---|---|---|---|---|---|
| 1 | v | v | v | sometimes | v | 1 farm |
| 2 | v | sometimes | sometimes | sometimes | | |
| 3 | v | sometimes | | | | |
| 4 | v | v | v | sometimes | sometimes | |
| 5 | v | v | v | v | v | |
| 6 | v | v | v | v | v | |
| 7 | v | | | | | |
| 8 | v | v | v | v | v | v |
| 9 | v | v | v | v | v | |
| 10 | v | v | v | sometimes | | |

Questions about the profitability of on-farm counselling were answered differently. Three practices could not say whether it was profitable, three said it was profitable, and four said it was not profitable. None of the practices, however, had conducted economic analysis to support their answer.

Charging the farmer for the time spent for counselling was an issue. Most practices found it hard to charge for the 'invisible' hours, e.g. time to prepare data analysis or time to write the report. and even harder to charge for the hours off the farm, e.g. a call out fee or preparation time. The social part of the farm visit, like coffee time, is important for the relationship with the farmer, and was almost never charged.

### *Structure of on-farm counselling*

All interviewed veterinarians stated that the way on-farm counselling was implemented on the farm was fully dependent on the farmers' wishes. There was a lot of difference between farmers; some farmers really wanted to fully implement a herd health program, with all elements of the on-farm counselling definition, whereas others only wanted the regular fertility checks.

Seven veterinarians did not work with goal setting and evaluation on the farms. They visited the farm and determined on the spot which things had to be discussed. Two veterinarians saw the importance of goal setting and evaluation, but had difficulties with the implementation. One veterinarian was using goal setting and evaluation at several levels: once per year for the long term goals, and every farm visit for the short term goals.

### *Communication*

Advices were not always properly followed up by farmers. There were a lot of differences between farmers, but most veterinarians experience a group of 'following' farmers and a group of farmers that did not or only partly follow the advices. Why some farmers chose not to follow the advice is often hard to determine. Farmers often theoretically agreed with the advices, but did not follow them in practice. Most veterinarians agreed, however, that the more tangible the advice the better it will be followed up by farmers.

All veterinarians stated that the way on-farm counselling is executed on the farm is fully dependent on the farmers' wishes. When analyzing the interviews, however, it appeared that the attitude of the practice itself towards herd health programs and on-farm counselling also played a role. All veterinarians had their own strengths and weaknesses in relation to on-farm counselling. Those strengths and weaknesses were related to the way on-farm counselling was executed on the dairy farms they visited.

Practices number seven and eight can illustrate these observations. Both practices were 20 kilometres apart, so little difference in both geographical and sociological structures was expected. The veterinarian interviewed in practice number three indicated that fertility management was his core activity during on-farm counselling. He showed little interest in expanding this with other activities like data-analysis or ration analysis, and stated that the farmers were not interested. Ten years ago, he tried to implement structural feed advice, but farmers preferred the feed advisor, since his advice was already paid for by buying concentrate.

He therefore focussed on fertility management, since that was part of the farm management he could contribute to. In his opinion the farmers were not open for more preventive veterinary medicine, especially not when they had to pay per hour.

The veterinarian interviewed in practice number eight indicated that innovation was an important way to stand out as a practice. The partners were always looking for new ways to improve their on-farm counselling. On-farm counselling in this practice was extensive; next to fertility management, data analysis, feed, udder health and milk production also other topics like grass management, claw health and housing were discussed. Not all farmers were enrolled in the whole programme, most farmers received advice on fertility, udder health and milk production only, together with data-analysis. On some of the larger farms, however, blood samples were collected of all cows, to determine the mineral- and fatty acid status. These results were discussed with both farmer and feed advisor to be able to optimize the rations.

## Discussion

The veterinarians in this study relate the success of on-farm counselling in their practice to the farmers. Literature supports this view; on-farm counselling is a product, sold to farmers, and should therefore be adjusted to farmers' wishes (Noordhuizen and Wentink, 2001). When analyzing the interviews, however, it appears that there is a connection between the veterinarian's perception and the execution of on-farm counselling. Although there is no literature directly supporting this observation, some studies have described the importance of a proactive attitude of the veterinarian (Vollebregt *et al.*, 2001; Jansen *et al.*, 2010b).

Not all practices have udder health as a standard item in their on-farm counselling program. This implies that udder health is only discussed when the farmer indicates a problem and asks the veterinarian for advice. The potential of on-farm counselling programs to improve the mastitis situation on farms is in that way reduced.

Most veterinarians in this study indicate that farmers are not following advice. In their opinion, they put down a well-defined advice, which is not or only partially followed up by farmers. From these interviews, however, it remains unclear what the quality of the given advices is. Several studies have shown that veterinary advising skills are not always up to date (Jansen *et al.*, 2010a; Sorge *et al.*, 2010). Also, farmers may receive advices they did not ask for. Additional research in which the farmer's opinion is included might help shed light on the question whether compliance with veterinary advice is dependent on farmer, veterinarian, or a combination of both.

The way on-farm counselling was executed in practice was dependent of both the motivation of the farmer as on the attitude of the veterinarian towards on-farm counselling. The differences in on-farm counselling between practices which were situated in the same region, combined with the other interview results, indicate that the attitude of the veterinarian and/or the veterinary practice played an important role in the way on-farm counselling was implemented in practice.

## Conclusion

Veterinarians who were enthusiastic about the concept of on-farm counseling and who saw possibilities to expand it in their practice, experienced less communication problems. They also had fewer difficulties selling it to farmers, and perceived their farmers as motivated more often. Main pressure points of on-farm counselling were structure in advising, writing hours on the bill, and the follow up of advice by the dairy farmers.

If a practice wants to expand the number of hours spent on advising, it should invest in knowledge, advising techniques and a pro-active mindset of their veterinarians. Also, it should ask for the farmer's wishes and be transparent towards the farmer in terms of product and price. If these measurements are taken, it is expected that the sales and implementation of on-farm counselling will improve.

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# Organizing external communication in the veterinary practice

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Evidence shows that there is a need to develop a communicative structure for the veterinary consultation. The Calgary-Cambridge Model on communication within the veterinary practice demonstrates a parallel development of personal relationship and structure of the consultation. This applies to all types of veterinary practice. Unlike companion animal practice, however, production animal practice regularly involves elements of long-term consultancy work. Therefore, next to the structure of a mere consultation, the relationship with the client has to be built in order to sustain this advisory kind of veterinary service. Veterinary advisory practice is therefore characterised by communication on different levels beyond the consultation itself. While the person-orientated communication is a permanent process between veterinarian and client with a rather personal perspective, the problem-orientated communication deals with emerging difficulties; the objective here is to solve an acute health problem. Finally, the solution- orientated communication is a form of communication in which both veterinarian and client address longstanding situations or problems with the objective to improve herd health and subsequently productivity performance. Although all three forms of communication seem to overlap, it appears to be of use to analyse them separately. A veterinary practice intending to offer both curative and advisory service, should keep these two separate wherever appropriate. This is relevant especially with respect to the frequently described problems of invoicing services within solution-orientated communication.

# Presenting uncertainty and variability to the decision maker: A computer program that uses Monte Carlo simulations to improve the management of the dry period

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Each piece of advice has a certain degree of uncertainty attached to it which can be hard to convey to dairy farmers. The aim of the present work was to facilitate good communication between advisor and client through using a decision system. Software was designed that estimates the expected financial return of specified interventions as probabilities as opposed to point estimates when aiming to reduce mastitis following the dry period. The program was built in MS Excel. The user is asked to enter information on herd milk recordings, mastitis cost data, as well as to choose dry period interventions expected to reduce mastitis prevalence after calving. Each intervention has a distribution associated with its expected effect. Using a Monte Carlo method, a model is run internally for a number of iterations chosen by the user, typically several hundred. The model incorporates recent research findings as well as estimates from the literature on cow and herd level predictors of mastitis. The prevalence of mastitis in the first month of lactation and the associated costs are simulated both with and without interventions. The user is then presented with probabilities for different levels of mastitis and associated costs in both scenarios and the probability that the intervention will be cost-effective. The handling of uncertainty is fundamental in communication between advisors and farmers and this type of probabilistic tool has the potential to be more realistic because decision makers are better informed by considering inevitable uncertainties that are inherent to any intervention.

# Dairy farmer and the veterinarian: an issue of communication

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Effective communication is usually not known to be one of the veterinarian's strengths. Four of five complaints to the disciplinary board deal with misunderstandings or lack of commitment. The purpose of this study was to investigate how skillful the veterinarian communicates his or hers advice to the dairy farmer. Five specific counseling situations with five veterinarians have been evaluated. All had undergone the Swedish Dairy Association's course 'Hälsopaket Mjölk', a continuation course for herd health veterinarians. The sessions were recorded and analyzed using a combination of standardized subjective and objective methods regarding the structure, LSF (listen, summarize, continue to ask questions), SMART goals, open or closed questions and balance of the conversation. According to the results, veterinarians in this study know how they in theory should use effective communication; however they do not practice this to the extent that they should. Dairy farmers have generally been satisfied with the veterinarian's input. But the survey shows that there is room for improvement within the veterinary medical advice. Veterinarian's communication with dairy entrepreneurs needs improvement! This is achieved through structure and good balance in the communication. Aspects of the work related to communication: The study evaluates the communication between the veterinarian and the dairy farmer during counseling.

# Part 5
# Training to improve udder health

# Bilingual trainings for milkers in New York State: a success for quality milk

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## Abstract

The National Milk Producers Federation in 2009 reported the economic impact that immigration has on the United States dairy farms. Approximately 46% of surveyed farms (n=5,005) use immigrant labor. As dependence on immigrant work increases, it becomes clear that language is a substantial challenge to both employers and employees, especially when neither is bilingual. Different mechanisms have been used to overcome the language and cultural obstacles that may inhibit communication and a positive relationship between employers and employees. The strategies implemented target the language barrier, cross-cultural understanding, and design incentives for producing high milk quality. The objective of this paper is to describe the training and methods that Quality Milk Production Services (QMPS) educators have developed for bilingual training sessions on dairy farms. Quality Milk Production Services (QMPS) at Cornell University understood that effective training is a key issue in the development of employee productivity. Today, more than ever, reliable and bilingual training options need to be available for all dairy producers. The bilingual and customized dairy training we offer at QMPS focuses on a hands-on teaching and practical perspective. The emphasis is on explaining workers the reason for doing what they do when milking, and following standard NMC milking procedures. Trainings are specific to the farms needs and built on two visits to identify eventual gaps in the milking routine. The dairy manager in the first visit indicates his/her specific farm situation, concerns and goals. After documenting this process by taking pictures and videos, the information along with our suggestions, are compiled into the training presented to the farm personnel in our second visit.

**Keywords:** extension agents and advisors, customized dairy training

## Introduction

Extension agents and advisors have provided research-based education and information to the production sector. Their role has not been static over the years, it has adapted to the clientele, to the new and available delivery methods, and the responsibilities and funds available. This has been true for most of the agricultural sector. Our objective in this paper is to discuss the changes in the dairy extension services and the assistance Quality Milk Productions Services (QMPS) at Cornell University offers to dairy farms. We will expose the methods used in the

QMPS trainings, and discuss the reasons for why we believe these trainings are successful. At the end of the paper, we will analyze and compare two successful case studies.

## Changes in dairy extension services

The shift in size and configuration of dairy farms on the United States has had an effect on the role of extension agents and advisors. The total number of farms in the country has decreased by 74% since 1980, and the number of cows per farm has increased by 325% since 1980 (Chase *et al.*, 2006). Because we are seeing bigger and more specialized farms, producers are asking for more in-depth, research-based information. The activities presented by extension agents and advisors need to meet these specific requirements. For that reason, generalized information has less value every time, and specialized and customized trainings have gained relevance.

The increased number of immigrants employed on dairy farms also influenced the role of extension agents and advisors. Comprehensive data is not currently available, but the trend toward hiring Hispanic workers appears to be increasing as producers seek greater production (Thomas *et al.*, 2005). In 2009, The National Milk Producers Federation published the most recent and complete national survey available determining the economic impact immigration has on US dairy farms. The study, conducted in 5,005 dairy farms, reported that approximately 46% of farms use immigrant labor in one way or another, and about 72% of the milk is produced by immigrant labor force. As dairy farms have become more dependent on immigrant labor, extension programs have increasingly presented programs to train this population. The education efforts that have proven to work best are small bilingual group trainings, hand-on workshops that emphasize on technical information and practical skill training (Chase *et al.*, 2006).

Bilingual trainings, which developed in the last 10 years and will continue to grow, have made clear that language is a substantial challenge by both employers and employees. Integrating Hispanic employers into the American society can be both challenging for both parties, especially when neither is bilingual. Different mechanisms have been used to overcome the language and cultural obstacles that may inhibit communication and a positive relationship between employers and employees. Some producers hired translators, other tried to visually train workers, and most of them developed procedures for dairy communication, and started investing in personnel training. The strategies implemented target the language barrier, cross-cultural understanding, and the design of incentives for producing high milk quality (Chase *et al.*, 2006).

## Quality milk production services trainings

The bilingual and customized dairy training we offer at QMPS focuses on a hands-on teaching and practical perspective. The emphasis is on explaining workers the reason for doing what they do every day because we believe that knowledgeable workers increases effectiveness and efficiency at the parlor, which translates into profitability for owners and managers. We promote a holistic approach to dairy health where owners and workers need to be educated and motivated to implement the right management practices. Furthermore, breaking the language barrier also increases understanding and productivity by allowing workers to know more and make better decisions at their work.

Additionally, we encourage communication with expectations. The efficiency of a milker determines the productivity of the dairy. An employee needs to know what outstanding performance is before they can achieve it. For that reason, it is important to have precise and clear goals and adequate tools to implement them. This requires information about the how, when, and what needs to be done. When expectations are clear, managers can make their employers accountable for meeting these goals. When employees work with a well-defined purpose, know precisely what the outcome or results of their efforts will be, have a strong belief that their contribution is appreciated, and have a clear idea of how their work contributes to the goals, they can be efficient and proactive (Cavazos, 2003).

Because a one-size-fits-all approach to improve mastitis management and to develop trainings is unlikely to perform as expected, QMPS offers a customized training to target the farms' needs. Different farmers and farm workers are motivated by different factors and learn in different ways, and for that reason QMPS provides information in different formats and uses various communication strategies. For instance, farmers are not only motivated by money or financial penalties, there are other internal nonmonetary factors such as pleasure in having healthy animals that QMPS keeps in mind when developing trainings and educational materials. Because research has shown that personality styles of dairy producers relate differently to specific udder health communication strategies (Steuten *et al.*, 2008), we provide information in different ways adapting it to management style and acknowledging that not all producers obtain information in the same way.

Those customized trainings involve two visits to the farm. The first visit allows the advisors to assess the farm, evaluate routines and gather all the necessary information to develop a meaningful training, which will be given by the advisor during the second visit. The advisor meets the dairy manager in the first visit to tour the farm, discusses specific concerns, and decides the direction, length, and available materials for the training. The advisor then collects data on parlor efficiency, milking routine, cow's hygiene, and treatment protocols, among others. All that information is documented in forms, pictures and videos, which will be used for developing the training.

As important as evaluating the farm is the act of communicating and making useful the information to the farm manager and farm workers. Each of the trainings will last between 1.5 and 2 hours depending on the farm's demands, and the amount of time available for questions. Because people have different preferences for learning and obtain knowledge in various ways, it is important to provide the information in different formats (Klerkx, 2010). For instance, when a management practice can be improved the advisor could use pictures, videos, or hard data to help highlight the issue. Open discussions also help improve the communication channels between the farm manager and workers. In addition, it is very important to increase the farmer's frame of reference. Farmers do not always know what a serious problem is, so social pressure or national standards can be used to let them know what has been done in other places and what they can do (Jansen *et al.*, 2009).

Each of the information formats, the power point presentation, pictures, videos, group discussions, and written reports, have different purposes and target audiences. For that reason, the message and the training is personalized and special to a particular farm. Personalizing the message convinces farmers about the usefulness of the message for their particular case. If farmers do not feel the message is useful, it will be very difficult to motivate them to further continue processing the message (Cavazos, 2003). When each of the messages is different, we are acknowledging that each farm is unique.

When workers are Hispanics or speak a different language than the one spoken by the manager, the trainings need to in both languages. Depending on the time available, and the manager's preferences, either the entire training is conducted on both languages, or only the key issues are translated. Regardless of the decision, everyone involved in the training needs to know what is being discussed and everyone should be able to comment and ask questions thorough the training.

## Case studies

In the following section, we will comment on two successful case studies. The farms described below are different in terms of size, management, and communications techniques, among other aspects. Because of these differences, these are excellent examples of how QMPS adapts to the farm's needs and specificities. Farm A operates 24 hours a day, has 1,500 cows milked three times a day, and has 12 workers, all of them coming from Mexico. Farm B has 400 milking cows under an organic production system, and three milkers from Guatemala milk them twice a day. In both cases, the first visit allowed the advisor to understand the farm and discuss with the manager about the training. With the information gathered in the first visit, the advisor developed a customized training based on their needs.

Farm A required QMPS's services because they were going to implement some constructions in the parlor and the manager wanted his employees to be as prepared as possible. At the time of the first visit, the farm had a double 20 herringbone parlor, and they were changing to a double 40 parallel parlor. With the new parlor, they would milk as twice as much cows as they did before, which meant that they were expanding. This tremendous change, with the addition that they will never stop milking, made this assignment a challenge.

QMPS would help the farm during the construction, and the trainings were built specifically to this particular situation. During a two month period, a QMPS advisor went to the farm 5 times. In the initial visit, the advisor toured the farm, and talked to the manager about the implications of the new parlor and the role he had envisioned for this training. The manager was very clear that he wanted QMPS's advisor to prepare workers for the changes during and after the construction, which meant communicating them how things were going to be, and made sure workers understood what was happening, and how they could adapt to the new system. The main issues discussed were the new milking routine, logistics, and the differences between parlors.

A major difference between a herringbone parlor and a parallel parlor is the way employees attach the milking units. Only one milker had worked in a parallel parlor before, the others had not even seen one. To prepare workers for the new parlor, the QMPS advisor took some of the employees to a parallel parlor and had them practice attaching units. Because not all of them could be taken to the other farm, the QMPS advisor recorded the practice and showed that video to the ones who could not go, so that at least they could see how it looked like and how they had to attach the units. This exercise prepared milkers for when they would have to milk in the parallel parlor, and it made the change run smoothly.

Farm B is a smaller organic farm. Because they have a permission to sell raw milk, the training was oriented towards foodborne pathogens and mastitis prevention. During the training, the advisor discussed the differences among types of mastitis and the efforts employees should take in order to detect and prevent mastitis. The discussion included common dairy pathogens such as *Listeria sp* and *Salmonella sp* that may be transmitted from cows to humans. Additionally, the training highlighted the opportunities employees have on preventing the spread of foodborne pathogens and contagious mastitis by using good udder preparation and implementing good hygiene practices.

Because the employees from these two farms were from Mexico and Guatemala, the trainings were in Spanish. However, all the materials were in English and Spanish. The manager of Farm A knew some Spanish and could follow most of the conversations, and the manager of farm B only knew some words, so he followed the training through the translations. Both managers intervened in the training every time they had something to say to their employees, and through group discussions, the advisor encouraged a positive communication between them.

Both managers had their own management style, and each one had envisioned a different training. Adapting to their style and being able to develop what each one had in mind is a very important part of the trainings. For instance, the QMPS advisor visited farm A five times in a two month period, and only two times farm B. Regardless of the amount of times the advisor visited each farm, the trainings targeted the specific needs of each of the farms.

Advisors need to adapt to specific situations and herds, and develop meaningful materials for farms interested in these types of services. In both cases, the advisors developed material that stayed at the farm. The advisor developed for farm B a laminated poster depicting the milking routine to be hanged at the entrance of the parlor, and for Farm A, the advisor developed standard operating procedures (SOPs) and a scheme for the new milking routine based on their own goals, parlor size and configuration.

## Conclusions

Many different factors have influenced the role of the advisors and extension agents, including the size and configuration of the dairy industry in the United States, the increased number of Hispanics hired in dairy farms, and the needs of the clientele. The role of extension agents and advisors is to offer research-based education and information to the managers, employees, and farm owners. For that reason, advisors need to adapt to the needs and requirements of the clientele. By doing this, advisors and extension agents will be making sure that their job is perceived as useful. For QMPS, extension efforts are extremely valuable. We believe that effective training is the key issue in the development of employee productivity. We take the time to meet our clients and offering them the services they need is the key to our success.

Future extension work at QMPS will be linked to program impact measurements. The QMPS staff has been developing a system with the use of the i-clicker technology to measure the impact of our trainings. Further studies are required to analyze the implementation of this technology and to measure the impact of QMPS's trainings.

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# A coordinated udder health training strategy in Quebec, Canada

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## Abstract

An udder health training program was developed to integrate the roles of veterinarians, farm advisors and dairy producers in a team approach to improving udder health in Quebec, The program, inspired by the Dutch Udder Health Center' (UGCN) program, was a collaboration of the Quebec Association of Bovine Practitioners (AMVPQ), Valacta, the Canadian Bovine Mastitis Research Network, the Faculty of Veterinary Medicine-University of Montreal and the Dairy Producers Federation of Quebec. Three levels of training workshops for veterinarians, for farm advisors and for producers were conducted from April 2009 to April 2010. Bovine practitioners and local Valacta farm advisors collaborated to deliver producer workshops. The UGCN training kit was adapted in cooperation with UGCN to produce the TACTIC Udder Health Kit for Canadian conditions. TACTIC and USB memory devices with printable udder health evaluation, planning and technical information tools for use on-farm were distributed to practitioners. Half of Québec bovine practitioners participated in advanced workshops and received TACTIC. Next, 95% of Valacta advisors received training with an adapted version of the kit, and 30% of Quebec dairy producers attended fee-based workshops team-led by local veterinary practitioners and Valacta advisors. Strengths of this strategy were: (1) clear identification of the complimentary roles and harmonization of the core messages; (2) wide dissemination of practical materials; (3) involvement of local advisors in farmer training; and (4) adaption of farmer training to local farm conditions using animal health and milk recording data.

**Keywords:** communication, workshops, veterinary advisors

## Introduction

Dairy industries in developed countries are confronted with important challenges. At the industry level, there are market and regulatory uncertainties as well as the need to maintain the positive public image of dairy and dairy products. At the farm level, optimising profitability in the face of increasing costs of production is of concern. Proactively confronting these issues argues for dairy farmers to continually adopt the best management practices for udder health and milk quality because they relate to preventing premature cow loss, optimising production efficiency and profitability, and to protecting animal welfare, food quality and food safety. Canadian Quality Milk (a national milk quality assurance program) and a reduction in the statutory bulk tank milk somatic cell count (SCC) limit to 400,000 cells per ml of milk will both be fully implemented shortly. In view of these advances, several dairy industry stakeholders in Quebec, Canada collaborated to train dairy farmers in best management practices for udder health control. The Dairy Producers Federation of Quebec (FPLQ), Faculty of Veterinary Medicine (FMV) of the University of Montreal, Association of Veterinary Practitioners of Quebec (AMVPQ), Valacta Inc. (Dairy herd improvement agency for Quebec and the four Atlantic provinces of Canada) and the Canadian Bovine Mastitis Research Network (CBMRN) collaborated to develop and deliver a Provincial Udder Health Strategy (Stratégie provinciale pour la santé de la glande mammaire). Aspects of the strategy were inspired by UGCN (Dutch Udder Health Centre) and its collaborations with CBMRN.

The Provincial Udder Health Strategy was developed to fulfill six objectives:
1. Upgrade and harmonize the knowledge of dairy veterinary practitioners, other advisors and dairy farmers.
2. Create synergy between the different advisors to the farmer and help them to define their respective areas of intervention.
3. Encourage the creation of response teams to support farmers' udder health improvement efforts.
4. Promote a comprehensive approach to udder health improvement at the farm with defined objectives and regular monitoring.
5. Encourage implementation of biosecurity practices at the farm and the adoption of best management practices for udder health.
6. Promote dairy farmers' readiness to for implementation of decreased bulk tank SCC limit of 400,000 cells/ml.

## Program description

Three levels of training workshops were designed. The partners in the Strategy contributed expertise, in-kind inputs of human resources and organisational support, or cash inputs from competitively awarded funds. The first level of training was designed for dairy veterinary practitioners who are involved as first-line advisors when mastitis problems occur in herds. The second level was adapted for other farm advisors who play a complementary role and support practitioners' interventions. The third level of training was for dairy farmers. The main message at the third level was that farmers can count on veterinarians and advisors for support but that they are ultimately responsible for driving optimisation of udder health on their farms. The provincial strategy sought encourage dairy producers' awareness of the high cost of mastitis at the farm and the industry levels, to be prepared to assess their own situation and to be prepared to change management practices as needed. The entire strategy coincided with a timely initiative undertaken by the FPLQ in April 2009 to implement milk quality premiums. This, combined with the November 2009 approval of lowering bulk the tank SCC limit from 500,000 cells per ml to 400,000 cells per ml, probably stimulated interest in the Provincial Udder Health Strategy.

Many of the same educational materials were redistributed at each of the three levels of training to harmonise the knowledge transmitted and to maximise the impact on the farms though reinforcement at all levels. A series of nine illustrated factsheets inspired by UGCN material were chosen as practical education material that were suitable for all three levels of stakeholders. Jointly, the organising partners also developed a plan to co-author a series of articles reinforcing major messages on mastitis and udder health for the November 2009 issue of *Le producteur de lait québécois*, a magazine distributed for free to all farmers and many stakeholders in the province of Quebec (more than 10,000 copies).

### *First level of training – veterinary practitioners*

A funded project to adapt the UGCN veterinarian training kit to the Canadian context was initiated. The UGCN kit was translated from Dutch into French and into English followed by revision and adaptation of the two versions to the Canadian context by two working groups so that practitioners could easily use the material on-farm. Organisation of material into five segments of intervention was maintained:

1. assessment of udder health management;
2. treatment;
3. infection pressure;
4. milking;
5. cow resistance and transition period.

The TACTIC Udder Health Veterinary Kit, the name given to the resulting adapted training kit, consisted of a binder and a USB key that includes several ready-to-use tools (practical illustrated factsheets, videos, calculation tools, assessment questionnaires, information sheets, for example). For the French version, a team of twelve veterinarians (professors, researchers and dairy practitioners) identified as mastitis experts and other collaborators voluntarily contributed adaption and revision of the Kit. The French version was ready in October 2009, just preceding the aforementioned udder health issue of *Le producteur de lait québécois*.

The AMVPQ, the FMV, the CBMRN and Pfizer Animal Health Canada designed and delivered a fee-based two day provincial training session delivered to dairy veterinary practitioners in April 2009. A third day of training was offered in the form of three regional sessions in November 2009. Each participant received a copy and a global presentation of the TACTIC Udder Health Veterinary Kit.

### *Second level of training – farm advisors*

The AMVPQ, Valacta and CBMRN collaboratively developed one day training sessions for Valacta's field advisors. Valacta field advisors are involved in different technical aspects of udder health. They work in partnership with the veterinary practitioners to implement preventive measures related to feeding, housing and management. Valacta also provides SCC data and milk equipment analysis services to dairy farmers. The Valacta advisors' one-day training was held in October 2009 in the form of three regional sessions with costs underwritten by Valacta. A half-day supplementary fee-based training session was offered in December 2009 to all other farm advisors or stakeholders interested in mastitis and milk quality. The objective was to provide the industry with a consistent message. Each farm advisor attending a training session received nine of the illustrated factsheets extracted from TACTIC Udder Health Veterinary Kit:

- milk sample collection technique for bacterial testing;
- the California Mastitis Test (CMT);
- administration technique of intramammary treatment in dairy cows;
- injection technique for dairy cattle;
- cow cleanliness assessment;
- teat abnormalities;
- teat condition evaluation table;
- step-by-step milking procedure;
- observation of mammary system conformation.

### *Third level of training – dairy farmers*

Training sessions for dairy farmers were developed by the AMVPQ and Valacta. Each third-level training session was delivered by a team of one veterinary practitioner and one Valacta advisor, both of whom participated in their respective first and second level training sessions. The sessions where promoted by veterinary practitioners and by Valacta field advisors during farm visits. Promotional flyers were also distributed at major dairy events or posted on various dairy industry websites. Forty-nine practitioners from AMVPQ and twelve advisors from Valacta delivered ninety-two fee-based sessions across the province of Quebec between January and April 2010. Theoretical and practical segments were delivered during the one day session for farmers. The complete series of practical illustrated factsheets were again distributed at this level, giving three levels of reinforcement of certain best practices.

## Results and impact of the training strategy on herd average somatic cell count

Of 399 dairy veterinary practitioners from AMVPQ, 213 veterinarians attended a level-one training session. This high participation confirmed the interest among practitioners to update their knowledge on udder health issues. The totality of Valacta's advisors (225) attended the level-two training session. The half-day supplementary level-two training session held in December 2009 reached 108 participants, most from milking equipment suppliers, feed advisors, teachers and private consultants. A total of 2043 dairy producers (32% of all the dairy farmers in the province of Quebec) attended the third-level training workshop. The team approach (veterinary practitioner and advisor) was appreciated by both the dairy producers and the trainers.

To assess the impact of the training strategy, the dynamics of herd average individual cow test-day somatic cell count (SCC) from May-December 2009 (before dairy farmer workshops) to May-December 2010 (after dairy farmer workshops) were compared between farms with personnel following the above training and farms with no personnel following the training. The tested population was all farms subscribing to Valacta milk recording SCC services. The following questions were addressed: (1) were participating and non-participating farms comparable before the training; (2) did more participating farms experience a SCC decrease from the first to second period than non-participating farms; and (3) did participating farms' magnitude of SCC change between periods exceed that of non-participating farms?

Participating farms were not completely comparable to non-participating farms before the training program. Participating farms' average linear scores (L2) during the May-December 2009, before the training were higher than non-participating farms' average scores (2.92 versus 2.86, T-test $P<0.05$). The differences between corresponding May-December 2009 herd average (milk production weighted) individual cow SCC were not statistically significant however (272,000 and 262,000, respectively; t-test (SCC logarithm) $P>0.05$), demonstrating uncertainty as to the pre-training differences between the farms. Among participating farms over the pre-training period; milk production was higher than non-participating farms (8,500 kg versus 8,300 kg; t-test $P\leq0.05$). Moreover, more non-participating farms had average SCC <200,000 (29% versus 26%) and more participating farms had average SCC >300,000 (35% versus 30%; over all Chi-square $P$-value ≤0.05). Participating farms seem possibly to have been less successful udder health managers than non-participating farms before the training, which might suggest in part participants' decisions to enrol in the training program.

Participating farms experienced better SCC improvements during the May-December 2010 10-month period following the training than did non-participating farms. Fifty-four percent of participating farms experienced a decline in average SCC, versus 50% of non-participants (Table 1). The mean SCC change was also a more pronounced reduction among the participating farms (participating farms in all pre-training average SCC ranges combined) than the non-participants (all average SCC ranges combined) (Table 1).

The observed improvements are not explained simply by more evident regression toward long-range mean herd average of individual cow SCC among participants. Rather, farms that did not participate in the training experienced increased herd 10-month average individual cow SCC that participating farms did not experience (Table 2). The different experiences

*Table 1. Distribution of increased and decreased herd-average (milk production weighted) individual cow somatic cell counts (SCC) from May-December 2009 to May-December 2010 and comparison of mean SCC change between herds participating in an udder health improvement course in January-April 2010 and herds not participating.*

| Course participation | Number of herds[1] | | SCC change × 1000 | | |
|---|---|---|---|---|---|
| | SSC decrease (%)[2] | SCC increase (%)[2] | Mean[3] | 95% Confidence interval | |
| No | 1,603 (50) | 1,630 (50) | -1.1 | -4.0 | 1.9 |
| Yes | 795 (54) | 677 (46) | -10 | -14 | -5.6 |

[1] Chi-square = 7.9 (1 df), $P<0.05$.
[2] Row percent.
[3] T-test = 3.3 (4703 df), $P<0.05$.

*Table 2. Mean change in herd 10-month average (milk production weighted) individual cow somatic cell count (SCC; cells/ml x 1000) among farms participating, and farms not participating in udder health training, by pre-training somatic cell count range.*

| Course participation | Average SCC change (× 1000) versus pre-training SCC level[1] | | |
|---|---|---|---|
| | <200/ml[2] (n) | 200-300/ml[3] (n) | >300/ml[4] (n) |
| No | 31.1 (941) | 10.6 (1,310) | -47.3 (982) |
| Yes | 30.3 (378) | -0.6 (580) | -50.0 (514) |

[1] Interaction of Course participation with pre-course SCC category was not significant (2-way ANOVA F=1.75, df 2, 4699; $P>0.05$).
[2] Least-squares mean (LSM) difference = 0.8 (95% confidence interval: -8.6, 10).
[3] LSM difference = 11 (3.5, 19).
[4] LSM difference = 2.7 (-5.7, 11).

were particularly evident among farms whose average SCC were 200,000-300,000 before the training in which the mean 10-month average SCC of herds participating in the training did not increase whereas that of non-participants' increased by a mean of over 10,000 cells/ml (Table 2). The average 10-month SCC did not differ significantly between participants and non-participants that were in either the <200,000 cells/ml or >300,000 cells/ml ranges before the training program (Table 2).

A coordinated udder health control training program reaching dairy practitioners, milk quality farm advisors and allied industry participants, and dairy farmers was associated with incremental improvement in average SCC for the 10 months following the course. While it appears unlikely that different average SCC dynamics between participating and non-participating farms occurred independently of training course participation, it must be recognised that many different unmeasured factors which influence herd average SCC could be operating to cause the observed differences. Assuming that the observed SCC performance differences are indeed attributable in part to training course participation, two important questions remain and should be addressed by future research on the subject: 1) what nature of follow-up reinforcement of best-practices maximises persistent performance gains, and 2) can greater gains be obtained by optimising the training strategy.

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# Focus courses

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Animal health in general and udder health in particular is deeply dependant on maintenance procedures. Difficulties to replace poor routines to better ones are known to most veterinarians and advisors. The FOCUS concept is a 3 step method enhancing this process. The key words are KNOW meaning receiving new and familiar knowledge in a structured form, FEEL referring to concern about the matter and DO which actually results in new and better Standard Operating Procedures (SOP) on the farm. The FOCUS pedagogic principle has been successful on many medium sized and large dairy farms in Sweden and is implemented within the Swedish herd health program Health Package Milk. A FOCUS course gathers one or more milk entrepreneurs and their personnel around an animal welfare matter identified as important for the farm. The group normally meets during a semi day that is devoted to education and discussion around the subject. Educational material is available for 14 different animal welfare matters; Cow Signals, Milking, Robot Milking, Biosecurity, Mastitis and Milk Quality, Antibiotics and Resistance, Claw Health, Animal Health Costs, Calving, Calves, Fresh Cows, Fertility, Feeding Balance, Dry Period and Grazing Period. A lecture PowerPoint, some fact sheets, workshop questions, on farm checklists, important SOP and take home messages are available for every subject. New and updated material is produced continuously by the Swedish Dairy Association and can be downloaded by authorized mentors from a website. During 2009-2010, 148 FOCUS courses with a total number of 1,784 participants were held by 47 trained FOCUS leaders. More than 2,500 participants have rated the courses during the last 2 years to an 85% content index.

# Part 6
# Economics

# *Ex-ante* assessment of profitability of a new control plan for mastitis as a motivation tool for dairy farmers

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## Abstract

Technical advice provided to the farmers to improve the udder health situation of their herd is not always efficient. The compliance with the control plan is quite low (Green *et al.*, 2007). It could be partially due to the difficulty for the farmer to perceive the economic impact of such diseases and therefore also the cost-effectiveness of a new control plan. The aim of this study is to assess the effectiveness of an economic based approach to induce acceptance of the control plan by the farmers. The advisor's intervention for mastitis control consisted in a classical technical analysis and a diagnosis of the origin of mastitis followed by a discussion of a new control with technical and economic arguments with the farmer. Software was used to provide an economic estimation of mastitis problems on the farm based on annual incidence and severity of the disease and farm characteristics. Both initial (over 12 month before the intervention) and expected (over 12 month after the implementation of the plan) economic impact were estimated. It included the costs related to treatments and prevention measures, and the estimated loss of gross margin due to reduced milk yield, impaired longevity and diminished milk price. The approach was tested in 30 farms by 6 advisors (veterinary practitioners and specialized engineers) and was found relevant, operational and efficient by the farmers and advisers. A high level in compliance with the control plan by the farmer was obtained by this economic estimation taking into account the specificities of their farms. The new downloadable free software can now be used on the computer of every interested advisor or farmer in France.

**Keywords:** dairy farmers, mastitis, economy, control plan, compliance

## Introduction

Poor health of the dairy herd has negative consequences on the income and the workload of the farmer, on animal welfare, and on quality and image of dairy products. Currently, technical advice provided to the farmers is not always efficient, in particular for production diseases. It is partially due to the difficulty for the farmer to perceive the economic impact of such diseases and therefore also the cost-effectiveness of a new control plan. In this context, a software-based economic approach was developed in partnership with field-actors, to support adviser's interventions for mastitis control. The objective of this paper is first to present the software and second to assess its effectiveness to induce acceptance of the control plan by the farmer.

## Material and methods

### *Presentation of the software*

A downloadable free computer program was developed to provide an economic estimation of mastitis problems on a given farm knowing annual incidence and severity of the disease and farm characteristics. The economic impact is estimated over the past twelve months and includes, on the one hand, the costs related to treatments and prevention measures, and, on the other hand, the estimated loss of gross margin due to production effects and diminished milk price.

The costs related to treatments and prevention measures can be found in the invoices of providers. However, a simpler approach can be retained using the updated database on the costs of common treatments and preventive actions under current French conditions available on the software. Production effects retained are based on the available average estimates of the effects of mastitis on milk yield (Coulon *et al.,* 1989; Grohn *et al.,* 2004; Hortet *et al.,* 1999; Seegers *et al.,* 2003), longevity (Beaudeau *et al.,* 1995, 2000) and lethality (Fourichon *et al.,* 2000) of cows with an adaptation for 4 types of clinical mastitis (Table 1). The effects of subclinical mastitis were modelled by a reduction of 1.7 kg of milk per day in lactation for each cow with a somatic cell count >300,000 cells/ml. After data capture of the incidence of the 4 types of mastitis

*Table 1. effects associated with the occurrence of 4 types of mastitis on milk production, probability of culling and lethality of affected cows, retained for the economic estimation.*

| Type of mastitis | Milk yield loss (kg/year) | Annual probability of culling | Probability of lethality |
|---|---|---|---|
| Short-lasting mastitis with only local signs (without recurrence) | 80 | 0.01 | 0 |
| Long-lasting mastitis with only local signs (with recurrence of clinical signs) | 150 | 0.01 | 0 |
| Short-lasting mastitis with severe systemic signs (without recurrence) | 250 | 0.07 | 0 |
| Long-lasting mastitis with severe systemic signs (with recurrence of clinical signs) | 800 | 0.07 | 0.06 |

in the herd and the percentage of monthly individual somatic cell count >300,000 cells/ml, the economic consequences of the production effects are estimated using a partial budget model (Fourichon *et al.,* 2001b). This model calculates losses consecutive to diseases with management, production costs, and prices of this farm for the period of concern (information must be provided for 10 technical characteristics of the herd and for 10 economic parameters and prices applicable to the farm). Transposition of production effects into economic effect on the gross margin takes into account two different situations. Under the first one, the farmer did not fulfil its entire milk quota which is assumed to be the consequence of disease, so it results in reduced milk sales from the herd. Under the second one, the farmer produced its entire milk quota and the partial budget consider that the farmer had increased the size of the herd to reach a milk delivery equal to the quota despite disease occurrence, so it results in increased variable costs from the herd. In the calculations, the reference situation for milk yield, reproductive performance and disease incidence is set at the first decile values observed in a sample of 205 dairy farms in western France (Fourichon *et al.,* 2001a).

Besides estimating the economic impact over the past twelve months, this software can be used by an advisor during its intervention on a farm for mastitis control. After a technical analysis and a diagnosis of the origin of mastitis, the advisor proposes a new control plan to the farmer and provides an associated prognosis in terms of udder health over the twelve months following the implementation of the plan. He can then calculate the expected profitability of the new plan, taking into account the new control actions to be implemented and their expected effects on the udder heath status of the herd. Finally, the farmer is informed on the initial economic impact of mastitis in his herd, the approximate cost of the new control plan and the expected change in economic impact from the new mastitis situation. In other words, the assessment of the cost-effectiveness of the new control plan is implemented.

#### *Evaluation of its effectiveness to induce compliance with the control plan by the farmer*

The approach was tested in 30 farms in western France. Farms were recruited on 4 main criteria: a high motivation to improve their udder health situation, an annual lactational incidence of clinical mastitis higher than 35% of cows, a percentage of monthly individual somatic cell count >300,000 cells/ml lower than 25%, and the enrolment in the national record performance scheme. An advisor amongst 6 (3 veterinary practitioners and 3 specialized engineers) had to made a technical analysis and a diagnosis of the origin of mastitis in the farm. It consisted at least 2 hours of data processing and 2 hours of farm inspection. Afterwards, the advisor exposed its conclusions to the farmer, proposed a new control plan and used the software to estimate the cost-effectiveness of the new control plan. A discussion took place with technical and economic arguments; the goal of the advisor was to obtain an explicit acceptation for his control plan. The control plan was then written and sent to the farmer.

The relevance and the ease of implementation of the software were evaluated 2 months after the farm intervention by discussions with the farmers and the advisors. The compliance of the farmer with the control plan was assessed by means of follow-up farm visits on the year following the intervention. At each visit, a technician verified that the farmer had already implemented each recommended action written in the control plan. Then, the percentage of compliance of the control plan could be calculated for the farm by the ratio between the number of recommended actions implemented and the total number of recommended actions of the control plan.

## Results

Farms enrolled had on average 62 cows, 508,000 l of milk quota, an annual lactational incidence of clinical mastitis of 47% and a percentage of monthly individual somatic cell count >300,000 cells/ml of 19%. The mean economic impact was 9,800 € for the initial situation and 6,700 € for the expected situation.

The 6 advisors were unanimous to say that the estimation of the economic impact must be integrated into classical technical interventions ('it is an element which can help in the persuasion of the farmer'). Indeed, the initial economic impact and the cost-effectiveness of the new control plan provided by the software gave them strong arguments for the final discussion of the control plan with the farmer. Furthermore, they appreciated to have access to an updated database on the costs of common treatments and preventive actions to calculate an expected cost of the new control plan. Farmers could then accept the plan knowing its cost.

Most of the farmers (85%) considered that the economic data provided by the software allowed them 'to become aware of the importance of losses of gross margin' consecutive to mastitis in their herd. They appreciated the fact that the estimation took into account the technical and economic specificities of their farm. For some of them, the estimation of the cost-effectiveness of the new control plan was an incentive argument in the implementation of the recommended actions.

The new control plans proposed to the farmers included on average 7 recommended actions (minimum: 4 and maximum: 13). A high level of compliance with the control plan by the farmer was obtained: on average, 82% of the recommended actions were implemented. Half of the farmers implemented all the recommended actions and a quarter less than 50%. The percentage of compliance was not influenced by the initial economic impact or by its expected improvement.

## Discussion

The main originality of this software is to evaluate both the economic loss due to mastitis and the costs of control actions in a given farm providing the total economic impact of the udder health situation of the herd before the intervention. Furthermore, it allows estimating the improvement of the economic impact expected from a control plan resulting from a technical analysis of the situation. However, the software cannot do everything, and some points should be clearly exposed to the farmer. The prognosis of udder health situation on the months following the implementation of the recommended actions must be made by the advisor. It depends of the compliance of the farmer with the control plan. It is also recommended to know exactly how the loss of gross margin due to production effects is calculated because the farmers want to understand and the advisor want them to agree with the estimation. Farmers often ask questions such as 'I give the milk discarded for high somatic cell count to my calves, did you take it into account in your estimation?' (the response is yes). The technical and economic data integrated for the estimations are the ones of the farm, so the farmers are more confident in this estimation than others based on average calculations such as ' the cost of one clinical mastitis is 200 € '...

An intervention on farms for mastitis control integrating economic aspects seems to be effective in increasing compliance with the control plan by the farmer, the absence of a control group do not allow us to assert it. The level of compliance with the control plan is very high (82% of the recommended actions implemented) compared to another study were the intervention did not include economic aspects (only 8 farms out of 28 complied with more than two-thirds of the recommended; Green *et al.,* 2007). Perhaps the high motivation to improve their udder health situation of the farmers recruited also contributes to this result. However, due to a high percentage of compliance with the control plan, it could not be shown that the higher is the economic impact the better is the compliance. However, this software has also been developed for lameness control in dairy herds and tested in farms in similar way. For lameness, the percentage of compliance with the control plan was highly influenced by the initial economic impact (33% when lower than 5,000€ and 77% when higher than 10,000€) and by the expected improvement of this impact (41% when lower than 3,000€ and 78% when higher than 5,000€). One explanation could be that the farmers are more aware of the losses consecutive to mastitis (diminished milk price, milk discarded for antibiotic or high somatic cell counts reasons) than those due to lameness.

Integrating an estimation of the economic impact into classical technical interventions for mastitis control in dairy farms was found relevant, operational and efficient by the farmers and advisors. The downloadable free software can now be used on the computer of every interested adviser in France (http://www.sante.ouest-atlantis.com/).

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# Costs and benefits of mastitis management measures on individual dairy farms

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## Abstract

Economic optimal decision making with regard to mastitis management aims at a minimization of the total costs of mastitis. These total costs consist of failure costs and preventive costs. Failure costs are costs directly caused by clinical and subclinical mastitis. Preventive costs are costs made to reduce the level of mastitis. Optimal decision making can therefore be seen as a balance between failure costs and preventive costs. The level of failure costs in relation to preventive costs has, however, hardly been studied. In this study, data collected from 120 Dutch dairy farms were used to calculate the farm-specific costs of mastitis (clinical mastitis, subclinical mastitis and preventive measures). Calculations were based on data from milk production recording, farmer recorded information on clinical mastitis and a questionnaire on preventive measures carried out by the farmer. The total costs of mastitis were, on average, € 164 per average cow on the farm per year, of which respectively € 62, € 14 and € 88 were for clinical mastitis, subclinical mastitis and preventive measures.

**Keywords:** preventive measures, management, optimization

## Introduction

Mastitis is an important dairy cattle disease with a high incidence (Van den Borne *et al.*, 2010) and high economic losses (Hogeveen *et al.*, 2011). For the Netherlands, economic losses are estimated to be approximately € 80 per average cow on the farm per year with substantial differences between farms (Huijps *et al.*, 2008). With a few exceptions (e.g. Fourichon *et al.*, 2001), all calculations on the economic costs of mastitis described costs associated with production losses of mastitis. However, costs of mastitis consist of losses and expenditures. Expenditures can be seen as additional input to reduce the losses of mastitis. Besides treatment costs, expenditures are preventive measures. There is a substitution relationship between losses of mastitis and expenditures on mastitis that can be represented by a loss-expenditure function (McInerney *et al.*, 1992). The higher the expenditures for preventive measures, the lower the losses of mastitis and vice versa. If no control measures are taken, the losses due to mastitis are maximal. With maximum control, the losses due to mastitis will be at a minimum, which, for mastitis is more than zero. Because the relation between losses and expenditures is not linear, there is an optimal level of control. The concept of the loss-expenditure frontier can be applied to dairy farms by looking at the possible preventive measures against mastitis (expenditures) and compare these expenditures with the avoided losses when they are applied (Hogeveen *et al.*, 2011). The goal of this paper is to make an estimation (average and variation between farms) of the total costs of mastitis for Dutch dairy farms that can be used as a basis for a loss-expenditure function.

## Material and methods

For another study, 189 Dutch dairy farmers filled in a questionnaire with regard to mastitis management (Santman-Berends *et al.*, 2011). The questionnaire consisted of general questions (e.g. number of cows and barn type), questions on management of livestock (e.g. rearing young livestock, housing, grazing and drying off), lactating cows (e.g. mastitis treatment), milking process (e.g. cleaning of the udder), feed (e.g. diet, minerals and water). The farmers were asked to keep track of cases of clinical mastitis. Finally, the milk production recording data of these farms were made available (CRV, Arnhem, the Netherlands), consisting of milk yield, fat and protein percentages and somatic cell count (SCC) of each individual cow for each test day. From a total of 120 farms, questionnaire data, milk production recording data and data on clinical mastitis was available.

Costs of clinical mastitis were calculated based on the number of cases of mastitis and milk production level of the farm. For all other factors assumptions were made in such a way as to resemble the Dutch farming situation as good as possible. Assumptions were based on scientific literature, available databases or the expertise of the authors (Table 1). Economic costs of clinical mastitis consisted of reduced milk production during the remain of the lactation, costs for treatment (antibiotics, labour and discarded milk), costs for veterinary visits and costs for culling. Calculations were carried out according to Huijps *et al.* (2008).

A cow SCC above 100,000 cells/ml is associated with a reduced milk production (Halasa *et al.*, 2009). Because milk production recording data were available, the milk production losses due to subclinical mastitis for each farm could be based upon SCC measurements of individual cows throughout the year 2008. First of all for every individual cow, test day intervals were determined, using the start of lactation of a cow (calving date), the dates of the test days and the end of lactation (calving date minus an assumed length of the dry period of 50 days). The first test day interval of a lactation started at the calving day and ended between the first and second test day in that lactation. The next test day interval of a lactation started halfway the first and the second test days and ended halfway the second and the third test day. The final test day of a lactation started halfway the last and the second last test day and ended at the day of drying off. Using these defined test day intervals, and the relation between SCC and milk

*Table 1. Generic assumptions used to calculate the costs of clinical mastitis, subclinical mastitis and preventive measures.*

| | |
|---|---|
| Market and price assumptions | |
| Costs milk production losses (€/kg milk) | 0.12 |
| Costs discarded milk (€/kg milk) | 0.17 |
| Costs antibiotics for treatment (€/treatment) | 22 |
| Costs veterinary visit (€/visit) | 22 |
| Costs labour (€/hour) | 20 |
| Costs of culled cow (€/cow) | 480 |
| Other assumptions | |
| Milk production losses (% of 305 milk production) | 5 |
| Duration treatment (days) | 3 |
| Duration withdrawal time (days) | 3 |
| Labour treatment (min) | 45 |
| Veterinary visits (% of cases) | 5 |
| Culling (% of clinical cases) | 15 |
| Milkings per day | 2 |
| Calving interval (days) | 410 |
| Dry period (days) | 60 |

production as found by Halasa *et al.* (2009), the total milk production losses due to subclinical mastitis for a single farm were calculated as follows:

$$Losses = \begin{cases} \textit{if primiparous}: \sum_{i=1}^{n} \sum_{j=1}^{n} -1 \times (0.72 + \ln([SCC_{ij} \times - 0.22]) \\ \\ \textit{if multiparous}: \sum_{i=1}^{n} \sum_{j=1}^{n} -1 \times (1.9 + \ln([SCC_{ij} \times - 0.47]) \end{cases}$$

Where $SCC_{ij}$ is the SCC measured for cow i during test day interval j. Economic costs of subclinical mastitis were calculated by multiplying the milk production losses with the costs of milk production losses (€ 0.12 per kg; Table 1). No further costs for subclinical mastitis were assumed.

From the questionnaire, for 10 of the 18 preventive measures described by Huijps *et al.* (2010), it was known whether farmers were applying them or not. These preventive measures were: cleaning cubicles, cleaning walking lanes, using antibiotics while drying off cows, pre-stripping, cleaning of dirty udders, use of milker gloves, cleaning milking cluster after a clinical case, milking cows with a high SCC as last, post milking teat disinfection and fixing cows after milking. For each farm the economic costs of applying these preventive measures were calculated using assumptions given in Table 2.

*Table 2. Assumptions used to calculate the economic costs of preventive measures, values of application and frequency of application as reported by 1201 farmers used in this study.*

| | | Assumption | Values | Frequency (%) |
|---|---|---|---|---|
| Cleaning cubicles | Expenditures (€/cow/year) | 3 | Never | 11 |
| | Start-up labour (min) | 5 | Once per 2 days | 1 |
| | Labour per cubicle (min) | 0.1 | Once per day | 48 |
| | | | Twice per day | 40 |
| Cleaning lanes | Start-up labour (min) | 5 | Never | 18 |
| | Labour per cubicle (min) | 0.05 | Once per day | 82 |
| Drying off | Antibiotics (€/cow) | 12 | No | 9 |
| | Labour (min/cow) | 2 | Yes | 91 |
| Pre-stripping | Labour (min/milked cow) | 0.08 | Never | 33 |
| | | | Sometimes | 19 |
| | | | Always | 48 |
| Cleaning dirty udders | Proportion of cows dirty | 5% | Never | 78 |
| | Labour per cleaning (min) | 0.5 | Sometimes | 8 |
| | Water (ltr/cleaning) | 2 | Always | 14 |
| | Price of water (€/m$^3$) | 1.20 | | |
| | Labour for drying (min/cleaning) | 0.25 | | |
| Milker gloves | Expenditures (€/pair) | 0.10 | Never | 42 |
| | | | Sometimes | 18 |
| | | | Always | 40 |
| Cleaning cluster after clinical case | Labour (min/cleaning | 5 | Never | 38 |
| | Water (ltr/cleaning) | 10 | Sometimes | 46 |
| | | | Always | 16 |
| Milking high SCC cows as last | Expenditures (€/year) | 200 | Never | 77 |
| | Labour (min/milking) | 5 | Sometimes | 12 |
| | Labour new high SCC cow (min) | 5 | Always | 11 |
| Post milking teat disinfection | Labour (min/milked cow) | 0.05 | Never | 7 |
| | Use of spray (ml/milked cow) | 5 | Sometimes | 30 |
| | Price of spray (€/20 ltr) | 50 | Always | 63 |
| Fixing cows after milking | Labour (min/milking) | 2 | No | 31 |
| | Expenditures (€/year) | 250 | Yes | 69 |

## Results and discussion

The average farm seize of the 120 farms used in this study was 80 cows, varying from 18 to 350, with an average milk production of 27.04 kg per cow per day, varying from 16.3 to 34.59 kg per cow per day. The average, reported, incidence of clinical mastitis (cases per average cow on the farm per year) was 0.33, varying from 0.03 to 1.21, showing an enormous variation. The resulting economic costs of clinical mastitis were, as a consequence of the variation in incidence of clinical mastitis, also large. The average economic costs of clinical mastitis were € 62 per average cow on the farm per year and varied from € 16 to € 151 per cow per year (5% - 95% percentile; Table 3). The variation between farms was caused by a difference in incidence of clinical mastitis and milk production level. Other factors contributing to the costs of clinical mastitis were normative (Table 1) and equal between the farms. As was also found by others (Hogeveen *et al.*, 2011), the most important factors contributing to the costs

*Table 3. Estimated costs (€ per average cow on the farm per year) for mastitis.*

| | **Average** | **Percentiles** | |
|---|---|---|---|
| | | **5%** | **95%** |
| Milk losses clinical mastitis | 17 | 4 | 42 |
| Antibiotics | 7 | 2 | 17 |
| Discarded milk | 9 | 2 | 23 |
| Labour | 5 | 1 | 11 |
| Veterinary visits | 0 | 0 | 1 |
| Culling | 24 | 5 | 56 |
| Total clinical mastitis | 62 | 16 | 151 |
| Milk production losses subclinical mastitis | 14 | 9 | 21 |
| Total failure costs mastitis | 76 | 26 | 164 |
| Cleaning cubicles | 31 | 0 | 52 |
| Cleaning lanes | 9 | 0 | 16 |
| Drying off | 9 | 0 | 10 |
| Prestripping | 9 | 0 | 17 |
| Cleaning dirty udders | 1 | 0 | 5 |
| Milker gloves | 0 | 0 | 1 |
| Cleaning cluster after clinical case | 1 | 0 | 4 |
| Milking high SCC cows as last | 6 | 0 | 32 |
| Post milking teat disinfection | 17 | 0 | 18 |
| Fixing cows after milking | 8 | 0 | 17 |
| Total prevention costs | 88 | 43 | 131 |
| Total costs mastitis | 164 | 99 | 281 |

of clinical mastitis were milk production losses and risk of culling. The costs per case of clinical mastitis were estimated to be on average € 186, varying from € 165 to € 208 (5% - 95% percentile). The variation in costs of clinical mastitis were only caused by a difference in milk production per cow per day. Other information that influence the costs of a case of clinical mastitis, such as duration of the case, severity of the case and stage of lactation in which the case occurs were not available.

Estimated economic costs due to subclinical mastitis were solely based on milk production losses due to an increased SCC and were estimated to be, on average, € 14 per average cow per year (Table 3), varying from € 9 to € 21 (5% - 95% percentile) per average cow per year. These estimates are very precise, because they were based upon SCC measurements of individual cows throughout a complete year. The total failure costs of mastitis (the sum of the costs for clinical and subclinical mastitis) was € 76 per average cow on the farm per year, which is close to earlier Dutch estimations for the failure costs of mastitis.

The average prevention costs for mastitis were € 88 per average cow on the farm per year, varying from € 43 to € 131 (5% - 95% percentile) per cow per year. The costs of prevention are predominantly (more than 75%) made up by costs for labour and were, on average, more than the failure costs. We used a value of € 20 per hour, which is the replacement costs of labour for an experienced person. In reality, farmers might work with lower internal costs for labour, because the opportunity costs for labour might be less than € 20 per hour. From the 18 management measures defined in previous research (Huijps *et al.*, 2010), data of only 10 measures were available. In reality farmers most probably will carry out more preventive measures than studied in this paper and the preventive costs will, consequently, be higher also. The preventive measures contributing most to the failure costs, were cleaning cubicles and post milking teat disinfection. There was a large variation between preventive costs between farms. For all preventive measures the minimum preventive costs were zero, because for all studied preventive measures one or more farms did not apply that measure at all.

The relation between failure costs and preventive costs for mastitis is given in Figure 1. It can be seen that, although farms with very high preventive costs have very low failure costs, there is not a clear relationship between failure costs and preventive costs, an observation also made in earlier work (Yalcin *et al.*, 1999). Further work should focus on the cost-effectiveness of additional preventive measures for individual farms.

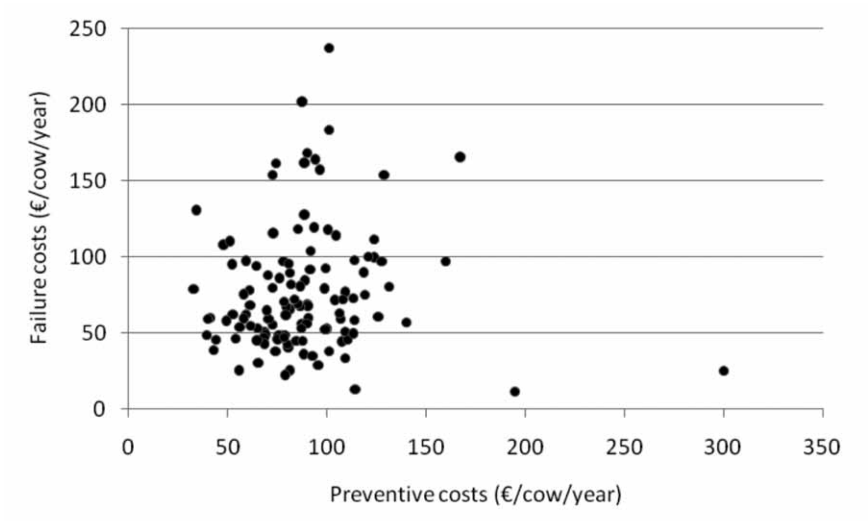


*Figure 1. Relation between failure costs and preventive costs for mastitis on 120 Dutch dairy farms.*

## Conclusions

Both failure costs of mastitis (costs of clinical and subclinical mastitis) and preventive costs (based on ten preventive measures) were estimated for 120 Dutch dairy farms. Costs of clinical mastitis were mainly based on the incidence of clinical mastitis, the costs for subclinical mastitis were calculated with a high level of detail, based on test day records of SCC and the costs of preventive measures were based on questionnaire data. The total costs of mastitis were, on average, € 164 per average cow on the farm per year, of which respectively € 62, € 14 and € 88 were for clinical mastitis, subclinical mastitis and preventive measures.

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# Estimating the impact of mastitis on the profitability of Irish dairy farms

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## Abstract

The objective of this paper was to estimate the impact of mastitis on the profitability of Irish dairy farms. Data was collected from four sources, the data included milk production losses, cases treated and on farm practices around mastitis management. The Moorepark Dairy Systems Model which simulates dairying systems inside the farm gate was used to carry out the analysis. The cost components of mastitis which effect farm profitability and which were included in the model were milk losses, culling, diagnostic testing, treatment, veterinary practices and discarded milk. Farms were grouped by five somatic cell count (SCC) thresholds of ≤100,000; 100,001-200,000; 200,001-300,000; 300,001-400,000; and >400,000 cells/ml. The ≤100,000 cells/ml threshold was taken as the baseline and the other four thresholds were compared relative to this baseline. The analysis found for a 40 hectare farm that as SCC increased milk sales decreased, the number of cows culled due to mastitis increased, total farm receipts increased, total farm costs increased and net farm profit decreased.

**Keywords:** costs, production disease, culling, milk production losses, somatic cell count

## Introduction

As EU market supports are removed and the world dairy markets open up, milk price volatility will become a constant challenge within the Irish dairy industry. As Irish dairy farmers strive to expand in preparation for a post quota environment (Health Check, 2008), insulating themselves against this volatility is essential for the future viability of the farm business. Irish dairy farms need to reduce production costs and remove avoidable on farm losses.

Numerous international studies have highlighted the significant costs associated with mastitis (Hujips *et al*., 2008; Hagnestam-Nielsen and Ostergaard, 2009). The losses associated with mastitis are often underestimated at farm level due to the returns which the farmer has never realised in terms of the reduced milk production. Additional costs include diagnostic testing, cow treatment, increased labour, higher rates of culling, increased mortality and lower herd growth potential (Hogeveen and Osteras, 2005). The objective of this paper was to estimate the impact mastitis has on the profitability of Irish dairy farms. The farms were characterised by five somatic cell count (SCC) thresholds of ≤100,000; 100,001-200,000; 200,001-300,000; 300,001-400,000; and >400,000 cells/ml. The ≤100,000 cells/ml threshold was taken as the baseline and the other four thresholds were compared relative to this baseline.

## Materials and methods

### *Methodology*

A number of data sources were interrogated for each of the costs components included in the model. Once the biological and cost data was collated it was incorporated into the Moorepark Dairy Systems Model (MDSM) (Shalloo *et al.,* 2004).

### *Moorepark dairy systems model*

The MDSM (Shalloo *et al*., 2004) is a stochastic budgetary simulation model of a dairy farm. It allows investigation of the effects of varying biological, technical, and physical processes on farm profitability. The model integrates animal inventory and valuation, milk production, feed requirements, land and labour utilization, and an economic analysis of the production system. The default parameters of the MDSM were obtained from the results of experiments conducted in Moorepark over recent years (Dillon *et al*., 1995; Horan *et al*., 2005; McCarthy *et al*., 2007). The land area assumed in this analysis was 40 hectares. Land area is treated as an opportunity cost, with additional land rented when required and leased out when not required for on-farm feeding of animals. The MDSM assumes that all male calves were sold and replacement heifers were reared on farm from birth. Feed energy requirements are calculated in the MDSM based on the net energy required for milk production, maintenance, and BW change (Jarrige, 1989). Variable costs (fertilizer, contractor charges, medical and veterinarian fees, artificial insemination, silage, and reseeding), fixed costs (machinery maintenance and operating costs, farm maintenance, car, telephone, electricity, and insurance), and market prices (calf, cull cow, and milk) in the MDSM were based on 2008 management data for farm planning (Teagasc, 2008). The MDSM also includes full labour expenses, where one labour unit costs € 22,855 per year (1,848 h).

### *Cost components & data*

The cost components included in this analysis were production losses, culling, diagnostics, clinical and subclinical cases treated, veterinarian and discarded milk. Data in relation to: (1) the volume of milk lost due to SCC; (2) the proportion of the herd culled due to mastitis; (3) the proportion of farmers carrying out mastitis culture testing; (4) the proportion of herds treated for clinical and subclinical mastitis; (5) the treatments administered; and (6) the use of high SCC and antibiotic residue milk was required. The data to estimate the cost implications of mastitis on Irish dairy herds was taken from four sources:

1. The milk production losses were taken from the PhD thesis completed by Kelly (2009) in which the association between SCC and milk yield on Irish dairy farms was examined.
2. The proportion of clinical mastitis cases treated was taken from the Herd Ahead Survey which captured data on animal health and bio-security on a sample of 319 milk recording Irish dairy farms.
3. The Irish Cattle Breeding Federation (ICBF) database was consulted for the sample of 319 dairy farms and data on the herd size, parity structure and SCC status of the sample was collated.
4. The Mastitis Farm Practice Survey was administered to a subset (78) of the farmers who participated in the Herd Ahead programme to gather data on diagnostics, treatment practices, discarded milk and culling.

Utilising these data sources for each of the five SCC thresholds data was available on the production losses, clinical and subclinical cases treated, antibiotic and veterinary treatment, diagnostic testing, discarded milk and culling.

### *Production losses*

In the analysis, individual cow test day SCC records were extracted from the ICBF database over a 3 year period, from 2003-2005 (Kelly, 2009). In total 235,163 test day records from 23,791 dairy cows, in 366 herds were used. The analysis estimated the milk production loss per day across the total lactation for parity 1 to 5 cows for each SCC threshold. This data was coupled with the average herd parity structure of the sample of 319 Irish dairy farms for each SCC threshold. The milk production loss for each SCC threshold was calculated by multiplying the milk production loss per day for parity 1-5 cows by the proportion of the herd within each parity; this was then multiplied by the days in milk (280 days). The average number of days in milk was calculated using a mean herd calving date of February 20$^{th}$ and a herd drying off date of December 10$^{th}$ similar to on-farm practice in Ireland. Table 1 summarises the estimated milk production loss for each SCC threshold.

*Table 1. Milk production losses per somatic cell count threshold (Kelly, 2009).*

| | **Annual milk production loss across each somatic cell count threshold (assumed 280 days in milk)** | | | | |
|---|---|---|---|---|---|
| | **50,001-100,000** | **100,001-200,000** | **200,001-300,000** | **300,001-400,000** | **>400,000** |
| Volume of milk lost/ annum per cow (l) | 176.92 | 351.04 | 485.44 | 544.26 | 601.49 |

***Diagnostic testing***

The proportion of farms undertaking bulk tank and individual cows tests for mastitis culture was collected from the Mastitis Farm Practice Survey. Table 2 summarises the findings for each SCC threshold.

***Cases treated***

The proportion of the herd treated for clinical mastitis was sourced from the Herd Ahead Survey. In addition the proportion of the herd treated for subclinical mastitis was sourced from the Mastitis Farm Practice Survey. Table 2 summarises the finding for each SCC threshold.

***Antibiotic and veterinary treatment***

When mastitis cases (clinical and subclinical) were treated, the method of treatment with intra-mammary tubes and/or IV antibiotics and the use of pain relief was collected from the Mastitis Farm Practice Survey. It was assumed that if IV antibiotics were used the cost of a veterinary call out to administer this treatment was included. The assumptions in relation to treatment practices for each SCC threshold are summarised in Table 2.

*Table 2. Treatment practice assumptions per somatic cell count threshold.*

| **Assumptions** | **<100,000 (baseline)** | **100,001-200,000** | **200,001-300,000** | **300,001-400,000** | **>400,000** |
|---|---|---|---|---|---|
| Milk production loss, l/lactation length | 176.92 | 351.04 | 485.41 | 544.26 | 601.49 |
| Testing (%) | | | | | |
| Proportion of farms carrying out bulk tank tests | 1.8 | 1.5 | 0.6 | 0.9 | 1.2 |
| Proportion of farms carrying out individual cow tests | 3.2 | 3.1 | 1.1 | 4.3 | 5.0 |
| Cases treated (%) | | | | | |
| Proportion of clinical cases treated | 10.50 | 15.23 | 20.73 | 29.36 | 35.65 |
| Proportion of sub-clinical cases treated | 1.05 | 1.45 | 3.74 | 2.30 | 2.71 |
| Treatment practices (%) | | | | | |
| Proportion using intra-mammary tubes only | 58.78 | 90.30 | 72.94 | 55.00 | 55.00 |
| Proportion using IV antibiotics only | 4.55 | 1.08 | 5.88 | 18.75 | 18.75 |
| Proportion using both | 36.67 | 8.61 | 21.18 | 26.25 | 26.25 |
| Proportion using pain relief | 21.43 | 20.51 | 17.65 | 12.50 | 12.50 |
| Proportion dumping milk | 11.55 | 16.68 | 24.47 | 31.66 | 38.36 |
| Proportion of herd culled due to mastitis (%) | 2.81 | 4.51 | 8.68 | 10.62 | 13.23 |

### *Discarded milk*

Whether farmers fed high SCC milk and antibiotic residue milk to calves or whether it was discarded was captured in the Mastitis Farm Practice Survey. It was found that a large proportion of the respondents fed this milk to calves. It was assumed in this analysis that all high SCC and antibiotic residue milk could be fed to calves from January to May while calves were in the system, thereafter the milk was discarded and losses were incurred. Table 2 summarises the assumptions in relation to the proportion of farms discarding milk.

### *Culling*

The proportion of the herd culled due to mastitis, for each SCC threshold, was collected in the Mastitis Farm Practice Survey. The percentages assumed in this analysis are summarised in Table 2.

### *Cost data*

The costs included in this analysis were taken from published reference price lists and consultation with veterinary practices. Table 3 summarises the costs included in this analysis.

The biological and cost data for each of the five SCC thresholds, ≤100,000, 100,001-200,000, 200,001-300,000, 300,001-400,000 and >400,000 cells/ml, was incorporated into the MDSM model to estimate the impact mastitis has on farm profitability.

*Table 3. Costs assumed in the analysis.*

| Cost components | Costs | Source |
|---|---|---|
| Bulk tank test, € | 5.05 | Regional veterinary laboratories, test and price list, department of agriculture fisheries and food |
| Individual cow test, € | 20.20 | Assumed four quarters tested: 4*€5.05 (as above) |
| Intra-mammary tubes only, € | 9.90 | Consultation with veterinary practices |
| IV antibiotics only, € | 84.00 | Consultation with veterinary practices. €34 for pain relief and €50 veterinary call out to administer treatment |
| Intra-mammary tubes & IV antibiotics, € | 93.90 | € 9.90 (intra-mammary tubes) + € 84.00 (IV antibiotics) |
| Pain relief, € | 16.50 | Consultation with veterinary practices |
| Milk price cents/l, € | 0.27 | Binfield *et al.*, 2008 |
| Cull cow value, € | 400.00 | Assumption |
| Heifer replacement costs, € | 1,451.00 | Kennedy *et al.*, 2011 |

## Results

### *Physical results*

As SCC increased the number of cows increased (Table 4). This reflected the decrease in milk yield per cow which reduced the energy demand per cow, as the model assumed that the same level of feed was utilised irrespective of SCC level the cow numbers increased. Also as the SCC increased the kg's of milk sales decreased from 496,204 kg at a SCC of <100,000 cells/ml to 478,982 cells/ml. The milk solids (MS) per cow decreased from 411 kg MS at a SCC of <100,000 cells/ml to 369 kg MS at a SCC of >400,000 cells/ml. As the SCC increased the number of cows culled due to mastitis increased.

### *Financial results*

As SCC increased the milk receipts decreased reflecting the milk production losses. Conversely total farm receipts increased as SCC increased, reflecting the returns from the mastitis cull cows (Table 5). Total farm costs increased as the SCC increased, increasing from €150,125 at an SCC of <100,000 cells/ml to €170,223 at an SCC of >400,000 cells/ml. As a result the net farm profit decreased as the SCC increased, falling from €29,224 at a cell count of <100,000 cells/ml to €11,055 at a cell count of >400,000 cells/ml.

*Table 4. Physical results of the analysis across each somatic cell count threshold.*

| **SCC[1] thresholds** | **<100,000 (baseline)** | **100,001-200,000** | **200,001-300,000** | **300,001-400,000** | **>400,000** |
|---|---|---|---|---|---|
| Cow numbers | 88 | 90 | 92 | 93 | 95 |
| Milk sales, kg | 496,204 | 489,202 | 483,813 | 481,354 | 478,982 |
| Cows culled | 15 | 17 | 21 | 23 | 25 |
| MS per cow, kg | 411 | 397 | 382 | 376 | 369 |

*Table 5. Financial results of the analysis across each somatic cell count threshold.*

| **Somatic cell count thresholds** | **<100,000 (baseline)** | **100,001-200,000** | **200,001-300,000** | **300,001-400,000** | **>400,000** |
|---|---|---|---|---|---|
| Milk receipts, € | 138,796 | 136,814 | 135,243 | 134,524 | 133,820 |
| Total farm receipts, € | 179,177 | 178,683 | 179,809 | 180,359 | 181,278 |
| Total farm costs, € | 150,125 | 153,861 | 161,496 | 165,531 | 170,223 |
| Net profit, € | 29,224 | 24,954 | 18,369 | 14,844 | 11,055 |

## Conclusion

Mastitis results in a considerable reduction in profit at farm level with this study presenting results similar to those found in international studies. An analysis conducted by Berry *et al.* (2006) to document temporal trends in bulk tank SCC in Irish dairy herds from 1994-2004 found the national geometric mean SCC to be 250,937 cells/ml in 2004. At this SCC level the Irish dairy industry is sustaining large losses based on the analysis carried out in this study. In order for Irish dairy farmers to prosper in a highly competitive post quota environment, unnecessary on farm costs and losses need to be minimised. Quantifying the costs of mastitis to demonstrate the losses being generated on Irish dairy farms is the first step in motivating farmers to acknowledge the scale of the problem and implement effective management practices aimed at reducing the costs associated with mastitis. The analysis presented here will be utilised to develop an Irish cost of mastitis calculator for use by farmers and farm advisors to estimate the costs associated with mastitis on their own dairy farms.

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# The effect of udder health on cow fertility: understanding the costs

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An udder health programme (either at farm level or in a wider, industry level context) will only be effective if it is communicated in such a way that on-farm compliance is maximised. This requires an understanding of the varying aspects which motivate different farmers to implement change: while many other elements have been shown to be important, economic justification is a highly powerful driver of change in many herds. A good understanding of the costs of both clinical and subclinical disease is critical in understanding the potential for and likelihood of cost-benefit as a result of implementation of specific udder health measures. Original aspects: This work used data from 105 UK dairy herds to evaluate the impact of clinical and subclinical mastitis on fertility performance. Sophisticated mathematical modelling techniques were used to explore the dataset, and allowed measurement of the effect of udder health on reproductive performance at cow level whilst accounting for potential confounding factors. Previous work in this field has mainly been performed on a limited number of (often high producing, intensively managed) herds; and in many cases using methods that failed to take account of potential confounding factors. This study addresses these problems, and makes simultaneous use of clinical case recording and somatic cell count data. Particular attention was placed on using complex sensitivity analysis to predict the likely impact (with uncertainty) of altering udder health on a herd's fertility performance. Outputs from these models are proposed that can positively enhance the communication process and allow us to make farm specific justifications for change.

# A partial budget analysis to estimate the economics of a mastitis vaccination program

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STARTVAC® is a vaccine aimed to reduce mastitis caused by *Staphylococcus aureus*, *Escherichia coli* and coagulase-negative staphylococci. The objective of this economical analysis was to estimate the net profit of vaccination using data from a clinical trial where 343 cows from six Spanishherds were randomized either to a control (C) or a vaccination group (V). Outcomes were evaluated up to 130 days after parturition. The economic value of the reduction in the days that milk was discarded was estimated by multiplying the difference between both study groups (C = 1.6 days; V = 0.9 days; Diff. = 0.7 days) by daily milk production (30 kg/cow) and milk price (0.30 €/kg). A cost of € 46 per casewas used in the calculation of the reduction in treatment costs due to less clinical mastitis (C = 15%; C = 4%; Diff. = 11%). Although there was a reduction in SCC weighted by the cow's milk production (C = 559,000 cells/ml; V = 431,000 cells/ml), no additional revenues were estimated because SCC did not drop below the 250,000 cutoff point used by most milk processors in Spain to pay premiums. In the estimation of the reduction in culling costs (C = 9%; V = 5%; Diff. = 4%), the cost of a cull cow was estimated as the average value of a cow in the herd minus the average cull cow's salvage value (€ 1,250 - € 500 = € 750). The vaccination program costs were estimated in € 17 per cow and lactation. The overall net profit of the vaccination intervention was €25 per cow in the first 130 after parturition (direct effects). In addition, the observed reduction in subclinical mastitis incidence (C = 46%; V = 18%) is expected to result on a reduction of cow-to-cow transmission of mastitis pathogens (indirect effects).

# Determination of economic loss from depressed udder health

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Depressed udder health from malfunctioning milking equipment, or for other reasons, typically results in reduced milk production. The paper will present a 10-case sample from approximately 100 dairies analyzed by the author, and which were experiencing economic loss from malfunctioning milking equipment, usually accompanied by depressed udder health and elevated somatic cell counts. The paper will use the actual milk production and herd size records from each dairy to show the annual and monthly milk production over several years before, during, and after the introduction of the source of the damage. The paper will use the message communicated by the cows in each herd's production data to show the impact on milk production and the probable direct and underlying causes of the changes before, during, and after the damage period. The paper will show the calculation of the amount of economic loss per cow from the introduction of damage in both absolute terms and relative to herd production without the damage.

# Part 7
# Mastitis diagnostics

# Characterization of MRSA from bulk tank milk of dairy herds using a commercial microarray

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## Abstract

Methicillin resistant *Staphylococcus aureus* (MRSA) has been identified as an emerging pathogen in livestock animals that is readily transferable to humans in contact with livestock. Moreover, MRSA is a mastitis pathogen in dairy cows that can be isolated from bulk tank milk. It was the objective of this study to characterize MRSA from bulk tank milk with respect to their *spa*- and SCC*mec*-type, their phenotypic antimicrobial resistance and resistance resp. virulence associated genes using broth microdilution and a microarray for *S. aureus*. Bulk tank milk samples (25 ml) were tested for MRSA using a 2 step selective enrichment protocol. Presumptive MRSA were confirmed using a triplex PCR targeted at identification of *S. aureus* and the *mec*A gene that encodes resistance to methicillin. A total of 36 isolates derived from monitoring programs and collected within other frameworks in 2009 and 2010 were included in the characterization. All isolates displayed *spa*-types assigned to the clonal complex CC398. Based on the epidemiological cut-off values for the interpretation of minimum inhibitory concentrations isolates were resistant to tetracycline (100%), clindamycin (58%) erythromycin (52%), quinupristin/dalfopristin (36%) and kanamycin (27%). Isolates did not carry genes associated with typical virulence factors for *S. aureus* such as the Panton-Valentine Leukocidin. However they did carry hemolysin genes. Results show that livestock associated MRSA of clonal complex CC398 does occur in German dairy herds and that the strains have similar properties as described for strains from pigs.

## Introduction

Methicillin resistant *Staphylococcus aureus* (MRSA) has been identified as an emerging pathogen in livestock animals that is readily transferable to humans in contact with livestock. MRSA has also been identified as a mastitis pathogen in dairy cows that can be isolated from bulk tank milk (Spohr *et al.*, 2011). So far, limited information is available on the prevalence of MRSA in dairy herds in Germany and other countries. Reports on MRSA in dairy herds are focussed either on clinical cases or on within herd prevalence of MRSA (Fessler *et al.*, 2010; Spohr *et al.*, 2011).

The objective of this study was to characterize MRSA from bulk tank milk samples in dairy herds with respect to typing, antimicrobial resistance and virulence associated genes using a commercial microarray.

## Material and methods

A total of 36 MRSA-isolates from bulk tank milk samples of dairy herds were investigated. Samples had been collected in the framework of national monitoring programs in 2009 and 2010 and in an additional project including 60 dairy herds in Northern Germany. Additional isolates that had been submitted to the National Reference Laboratory for coagulase positive staphylococci including *S. aureus* for diagnostic and confirmation purposes were also included.

Bulk tank milk samples were collected on farm and transported to the laboratory in cool boxes. Samples were analysed for MRSA using a two step enrichment protocol. Briefly, 25 ml of milk were incubated for 16-20 h at 37 °C in 225 ml Mueller Hinton Broth (Oxoid, Wesel, Germany) supplemented with 6.5% NaCl. One ml was then inoculated into 9 ml Tryptone Soy Broth (TSB) (Merck, Darmstadt, Germany) containing 3.5 mg/l cefoxitin (Sigma-Aldrich Chemie, Munich, Germany) and 75 mg/l aztreonam (Sigma-Aldrich Chemie, Munich, Germany), and incubated for a further 16-20 h at 37 °C. One loop-full of this suspension was plated onto a chromogenic agar selective for MRSA (Brilliance MRSA Agar, Oxoid, Wesel, Germany), and incubated for 24 h at 37 °C. Based on colony morphology and colour, presumptive MRSA colonies were subcultivated on sheep blood agar plates.

Isolates suspected to be MRSA were confirmed using a triplex PCR (Poulsen *et al.*, 2003). *Spa*-typing was performed according to Shopsin *et al.* (1999), SCC*mec* typing according to Zhang *et al.* (2005).

Antimicrobial resistance testing was performed using the broth microdilution method according to CLSI standards (CLSI 2008) and custom-made microtitre plate panels (TREK Diagnostic Systems, Magellan Biosciences, West Sussex, England). *S. aureus* ATCC 25923 was used as the quality control strain. Evaluation of resistance was based on epidemiological cut-off values published by the European committee for antimicrobial susceptibility testing for MRSA and *S. aureus* (www.eucast.org).

Genotyping of staphylococcal DNA was done using an array hybridization kit for DNA-based detection of resistance genes and pathogenicity markers of *S. aureus* and assignment of unknown *S. aureus* isolates to known strains based on the Staphy Type$^{TM}$ Kit (Alere, Jena, Germany). This kit detected among others the presence of genes encoding antimicrobial resistance, including for methicillin/oxacillin (*mec*A), beta lactams (*mec*A, *bla*I, *bla*R, *bla*Z), macrolides (*erm*A, *erm*B, *erm*C, *msr*A, *mef*A, *mpb*BM), lincosamides (*erm*A, *erm*B, *erm*C, *lin*A, *cfr*), streptogramin (*erm*A, *erm*B, *erm*C, *vat*A, *vat*B, *vga*, *vga*A, *vgb*), aminoglycosides (*aac*A-*aph*D, *aad*D, *aph*A), streptothricin (*sat*), trimethoprim (*dfr*A), fusidic acid (*far*, Q6GD50), mupirocin (*mup*R), tetracycline (*tet*K, *tet*M, *tet*Efflux), chloramphenicol (*cat*, *fex*A), and vancomycin (*van*A, *van*B, *van*Z).

Moreover, the presence of genes encoding staphylococcal enterotoxins (*ent*A, *ent*A-320E, *ent*A-N315, *ent*B, *ent*C, *ent*CM14, *ent*D, *ent*E, *ent*G, *ent*H, *ent*I, *ent*J, *ent*K, *ent*L, *ent*M, *ent*N, *ent*N_1, *ent*O, *ent*Q, *ent*R, *ent*U, *egc*-cluster) and virulence factors, such as toxic shock syndrome toxins (*tst*1, *tst*-RF122), Pantone-Valentine Leukocidin (PVL), leukocidins (*luk*M/*luk*F-P83, *luk*D, *luk*E, *luk*X, *luk*Y-var1, *luk*Y-var2), hemolysin alpha (*hla*), hemolysins beta (*hlb*, un-truncated *hlb*), hemolysins gamma (*luk*F, *luk*S,*luk*S-ST22+ST45, *hlg*A), and hemolysin delta (*hld*) were detected.

## Results

Overall, 36 MRSA isolates from bulk milk tank samples were included in the analyses. All MRSA isolates were from *spa*-types t011 (22 isolates, 61%) and t034 (14 isolates, 39%), both associated with the clonal complex CC398. According to the typing method of Zhang (Zhang *et al.*, 2005), most isolates (33 isolates, 92%) carried the staphylococcal cassette chromosome *mec* (SCC*mec*) type V, while two isolates carried type III and one carried type IVa. However, the microarray confirmed the presence of the gene ccrC and the absence of ccrA3 and ccrB3 in the two strains that were assigned to SCCmec type III by the typing scheme of Zhang. This indicates they are rather a variant of type V (Jansen *et al.*, 2009).

### *Antimicrobial resistance*

All 36 MRSA isolates from bovine milk were tested against 13 antimicrobial agents. All isolates were resistant to oxacillin and tetracycline, and the $MIC_{90}$ of oxacillin and tetracycline were 8 µg/ml and >64 µg/ml, respectively. Resistance to clindamycin, erythromycin, kanamycin, and quinupristin/dalfopristin was detected at high rates in 21 (58.3%), 19 (52.8%), 10 (27.8%), and 13 (36.1%) isolates, respectively. Resistance to ciprofloxacin was found in 3 isolates (8.3%). In the present study, only one isolate was resistant to chloramphenicol. All isolates were susceptible to mupirocin, vancomycin, and linezolid. The most frequent patterns were resistance to tetracycline and oxacillin alone (10 isolates, 27.8%) and in combination with resistance to erythromycin, clindamycin and quinupristin/dalfopristin (9 isolates, 25.0%). All other patterns were shown by 2 isolates at most.

### *Genes encoding for antimicrobial resistance*

All MRSA isolates in this study carried more than one antimicrobial resistance gene. Table 1 displays the number of isolates carrying the various resistance genes included in the array.

Eighteen different antimicrobial resistance gene patterns were identified. One MRSA isolate carried four of the 14 antimicrobial resistance genes included in the testing (2.8%), 3 carried six genes (8.3%), 16 carried seven genes (44.4%), 12 carried eight genes (33.3%), 3 carried nine genes (8.3%), and 1 isolate carried ten antimicrobial resistance genes (2.8%). The most common genotypic resistance patterns were *mec*A-*bla*Z-*bla*I-*bla*R-*tet*M-*tet*Efflux-*tet*K 8 isolates (22.2%), *mec*A-*bla*Z-*bla*I-*bla*R-*tet*M-*tet*Efflux-*erm*A 5 isolates (13.9%), *mec*A-*bla*Z-*bla*I-*bla*R-*tet*M-*tet*Efflux 3 isolates (8.3%), and *mec*A-*bla*Z-*bla*I-*bla*R-*tet*M-*tet*Efflux-*tet*K-*erm*A 3 isolates (8.3%).

### *Genes encoding for enterotoxins, toxic shock syndrome toxins, leukocidins, and hemolysins*

All isolates tested negative for all genes encoding staphylococcal enterotoxins. In addition, genes encoding toxic shock syndrome toxins (*tst*1, *tst*-RF122), Pantone-Valentine Leukocidin

*Table 1. Proportion of isolates carrying genes encoding antimicrobial resistance as revealed by DNA microarray analysis.*

| Resistance gene | Positive isolates | | Explanation |
|---|---|---|---|
| | N | % | |
| *mec*A | 36 | 100.0 | Methicillin, oxacillin and all beta lactams, defining MRSA |
| *bla*Z | 35 | 97.2 | Beta-Lactamase |
| *bla*I | 35 | 97.2 | Beta-Lactamase repressor (regulatory protein) |
| *bla*R | 35 | 97.2 | Beta-Lactamase regulatory protein |
| *erm*A | 11 | 30.6 | Macrolide, lincosamide, streptogramin |
| *erm*B | 3 | 8.3 | Macrolide, lincosamide, streptogramin |
| *erm*C | 7 | 19.4 | Macrolide, lincosamide, streptogramin |
| *vga*A | 5 | 13.9 | Streptogramin |
| *aac*A-*aph*D | 5 | 13.9 | Aminoglycoside (gentamicin, tobramycin) |
| *aad*D | 4 | 11.1 | Aminoglycoside (tobramycin, neomycin) |
| *tet*K | 19 | 52.8 | Tetracycline |
| *tet*M | 36 | 100 | Tetracycline |
| *tet*Efflux | 36 | 100 | Tetracycline efflux protein (putative transport protein) |
| *fex*A | 1 | 2.8 | Chloramphenicol |

including its bovine variant (PVL, *luk*M/*luk*F-P83), other leukocidins (*luk*D, *luk*E, *luk*Y-var2), and hemolysin beta (hlb), were not found in any of the strains in the present study. For the genes encoding leukocidins/haemolysin toxin family protein, the DNA microarray analysis showed *luk*X and *luk*Y-var1 to be present in all isolates in this study. In addition, all isolates harboured *hla* (haemolysin alpha), un-truncated *hlb* (haemolysin beta), *hld* (haemolysin delta), *hl* (hypothetical protein similar to haemolysin), *hl*III, *hl*_III_other than RF122 (putative haemolysin III), and *luk*F, *luk*S, *hlg*A (haemolysin gamma) (Table 2).

*Table 2. Proportion of isolates carrying genes encoding enterotoxin, toxic shock syndrome toxins, leukocidins, and haemolysins as revealed by DNA microarray analysis.*

| Gene | Positive isolates | | Explanation |
|---|---|---|---|
| | N | % | |
| *tst*-1 | 0 | 0 | Toxic shock syndrome toxin |
| *tst*-RF122 | 0 | 0 | Toxic shock syndrome toxin, allele from bovine strains |
| PVL | 0 | 0 | Pantone-valentine leukocidin |
| *luk*M/*luk*F-P83 | 0 | 0 | Bovine Leukocidin |
| *luk*F | 36 | 100 | Haemolysin gamma, component B |
| *luk*S | 36 | 100 | Haemolysin gamma, component C |
| *luk*S-ST22+ST45 | 2 | 5.6 | Haemolysin gamma, component C, allele from ST22 and ST45 |
| *hlg*A | 36 | 100 | Haemolysin gamma, component A |
| *luk*D | 0 | 0 | Leukocidin D component |
| *luk*E | 0 | 0 | Leukocidin E component |
| *luk*X | 36 | 100 | Leukocidin/haemolysin toxin family protein |
| *luk*Y-var1 | 36 | 100 | Leukocidin/haemolysin toxin family protein |
| *luk*Y-var2 | 0 | 0 | Leukocidin/haemolysin toxin family protein, allele from MRSA252 |
| *hl* | 36 | 100 | Hypothetical protein similar to haemolysin |
| *hla* | 36 | 100 | Haemolysin alpha (alpha toxin) |
| *hld* | 36 | 100 | Haemolysin delta (amphiphylic membrane toxin) |
| *hl*III | 36 | 100 | Putative haemolysin III |
| *hl*_III_Other than RF122 | 36 | 100 | Putative haemolysin III (other than RF122) |
| hlb | 0 | 0 | Haemolysin beta (phospholipase C) |
| Un-truncated *hlb* | 36 | 100 | Haemolysin beta (phospholipase C/ un-truncated) |

## Discussion

Results of the study show that MRSA can be found in bulk tank milk in German dairy herds. This is of concern as MRSA of the *spa*-types identified in the present study have been shown to be involved in clinical mastitis (Fessler *et al.*, 2010), and are associated with high somatic cell counts (Spohr *et al.*, 2011). It has been pointed out that this is a major drawback for the control of *S. aureus* mastitis as most antimicrobials used in control programs either for therapy of clinical cases or for dry cow therapy are beta lactams (Spohr *et al.*, 2011). As the bacteria are also resistant to a number of other antimicrobials, the role of therapy in the control of *S. aureus* mastitis is further reduced. Identification of infected animals, culling or separation of infected animals from uninfected, strict milking time hygiene, post-milking teat dipping, cluster disinfection to avoid transmission of MRSA between cows are of highest importance.

Recently, it has been pointed out, that MRSA in dairy herds are not only observed as intramammary infections but can also be isolated from healthy calves fed with whole milk and other body sites of dairy cows. The importance of this colonization as a source of infection of the mammary glands has not been determined so far.

The high prevalence of resistance genes and the low prevalence of virulence associated genes are in line with results of previous studies on MRSA of the clonal complex CC398 in general (Argudin *et al.*, 2011) and specifically from cases of mastitis (Fessler *et al.*, 2010).

With respect to the zoonotic potential of this type of MRSA, people working on dairy farms have to be considered as being at an increased risk for colonization (Spohr *et al.*, 2011). Their awareness of the issue should be raised and health care facilities should consider not only people working on pig and veal farms, but also those from dairy farms as a risk group for carriage of MRSA.

MRSA in milk are of minor importance as a food safety issue, as milk is nearly always heat treated before consumption. However, on farm consumption of raw milk that is widely practiced by farmers and their families might expose people to MRSA.

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# Mastitis diagnostics: qPCR for *Staphylococcus aureus* genotype B in bulk tank milk

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## Abstract

A novel real-time quantitative PCR assay for detecting the pathogenic and contagious *Staphylococcus aureus* genotype B (GTB) in bulk tank milk (BTM) was developed and evaluated. The detection of this pathogen in BTM would greatly facilitate its control as it is responsible for great economic loss in Swiss dairy herds. The assay is based on the simultaneous detection of 3 GTB-typical target sequences including 2 enterotoxin genes and a polymorphism within the leukotoxin E gene. A variety of mastitis-associated bacteria was used to validate the assay, resulting in an analytical specificity of 100%, and a high repeatability. The analytical sensitivity in milk was 40 cfu/ml corresponding to a calculated detection limit of 1 GTB-positive cow among 138 healthy ones using BTM. An exponential association between simulated cow prevalence and quantitative PCR result was observed. A first field study revealed 1 GTB-positive herd among the 33 studied herds. This novel assay for BTM analysis is suitable for routine purposes and is expected to be an effective tool for minimizing *S. aureus* GTB in Swiss dairy herds.

**Keywords:** cattle, disease, molecular analytics, udder health, pathogen control

## Introduction

*Staphylococcus aureus* is the most common cause of contagious mastitis in cattle worldwide (Schällibaum, 1999; Zecconi *et al.*, 2005). In Switzerland, it causes great economic loss (Kirchhofer *et al.*, 2007), and control of this pathogen would be very beneficial. Unfortunately, conventional routine bacteriology as a diagnostic tool is not entirely satisfactory, as the overall diagnostic sensitivity in single milk samples reaches only 79.9% (21.4 to 100%) (Studer *et al.*, 2008). As a consequence, triple sampling is necessary to achieve a satisfying diagnostic sensitivity (Sears *et al.*, 1990) but it is often too expensive, so that routine testing normally is accomplished with single analysis. From a clinical point of view, this approach is not acceptable as many cows falsely remain undetected making the control of *S. aureus* mastitis difficult.

Graber *et al.* (2007) developed a highly sensitive and specific assay to detect *S. aureus* in raw milk samples. Its potential for automation in routine examinations is the basis for a wide range of use. This assay is >500 times more sensitive than conventional bacteriology and is highly specific for *S. aureus* (100%). It was evaluated in a longitudinal field study by Studer *et al*. (2008) and showed a diagnostic sensitivity of 99.4% and a diagnostic specificity of 97.1%.

In the studies of Fournier *et al*. (2008) and Graber *et al*. (2009), various genotypes of *S. aureus* with different virulence and pathogenicity factors were identified and described. *S. aureus* genotype B (GTB) and genotype C (GTC) were predominant in Swiss dairy herds, whereas the remaining genotypes (GTOG) were rarely found. GTB was related to high contagiosity and increased pathogenicity, causing herd problems with cow prevalences up to 87% (Graber *et al*., 2009). In contrast, GTC and GTOG were found with infections of single cows.

Genotyping by Fournier *et al*. (2008) showed a high association between genotypes and virulence gene patterns. Among others, GTB was characterized by the presence of the *S. aureus* enterotoxin genes A (*sea)* and D (*sed)*, and by a polymorphism within the leukotoxin E gene (lukEB), caused by a point mutation. (Fournier *et al*., 2008) correctly identified 77% of GTB isolates by *sea*, 87% by *sed,* and 100% by lukEB. Correct negative results for non-GTB strains were observed in 100% for *sea*, 94% for *sed,* and 87% for lukEB.

As shown by Fournier *et al*. (2008) and Graber *et al*. (2009), GTB infects many cows in a herd and requires infected herds to be sanitized in order to reduce somatic cell count (SCC) at herd level. From clinical experience we know that proper sanitation alone takes 1 year and is expensive because of treatment costs, loss of milk, culling, replacements, additional work, and veterinary support. For minimizing intramammary infection (IMI) caused by GTB at the herd level, but also at the country level, detection and monitoring of GTB-positive herds would be most efficient and most economic by analyzing bulk tank milk (BTM). Screening of BTM is a convenient, fast, and comparatively cheap method.

To improve the diagnostics for *S. aureus* as a mastitis pathogen, it was the goal to develop a novel assay to detect GTB in BTM. With the triple detection of lukEB, *sea,* and *sed* by real-time quantitative PCR (qPCR), this new method showed a high analytical sensitivity and specificity as well as a high repeatability. The study was recently published by Boss *et al.* (2011).

## Material and methods

Full details are given in the publication of Boss *et al*. (2011). The development and validation of the assay specific for GTB were undertaken according to guidelines proposed by the OIE World Organization for Animal Health (OIE, 2008), adapted for qPCR. In particular, the analytical sensitivity and specificity of the assay as well as its repeatability were evaluated using a variety of bacterial DNA samples. The assay was then applied on simulated samples and on real BTM to get a first impression on its properties under field conditions.

### *Bacterial strains*

DNA samples of udder pathogens with known identity were tested. Considering *S. aureus*, they were obtained from former studies (Graber *et al.*, 2007; Fournier *et al.*, 2008) and were initially isolated from bovine milk with spontaneous IMI. In total, there were 33 strains of GTB, 18 strains of GTC and 20 strains of GTOG (Fournier *et al.*, 2008). In the case of non-*S. aureus* staphylococci (NSA), 26 IMI-associated isolates were used together with 9 strains with known identity (DSMZ, Braunschweig, Germany). Two strains each of the following pathogens were additionally included: *Streptococcus agalactiae*, *Streptococcus uberis, Streptococcus dysgalactiae*, *Enterococcus faecalis* and *Escherichia coli*.

### *BTM samples*

To obtain simulated BTM samples, GTB-positive cow milk samples were used to create simulated BTM (n=64) with a GTB cow prevalence between 0% and 95% by assembling constant volumes of GTB-positive milk and adding a calculated volume of GTB-free milk. To create simulated control herds (n=25), equal volumes of GTB-negative milk samples were combined. In the case of real BTM (rBTM) samples, they were collected from 33 herds located in the area of Berne, Switzerland, following the NMC (1999) guidelines.

### *Extraction of bacterial NA from BTM*

Preparation of bacteria from milk using *L. casei* and NA extraction were performed as described by Boss *et al.* (2011).

### *qPCR*

Primers and probes for qPCR were designed in our laboratory. The probes for *sea* and *sed* were minor groove binders (MGB). The probe for lukEB contained 6 locked nucleic acids The sense primer for lukEB specifically detects a point mutation typical of *Staph. aureus* GTB (Fournier *et al.*, 2008; Graber *et al.*, 2009). The primers and probes for *nuc*-qPCR were the same as described by (Graber *et al.*, 2007). QPCR for all genes were run in duplicates. Results were considered to be positive if both reactions were positive. If only 1 reaction showed a positive result or the difference of the 2 $C_T$ values ($C_T$: cycle to reach the threshold) were more than 2 cycles, the qPCR was repeated. Results <10 copies/reaction were considered as negative. For each assay and each gene, a standard and controls were included.

## Results

### *Assay performance*

Using serial dilutions of purified lukEB, *sea,* and *sed* amplicons, the assays were shown to give log-linear, well reproducible results between 10 and $10^5$ copies/assay. For this range, the coefficient of correlation of each of the 3 qPCR was 0.999. The amplification efficiency was 1.02 for lukEB and *sed* and 1.01 for *sea* and *nuc*, measured on the gradient.

### *Analytical specificity*

Different combinations are possible when qPCR results of 3 targets are combined. Using their analytical specificity, the probabilities were calculated, given that a milk sample was truly GTB-positive or GTB-negative, respectively. For a sample being positive for the 3 targets, the probability of actually being GTB-positive was 0.909, the probability of actually being a non-GTB was 0. All the other target gene combinations were typical of non-GTB samples.

### *Analytical sensitivity*

The analytical sensitivity of the different qPCR reactions was evaluated by serial dilutions of milk spiked with GTB. The limits of detection were 40 cfu/ml milk for lukEB, 100 cfu/ml for *sea*, 10 cfu/ml for *sed.*

### *Repeatability*

The intraassay variability was determined by simultaneous processing of the same milk sample spiked with GTB. The coefficient of variation (CV) was 2.9% for lukEB, 0.9% for *sea,* and 1.6% for *sed* ($log_{10}$-transformed values). The interassay variability was evaluated by a complete analysis of spiked milk on 10 different days. The CV was 1.7% for lukEB, 2.1% for *sea,* and 1.8% for *sed* ($log_{10}$-transformed values).

### *BTM samples*

Using simulates BTM samples, an exponential dependency ($R^2$=0.861; $P$<0.001) was observed between GTB cow prevalence of a herd and the logarithmic lukEB-qPCR value (number of copies per reaction). All GTB-negative samples were tested negative.

In total, 33 rBTM samples were examined. One of them (3%) was identified as positive for GTB, whereas all the remaining 32 samples were negative.

## Discussion

The present study describes a novel qPCR-based assay to detect GTB in BTM. The assay is highly sensitive and specific for this contagious mastitis pathogen and is characterized by a small intra- and interassay variability. It includes preparation of bacteria from milk as described by Graber *et al*. (2007) and qPCR for the 3 GTB-typical targets lukEB, *sea* and *sed* (Fournier *et al*., 2008; Graber *et al*., 2009). A BTM sample is GTB-positive, if qPCR for lukEB and *sed* and/or *sea* generates a positive result. BTM was used as it is the most efficient and economic way of detecting and monitoring GTB-positive herds.

So far, BTM analyses for *S. aureus*, using conventional bacteriological examination, was of limited value as there is only a weak association between cfu of *S. aureus* measured in BTM and the number of infected cows (Farnsworth, 1993; Gonzalez *et al*., 1986). This observation is not astonishing as *S. aureus* in BTM may also originate from other sites than the mammary gland (environmental *S. aureus*) including teat and udder skin, parlor, milking machine, air and bedding (Sears and McCarthy, 2003). According to Fox *et al*. (1991), Haveri *et al*. (2008) and Zadoks *et al*. (2002), however, *S. aureus* associated with IMI differed from the environmental ones and may be considered, therefore, as mastitis-irrelevant. To make the situation even more complex, there are IMI-associated subtypes which are not pathogenic (Fournier *et al*., 2008). The presented qPCR analytics, however, allows for the first time to detect highly sensitively an actual IMI-associated and pathogenic subtype of *S. aureus* (GTB) in BTM and to exclude all the remaining and interfering subtypes.

Considering the analytical specificity of the assay, 100% of the GTB-positive strains were correctly detected. In addition, all remaining genotypes, NSA, other mastitis-causing and environmental bacteria as well as further enterotoxin genes were safely excluded. Furthermore, qPCR permitted detection of targets within a wide dynamic range, rendering dilution steps of samples unnecessary.

The high analytical specificity of the present GTB-qPCR analytics was accompanied by a high analytical sensitivity as the detection limit for lukEB was 40 cfu of GTB per milliliter of milk. In addition, the repeatability of the lukEB-, *sea*- and *sed*-qPCR assays were high. Based on the $\log_{10}$-transformed values, the intraassay variability of the 3 qPCR ranged between 0.9% and 2.9%, the interassay variability between 1.7% and 2.1%. False negative qPCR caused by competitive or enzymatic inhibitors present in the sample NA were ruled out by inclusion and detection of an internal control.

To get an impression of how the novel methodology will perform under future field conditions, simulation analyses and a first, exploratory field study were performed. Simulation turned out that there was an exponential dependency between the logarithmic lukEB-value and the simulated GTB cow prevalence. These investigations further allowed calculating an expected detection rate of about 1 lukEB-positive cow among 138 cows using BTM. Extended field studies are in progress now.

## Conclusions

The described qPCR analytics is a fast and potent method of screening easily available BTM samples for the GTB. It is characterized by a high analytical specificity and sensitivity as well as by a high repeatability. Based on our simulation experiments and a first field study, the methodology is expected to provide a powerful tool for the control of this contagious pathogen in the future.

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# Identification of coagulase-negative *Staphylococcus* species by gas chromatography

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## Abstract

Researching the impact and epidemiology of coagulase-negative *Staphylococcus* species (CNS) causing intramammary infections (IMI) require their identification at the species level. Gene sequencing is the gold standard but faster and less expensive methods could be useful. The Sherlock Microbial Identification System is an automated gas chromatographic (MIS-GC) system able to speciate CNS isolates in human clinical medicine by identifying the unique cellular fatty acid patterns in bacteria cell walls. Our objective was to validate the MIS-GC method for speciating CNS responsible for IMI in dairy cows. The CNS isolates examined include 429 isolates of *Staphylococcus chromogenes,* 195 *Staphylococcus simulans*, 108 *Stapylococcus xylosus*, 81 *Staphylococcus haemolyticus* and 42 *Staphylococcus epidermididis* obtained from the Canadian Bovine Mastitis Research Network culture collection and speciated using *rpo*B gene sequencing. Isolates were harvested from apparently normal mammary quarters before and after the dry period or during lactation. CNS isolates were divided in 2 groups within species. Speciation by MIS-GC of the first group was performed with a human-source CNS fatty-acid profile library and was used to construct a bovine-source library. MIS-GC speciation of the second group was performed with the new library. Repeatability of the technique was evaluated by re-culturing and re-testing a minimum of 50 isolates of each species. Using *rpo*B sequencing as gold standard, sensitivities for *S. chromogenes*, *S. simulans*, *S. xylosus* and *S. epidermidis* with the human library were 63% (n=215), 58% (n=89), 40% (n=55) and 52% (n=21) respectively, and 91%, 79%, 71% and 100% with the bovine library. Repeatability was 80% (n=100), 81% (n=97), 72% (n=53). Sensitivity for *S. haemolyticus* was 8% with the human library and could not be included in the bovine library. Its repeatability was 90% (n=40). The final bovine library tested on a random sample of *S. chromogenes* gave a sensitivity of 89%.

**Keywords:** intramammary infection, fatty acid, sensitivity, repeatability

## Introduction

Coagulase-negative *Staphylococcus* species (CNS) are one of the most common mastitis-causing pathogens (Bradley *et al.*, 2007; Piepers *et al.*, 2007; Reyher *et al.*, 2011; Sampimon *et al.*, 2009a). However, their clinical significance is still open to debate (Pyörälä and Taponen, 2009). Routine veterinary laboratories do not usually identify CNS at the species level, for which there are more than 50 with a dozen found most commonly in intramamaary infections (IMI) (Sampimon *et al.,* 2009a). Researching the impact and epidemiology of CNS causing IMI require their identification at the species level. Gene sequencing is the gold standard (Zadoks and Watts, 2009) but faster and less expensive methods could be practically useful.

Bacteria are characterized by their unique cellular fatty acid patterns present in the cell wall. The fatty acids can be extracted from the bacteria, converted into their corresponding Fatty Acid Methyl Esters (FAME) and then separated by gas chromatography (GC) (Sasser, 2001). The sample containing FAME of an unknown CNS species can be compared to a database of bacterial acid profiles and can be classified based on a similarity index (SI) (index scale 0 - 1.0) taking into account the presence and relative concentration of FAME, eluting from nonanoic acid methyl ester (9:0) and eicosanoic acid methyl ester (20:0).

The Sherlock Microbial Identification System commercialized by MIDI Inc. (Microbial ID Inc., Newark, DE) is an automated gas chromatographic (MIS-GC) system able to speciate CNS isolates by identifying their unique FAMEs peak area ratios through principal component analysis (Sasser, 2001). The results are compared with proprietary database libraries which are only based on human isolates. New library entries can be created for isolates with unrecognized patterns.

The study objective was to estimate the sensitivity of cellular fatty acid analysis for the species identification of CNS responsible for IMI in dairy cows using MIS-GC using a proprietary human-derived clinical aerobe database library, and to develop and test a bovine mastitis-derived isolate-source library.

## Materials and methods

### *Study design*

All isolates were randomly chosen from the Canadian Bovine Mastitis Research Network (CBMRN) culture collection (Reyher *et al.*, 2011), from cows with subclinical IMI before and after the dry period or during lactation. The isolates were speciated using *rpoB* gene sequencing (Drancourt and Raoult, 2002), making our reference gold standard. Based on gene sequence homology ≥94% with >3% difference with the next homologous species, our isolate set consisted of 429 *Staphylococcus chromogenes*, 186 *Staphylococcus simulans*, 108 *Staphylococcus xylosus*, 81 *Staphylococcus haemolyticus*, and 42 *Staphylococcus epidermidis*.

The sequencing was performed with an Applied Biosystems 3730 Capillary DNA analyzer using Applied Biosystems Big Dye Terminator Chemistry.

Each CNS species were divided randomly into two groups. The fatty acid compositions of the test isolates of the first group were speciated using an up-to-date human-derived clinical aerobe database library. Fatty acid profiles of these tested isolates served to construct a new bovine mastitis-source library with the Library Generation Software (MIDI). The second group was identified with both the human and the new bovine library. Only isolates with a SI of 0.5 or higher and with a separation of 0.1 between the first and second indices were considered identifiable. If this identification corresponded to the *rpoB*-determined species, it was considered a correct identification. A minimum of 40 isolates of each species were randomly chosen, re-grown and re-tested twice with both libraries to evaluate the repeatability of the technique. The random procedure allowed for having at least one isolate per herd. The sensitivity MIS-GC technique with each library was evaluated using the *rpoB* gene sequence-based species identification as a gold standard. The bovine mastitis-source library was built sequentially, one CNS species at a time. Each of the foregoing species identification sensitivity estimates for the bovine-based library was made with the library in its progressively advanced stage of completion. After all species had been tested and the library construction was completed, a final estimate of sensitivity of the library to identify *S. chromogenes* was tested. For this estimated, 100 of the original full test population of *S. chromogenes* isolates were randomly selected testing with the full bovine mastitis-source library.

#### *Gas chromatography*

A single colony was quadrant streaked onto Trypticase soy agar plates and harvested in log-phase growth after 24 (±2) h of incubation at 35 °C in air. Approximately one 10 μl loopful of bacteria was harvested for each sample. Each sample was saponified (sodium hydroxide in methanol), methylated (hydrochloric acid in methanol), extracted (hexane in methyl *tert*-butyl ether), and cleaned (sodium hydroxide). Its organic layer was removed and injected into the MIS-GC. Calibration Instant Fame and negative and positive controls were run with each batch.

## Results

### Staphylococcus chromogenes

On initial testing of 214 *S. chromogenes* isolates with the human library, sensitivity of definitive identification was 60% (129/214). Incorrect identifications were *Staphylococcus felis* (n=6), *S. xylosus* (n=2) and *S. simulans* or *Staphylococcus hyicus* (n=1 each); 75 isolates (35%) were not identifiable. Repeatability of 100 isolates' identification was 80%. After constructing the first portion of a bovine mastitis-source library with 31 of the preceding isolates having SI >0.6 for *S. chromogenes*, 215 additional *S. chromogenes* (by *rpoB* sequence) isolates were tested against both libraries. The human-source library and the bovine mastitis-source library had sensitivities of 63% (135/215) and 91% (195/215), respectively (Table 1). The 20 isolates not correctly identified by the bovine mastitis-source library were not identifiable because of lack of other species in the library. With the human-source library, 13 were incorrectly identified and 67 (31%) were not identifiable.

### Staphylococcus simulans

Initial testing of 97 randomly selected *S. simulans* isolates using the human-source library had 70% sensitivity (68/97). Repeatability of identification was 81% (79/97). Profiles of 19 isolates with SI >0.6 for *S. simulans* were added to the *S. chromogenes* profiles in the bovine mastitis-source library. The isolates remaining (n=89) had sensitivities of 58% (52/89) and 79% (70/89) using the respective human-source and bovine mastitis-source libraries (Table 2).

### Staphylococcus xylosus

Sensitivity of identification of the first selection of isolates with the human-source library was 58% (31/53). Repeatability was 72%. The bovine library was updated with 22 of the foregoing isolates as described above and the remaining 55 isolates were identified with sensitivities of 40% (22/55) and 71% (39/55), with the respective human-source and updated bovine mastitis-source libraries (Table 3). The isolates not officially identified by the bovine library were given as *S. xylosus* (11) or *S. simulans* (4) by this library. It wrongly identified 1 isolate as *S. chromogenes*.

*Table 1.* Staphylococcus chromogenes[1] *identification by fatty-acid gas chromatography using a proprietary human-source library and an experimental bovine mastitis-source library*[2].

| **Human-source library** | **Bovine mastitis-source library identification** | | | | |
|---|---|---|---|---|---|
| | **Correct** | | **Not identifiable** | **Total** | |
| Correct | 135 | | 0 | 135 | (63%)[4] |
| Incorrect | 6 | | 7[3] | 13 | |
| Not identifiable | 54 | | 13 | 67 | |
| Total | 195 | (91%)[5] | 20 | 215 | |

[1] Species specific sequence of the *rpoB* gene as gold standard.

[2] Chi-square test of homogeneity (with 'incorrect' and 'not identifiable' combined) $P<0.001$.

[3] Identified by the human-source library as *S. hyicus* (2), *Staphylococcus lugdunensis* (2), *Staphylococcus aureus* (1), *S. haemolyticus* (1), and *Staphylococcus saprophyticus* (1).

[4,5] Sensitivity of identification by a human-source and a bovine-source library, respectively.

*Table 2.* Staphylococcus simulans[1] *identification by fatty-acid gas chromatography using a proprietary human-source library and an experimental bovine mastitis-source library*[2]*.*

| **Human-source library** | **Bovine mastitis-source library identification** | | | | | |
|---|---|---|---|---|---|---|
| | **Correct** | | **Incorrect** | **Not identifiable** | **Total** | |
| Correct | 51 | | 0 | 1 | 52 | (58%)[4] |
| Incorrect | 2 | | 0 | 8 | 10 [3] | |
| Not identifiable | 17 | | 0 | 10 | 27 [3] | |
| Total | 70 | (79%)[5] | 0 | 19 [6] | 89 | |

[1] Species specific sequence of the *rpoB* gene as gold standard.

[2] Chi-square test of homogeneity (with 'incorrect' and 'not identifiable' combined) $P<0.001$.

[3] Misidentified as *S. aureus* (3), *S. xylosus* (5) or presumptively identified only as *S. aureus* (2), *S. simulans* (4), *S. epidermidis*, *S. xylosus*, *S. cohnii* or *S. pasteuri* (each 1).

[4,5] Sensitivity of identification by a human-source and a bovine-source library, respectively.

[6] Presumptively identifiable only as *S. simulans* (11), *S. chromogenes* (6) or no match (2).

*Table 3.* Staphylococcus xylosus[1] *identification by fatty-acid gas chromatography using a proprietary human-source library and an experimental bovine mastitis-source library*[2]*.*

| **Human-source library** | **Bovine mastitis-source library identification** | | | | | |
|---|---|---|---|---|---|---|
| | **Correct** | | **Incorrect** | **Not identifiable** | **Total** | |
| Correct | 22 | | 0 | 0 | 22 | (40%)[4] |
| Incorrect | 0 | | 0 | 5 | 5 [3] | |
| Not identifiable | 17 | | 1 | 10 | 28 [3] | |
| Total | 39 | (71%)[5] | 1 [6] | 15 [6] | 55 | |

[1] Species specific sequence of the *rpoB* gene as gold standard.

[2] Chi-square test of homogeneity $P<0.001$.

[3] Misidentified as *S. equorum* (4) or *S. saprophyticus* (1), or presumptively identified only as *S. equorum* (7), *S. pasteuri* (2), or *S. saprophyticus* (1).

[4,5] Sensitivity of identification by a human-source and a bovine-source library, respectively.

[6] Misidentified as *S. chromogenes* (1), or presumptively identifiable only as *S. xylosus* (11) or *S. simulans* (4).

### *Staphylococcus epidermidis*

Identification of the first 20 randomly selected *S. epidermidis* isolates using the human-source library has a sensitivity of 65% (13/20). As above the bovine mastitis-source library was update with 7 isolates' patterns. Identification performed on the remaining 21 isolates had sensitivities of 52% (11/21) and 100% (21/21) using the human- and bovine mastitis-source libraries, respectively. Test of homogeneity of the test results was not possible due to the absence of negative or non-identifiable responses with the bovine mastitis-source library. Those isolates not definitively identifiable with the human-source library were presumptively identified as *S. epidermidis* (6), *S. haemolyticus* (3) or *S. aureus* (1).

### *Staphylococcus haemolyticus*

40 isolates were used twice with the human library, on which it identified correctly only 3 (8%). The repeatability of the technique was 90%. No bovine library could be built as no valid candidates emerged from the first group.

### *Final bovine library* on *Staphylococcus chromogenes*

Ninety-nine randomly selected isolates were tested with the human and the final bovine library holding information on bovine isolates for *S. chromogenes*, *S. simulans*, *S. xylosus* and *S. epidermidis*. The observed sensitivities of correct identification were 47% (46/99) and 89% (88/99), respectively (Table 4). When not identified by the bovine library, the isolates were

*Table 4.* Staphylococcus chromogenes[1] *identification by fatty-acid gas chromatography using a proprietary human-source library and an u-dated experimental bovine mastitis-source library*[2].

| Human-source library | Bovine mastitis-source library identification | | | | | |
|---|---|---|---|---|---|---|
| | Correct | | Incorrect | Not identifiable | Total | |
| Correct | 46 | | 0 | 0 | 46 | (47%)[4] |
| Incorrect | 5 | | 0 | 3 | 8 [3] | |
| Not identifiable | 37 | | 0 | 8 | 45 [3] | |
| Total | 88 | (89%)[5] | 0 | 11 | 99 | |

[1] Species specific sequence of the *rpoB* gene as gold standard.

[2] Chi-square test of homogeneity $P$=0.003.

[3] Misidentified as *S. hyicus* (2) or *S. simulans* (1), or presumptively identified only as *S. chromogenes* (6), *S. hyicus* (1), or *S. simulans* (1).

[4,5] Sensitivity of identification by a human-source and a bovine-source library, respectively.

misjudged as *S. chromogenes* (9), *S. simulans* (1) or *S. xylosus* (1) (*S. chromogenes* (6), *S. hyicus* (3) or *S. simulans* (2) as per human library).

## Discussion

CNS are increasingly considered to be potentially important pathogens causing bovine mastitis. Up to now they have been considered as a group but epidemiological investigation to elucidate more precisely the role of CNS in udder health requires an accurate species level identification. Phenotypic methods of identification are deemed inadequate for this purpose (Capurro *et al.*, 2009, Sampimon *et al.*, 2009b, Park *et al.*, 2011) and genotypic methods are accurate but also time-consuming, labour-intensive and expensive (Zadoks and Watts, 2009).

Identification of CNS at the species level through qualitative pattern recognition of FAME is recognized as an efficient epidemiologic tool in human medicine (Birnbaum *et al.*, 1994). It has never been evaluated against isolates of bovine origin however. The performance of the human library on bovine isolates ranged from 40% (*S. xylosus*) to 63% (*S. chromogenes*), which make it unsuitable for our purpose. The construction of a dedicated bovine library is therefore required, which improved the sensitivity of the test (71% to 100%) with 89% using the final library containing patterns for *S. chromogenes, S. sumulans, S. xylosus,* and *S. epidermidis*. Compared with results from Sampimon *et al.* (2009b), Capurro *et al.* (2009) and Park *et al.* (2011) who investigated sensitivities of phenotypic tests API Staph ID 32, API Staph ID 20 and Staph-Zym, the bovine library built was more accurate for *S. chromogenes* (91% vs. 37 to 80%), was similar to Staph-Zym but better than the API tests for *S. simulans* (22 to 29%), had similar results for *S. xylosus* and *S. epidermidis*. It should be noted that sensitivities of API tests and Staph-Zym for *S. haemolyticus* were equally deceiving (from 0 to 33%).

Even though the MIS-GC test had better sensitivities than other phenotypic methods, it was still unable to identify several isolates. However, when the isolates were not definitively identified by the bovine library, its best guess was still often accurate, suggesting the potential of improved performance with a richer library. Detection of *S. haemolyticus* was poor with the human library. This is similar to other phenotypic methods, meaning this particular species might have singular features which render these methods inefficient to identify it.

These preliminary results are sufficient positive to encourage further work on MIS-GC identification of CNS. But, further work on definition of a sufficiently rich bovine-source library is needed before widespread use should be make of the technique.

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# Real time PCR values for mastitis pathogens – relations to milk quality and herd characteristics in Danish dairy herds

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## Abstract

In October to December 2009 bulk tank milk samples from all 4258 Danish dairy herds were tested by real-time PCR. Data on bulk tank somatic cell count (BTSCC), for most herds from every milk delivery, and total bacteria count (TBC) for the last 3 weeks before to one week after sampling were available for all herds. Furthermore information on milking system (automatic milking system (AMS) divided by major brands or non-AMS), herd size and production type (organic and conventional) was also available. Linear relations between the last BTSCC and the Ct-values for *Staphylococcus aureus*, *Streptococcus uberis*, *Streptococccus dysgalactiae* and *Streptococcus agalactiae* were found when the Ct-values were below 33.5, 34.5, 32 and 32 respectively. Linear relations between the average log transformed TBC and the Ct-values for the same bacteria were also significant with slightly lower cut-off values. The prevalence of *S. agalactiae* increased with herd size in all herd types from 4% in the smallest herds to over 15% in herds with more than 250 cows. The prevalence also varied with production type and milking system with nearly double prevalence for one brand of AMS. The relation between the Ct-values and milk quality and especially the differences seen for *S. agalactiae* and special herd characteristics will be discussed.

## Introduction

In Denmark, bulk milk somatic cell count (BMSCC) and treatment frequency for mastitis are the two main parameters for monitoring the overall udder health status, and Danish veterinarians use bacterial culture of quarter milk samples routinely for monitoring prudent use of antibiotics and as a diagnostic tool in mastitis management. Bulk tank milk (BTM) culture has until know only been use to monitor the prevalence of *Streptococcus agalactiae.* In contrast, BTM culture is widely accepted in many other countries as a tool for evaluating the quality of milk and for monitoring udder health status (Jayarao and Wolfgang, 2003).

Molecular methods have been suggested to improve the sensitivity of intramammary pathogen detection. In particular, PCR based methods are now being used increasingly in mastitis diagnostics. Recently, analytical accuracy was reported for a real-time PCR based reagent kit capable of detecting 11 important intramammary infection (IMI) species/species groups and the beta-lactamase gene (PathoProof$^{TM}$ Mastitis PCR Assay, Thermo Fisher Scientific, Espoo, Finland) based on a large collection of culture isolates (Koskinen *et al.*, 2009).

The objective of this study was to evaluate the results of a PCR test of all Danish dairy herds to describe relations between PCR results and milk quality and to describe the effect of different herd characteristics on the prevalence of *S. agalactiae* based on PCR testing.

## Material and methods

BTM samples from all 4258 Danish dairy herds from 2009 were included. The samples were collected between the 20$^{th}$ October 2009 and 6$^{th}$ January 2010. BTM sampling was carried out during milk collection and stored on ice. Within 24 hours, the samples were shipped to Danish Milk Quality Laboratory Eurofins, Holstebro, Denmark,. In 2009, the milk samples for culture and PCR testing were taken after the BTM sample had been through the laboratory for routine testing of SCC, fat, protein and urea. Culture of *S. agalactiae* was done by mixing 120μl of milk on a selective aesculin agar containing 5% of sterile calf blood, 0.5% of N-solution and 0.3% *Staphylococcus aureus* β-toxin.

All BTM samples were tested using a PCR based assay (PathoProof$^{TM}$ Mastitis PCR Assay, Thermo Fisher Scientific, Espoo, Finland). A total of 350 μl of milk was used as a starting volume for DNA extraction. Cycle threshold (Ct) values were recorded for all samples and for all bacterial targets. The Ct value represents the number of PCR cycles it takes to obtain the threshold level. Ct values higher than 39.9 were set as negative (NoCt).

BTSCC was measured at each delivery to the dairy, typically every second day. Total bacterial count (TBC) was measured once every two weeks on samples collected the same way as samples for PCR. The TBC was not necessarily measured the same day as the PCR analysis. TBC from up to three weeks before to one week after the sampling for PCR was used in the analysis. The results of BTSCC and TBC were stored in the Danish Cattle Database for all herds. Information on herd size, milking system and production system was available from the Danish Cattle Database.

Herds infected with *S. agalactiae* are recorded in the Danish B-register on the basis of a positive individual cow or BTM testing. Free herds found BTM positive are tested again. If the second sample is positive, the herd will be recorded in the B-register. If the second sample is negative, a third test will settle the status of the herd. Herds can leave the register if four consecutive BTM samples each with more than 30 days' distance are tested negative for *GBS*.

The correlation between Ct-values for the different bacterial DNA and BTSCC and Ct values and the logarithm of TBC analyzed. First a generalized additive model was made using PROC GAM in SAS 9.2 (SAS institute) to explore changes in correlation with changing Ct values.

Based on the GAM a breakpoint was established and Ct values above the breakpoint were included in the model using a piecewise regression model.

## Results

The breakpoints for a correlation between Ct value and BTSCC were decided to be 32 for *S. agalactiae* or *Streptococcus dysgalactiae,* 34.5 for *Streptococcus uberis* and 33.5 for *S. aureus.* The breakpoints for the correlation between Ct value and the logtransformed TBC were decided to be 32 for *S. agalactiae* and *S. dysgalactiae,* 34.5 for *S. uberis* and 30.5 for *S. aureus*. The results of the piecewise regression are presented as graphs in Figure 1 and 2.

For *S. agalactiae* the correlation between a positive PCR reaction and herd size, milking system and organic farming status was analyzed. The correlation of herd size and milking system are shown in Figure 3 for herds with conventional milking and the each of the two most common automatic milking systems. The prevalence of *S. agalactiae* increased with increasing herd size. The prevalence of *S. agalactiae* was higher than conventionally milked herds for one automatic milking system (AMS) and lower for the another AMS.

Significantly fewer organic herds were positive for *S. agalactiae* compared to conventional herds (2.6% compared to 8.2%). Only one out of 41 organic herds with AMS had a positive reaction for GBS (2.4%).

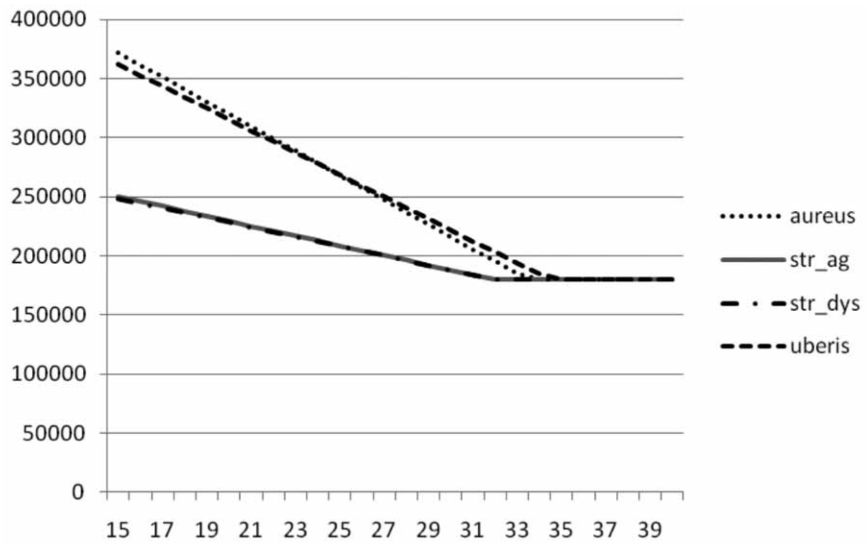


*Figure 1. Correlation between Ct value of the Pathoproof$^{TM}$ PCR assay for different mastitis pathogens and bulk tank somatic cell count in 4,298 Danish dairy herds.*

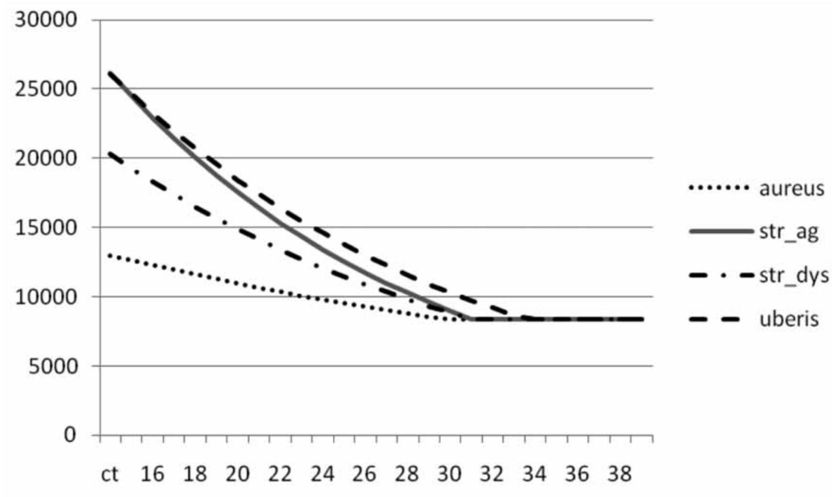


*Figure 2. Correlation between Ct value of the Pathoproof PCR assay for different mastitis pathogens and bulk tank total bacteria count in 4,298 Danish dairy herds.*

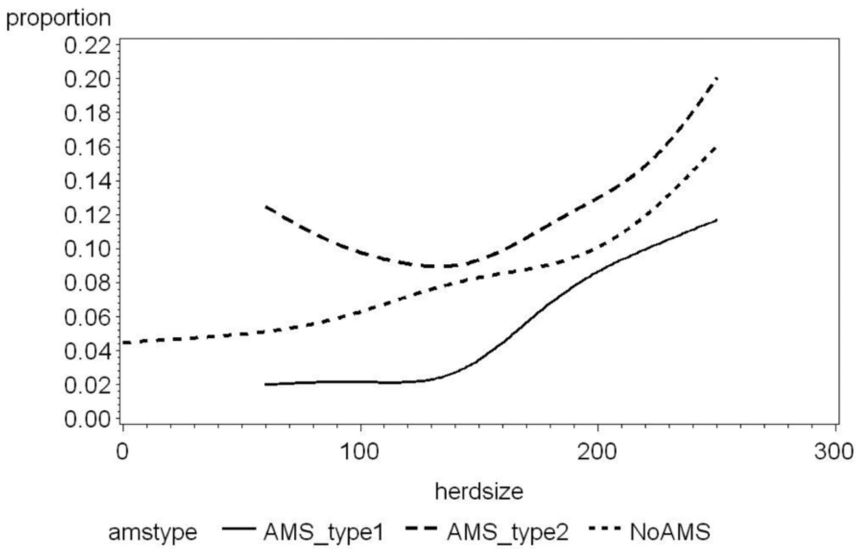


*Figure 3. Correlation between positive PCR reaction for* S. agalactiae*, herd size and milking system.*

## Discussion

The analysis showed that low Ct values for specific major mastitis pathogens are correlated with both higher BTSCC and TBC. The correlation to BTSCC was strongest for *S. aureus* and *S. uberis*. The correlation for TBC was strongest for *S. agalactiae* and *S. uberis*. The results indicate that surveillance of bulk tank milk Ct values for mastitis pathogens might give information relevant to milk quality.

The prevalence of *S. agalactiae* varied with both herd size and milking system. The effect of herd size is not surprising given the infectious nature of the bacteria. Large herds have more animals to acquire an infection whether it is from buying animals or from other sources of infection (humans, other animals). When the first cow is infected the bacteria can spread to other cows. The big differences between different milking systems are expected to be related to the milking process. In the AMS-type with the high prevalence of *S. agalactiae* the bacteria has been isolated from the cleaning aggregates and surfaces of the robot which come in contact with the teats during the milking process.

The low prevalence of *S. agalactiae* in organic herds was surprising. Danish organic dairy herds have the same size as conventional herds and the use of AMS is comparable to the conventional herds. One possible explanation could be if organic herds buy fewer adult cows in to the herds because of more restrictions on introducing conventional cows in the herd.

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# The use of strain typing as an on farm tool to highight particular points of interest in the control of *Staphylococcus aureus* mastitis

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In farm based control strategies of *Staphylococcus aureus* mastitis, focus should be placed on prevention of new infections. Various farm, herd and parlour based practices have been suggested to be implemented in a *S. aureus* mastitis control strategy. However, developing or evaluating existing control strategies of *S. aureus* mastitis can be complicated as various environmental, animal and human sources have been suggested as possible reservoirs for mastitis causing *S. aureus*. As a tool to identify particular points of interests of a farm specific *S. aureus* control strategy, the genetic relationship of strain types of *S. aureus* isolates from samples of bovine milk, cluster unit liners, teat skin and gloves of milking personnel of the case farm was investigated by both pulsed-field gel electrophoresis (PFGE) and spa typing. Spa typing enabled discrimination between isolates having the same PFGE profiles and thus adding epidemiological value to the study. The detection of a limited number of *S. aureus* strain types by both PFGE and spa typing, gave insight in the virulence and epidemiological potential of these strains and possible sources of contamination and mechanisms of transmission were identified on the case farm. The study suggests that the hygiene benefits of wearing gloves at milking can easily be overestimated and that cross-contamination can occur when foremilking is undertaken after teat preparation, leading to potential spread of *S. aureus* between cows. The results of the present study allow the producer of the case farm to make beneficial changes in the existing control programme of the prevention of *S. aureus* mastitis.

# Estimation of the diagnostic accuracy of a multiplex real-time PCR assay and bacteriological culture for four bovine intramammary pathogens

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Bacteriological culture (BC) is the traditional method for intramammary infection diagnosis but lacks sensitivity and is time-consuming. Multiplex real-time polymerase chain reaction (mr-PCR) enables testing the presence of several bacteria and reduces diagnosis time. Our objective was to estimate bacterial species-specific sensitivity (Se) and specificity (Sp) of both BC and mr-PCR tests for detecting bacteria in milk samples from clinical mastitis cases and from apparently normal quarters, using a Bayesian latent class model. Milk samples from 1,014 clinical mastitis cases and 1,495 samples from apparently normal quarters were analyzed by BC and mr-PCR. Two positive culture definitions were used: ≥1 cfu/0.01 ml and ≥10 cfu/0.01 ml of the specified bacteria. The mr-PCR was designed to simultaneously detect *Staphylococcus aureus*, *Streptrococcus uberis*, *Escherichia coli* and *Streptococcus agalactiae*. The priors used in our Bayesian model were weakly informative, with BC priors using the best available error data. Results were compared with obtained using uniform priors for mr-PCR to test robustness. Weak and uniform priors gave about the same posterior distributions except for *S. uberis* from normal quarters and *S. agalactiae*. Mr-PCR Seon milk from clinical mastitis were lower than for milk from normal quarters. Mr-PCR Se was higher than culture on milk from normal quarters. Mr-PCR Se was generally lower than culture on milk from clinical mastitis and it varied by clinical. The estimates Sp of detection for all pathogens were ≥99% whatever sample type.

# Part 8
# Treatment

# Promoting judicious antibiotic use: On-farm culture-based treatment strategies

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## Abstract

Traditionally, dairy farmers have treated all cases of clinical mastitis (CM) with antibiotics leading to incorrect or overtreatment of many cases. On-farm culture (OFC) allows rapid detection of pathogen groups allowing for a more targeted approach to treatment. In a Canada- wide clinical trial, cows with mastitis of mild to moderate severity were randomly allocated to either an OFC group or an antibiotic treated control (TC) group. In the OFC group, milk was applied to coliform count and total aerobic count Petrifilms at a 1:10 dilution with sterile water and incubated at 35 ˚C for 22-24 hours. Cases identified with Gram positive pathogens on OFC were treated with intramammary cephapirin sodium for 2 consecutive milkings. Cows in the TC group were promptly treated with intramammary cephapirin sodium. Milk samples were taken pre-treatment and 14-21 and 28-35 days post-treatment and submitted for standard bacteriologic culture in all cases. Producers recorded the date of mastitis occurrence and the date that milk returned to normal appearance. No difference in clinical cure ($P$=0.164) was observed between groups. Bacteriologic cure differed between groups which was attributable to false negative diagnosis ($P$=0.018). Primary antibiotic use was reduced by 40.2% in the culture group with no difference in risk of receiving secondary antibiotic treatment compared to the control group ($P$=0.588). The 3M Petrifilm culture system shows promise in developing selective treatment strategies for clinical mastitis. Results from this study will be used to educate dairy farmers on the importance of judicious antibiotic use and the benefits of culture-based targeted treatment strategies.

**Keywords:** mastitis, therapy, Petrifilm

## Introduction

Mastitis is the most common and costly infectious disease in dairy cattle world-wide and is most frequently bacterial in origin (Seegers *et al.*, 2003; Halasa *et al.*, 2007). Consequently, it is also the most frequent reason for antibiotic use in the industry in terms of treatment of clinical and subclinical mastitis and in preventative antibiotic use as cows enter into the dry period

(Leger *et al.*, 2003). Administration of intramammary antibiotics during lactation results in high concentrations of drug in the milk necessitating milk to be discarded for the duration of the treatment regime and for a withdrawal period following the last dose to allow clearance of all antibiotic residues. In fact, the majority antibiotic residues in milk have been attributed to antibiotics used in the treatment of mastitis (Erskine *et al.*, 2003). Substantial economic losses result from lost revenue due to milk discard and milk production losses in addition to additional costs for treatment, extra labour and culling. Use of antibiotics in agriculture has the potential to cause selective pressure on bacteria of human and animal health importance leading to the development of resistance.

A select number of intramammary antibiotics are available for the treatment of clinical mastitis (CM) during lactation, most of which belong to the beta-lactam class of antibiotics. Typically, dairy producers detect mastitis in one or more quarters during milking and opt to treat with one of these available preparations. Often this is done without knowing the causative organism but may also be based on historical culture results and knowledge of organisms which typically affect the herd or that particular cow. Less often, treatment decisions are based on milk culture results from the infected cow. While any one (or more) of a number of bacterial organisms may be the cause of mastitis, the spectrum of activity of each available intramammary antibiotic preparation does not include all possible organisms. Spontaneous cure of some pathogens is also frequently observed with a large proportion of clinical milk samples culturing negative on standard bacteriology (Olde Riekerink, 2008). Mild to moderate cases of coliform mastitis are reported to have high spontaneous cure rates as well calling into question the need to use antibiotics in such cases (Lago *et al.*, 2008; Erskine *et al.*, 2003; Hogan and Smith, 2003). With the exception of severe cases of mastitis or those cases which are chronic in nature, it has been proposed that antibiotic therapy of coliform mastitis may be withheld without compromising the clinical outcome or production of the cow. Treatment of gram positive infections including staphylococcal and streptococcal species, however, is necessary for increasing the probability of cure and preventing the risk of chronic subclinical mastitis and decreased production for the remainder of the lactation (Oliver *et al.*, 2004; Van Eenennaam *et al.*, 1995). Treatment of mild to moderate cases of CM may be delayed for up to 24 hours without compromising cow health or clinical outcomes in most cases. Identification of causative organisms would allow an appropriate antibiotic to be chosen and would enable selective or targeted treatment strategies to be employed. Therefore, a need for a user-friendly, rapid diagnostic culture system which could be utilized by the dairy producer has been identified (McCarron *et al.*, 2009; Leslie *et al.*, 2005; Sears and McCarthy, 2003).

The 3M Petrifilm on-farm culture system (OFCS) was developed by McCarron *et al.* (2009). In laboratory trials, the culture-system accurately identified 93.8% of CM cases caused by gram positive organisms after 24 hours of incubation. Negative predictive values of 89.7% were reported giving confidence in the diagnosis of non-treatment cases. Interpretation of culture results was repeatable between users with little to no microbiology training compared with an experience microbiology technician. To fully evaluate the effectiveness of the OFCS, application of the technology to the farm level was necessary to assess the ability of dairy producers to diagnose the causes of CM and to follow up on the clinical and economical consequences of using the system and selective antibiotic therapy.

## Materials and methods

A nationwide clinical trial was conducted using herds selected from the Canadian Bovine Mastitis Research Network (CBMRN) National Cohort of Dairy Herds (NCDF) based on willingness to participate and follow the outlined protocol. To increase the number of observations in the dataset, additional herds were invited to participate. Producers were provided with the OFCS, Turbo-fan incubator, intramammary antibiotics and training. Culture results of all clinical and follow up samples were also provided to the producer and an incentive of $30 CDN was paid for each CM case in which the protocol was followed and all data and milk samples were collected. All mild to moderate CM cases were eligible to be included. Random allocation to either the OFCS group or a treated control (TC) group was done by selection of a sealed, non-transparent envelope containing a treatment group allocation card. In all cases, pre-treatment (M1) milk samples were collected and submitted frozen for standard bacteriology. Cases allocated to the TC group were then promptly treated with cephapirin sodium (Cefa-lak, Boehringer Ingelheim Vetmedica, Inc) at 12 hour intervals for 2-4 doses. Cases allocated to the OFCS group were cultured and treated only if a gram positive organism was diagnosed as the cause. Herds were visited on a regular basis (approximately once per month) for milk sample collection and to follow up on questions regarding culture technique and interpretation of culture results. During this follow up period it became evident that some producers were having difficulty in interpreting culture results due to variability in colony growth. Producers were then requested to store labelled Petrifilm plates in the freezer immediately following interpretation for later validation in the lab.

Producers recorded general cow information such as identification, mastitis severity, rectal temperature, quarter infected and the date of the CM event. All OFCS results and treatments if applicable were recorded as well, along with the dates the milk returned to normal appearance and the date the milk returned to the bulk tank for sale. Follow-up milk samples were collected 14-21 (M2) days and 28-35 (M3) days following the CM event and submitted for standard bacteriology.

## Results

While the OFCS performed well in the laboratory setting in all previously published studies, the accuracy of the OFCS when used by dairy producers and herd personnel had not been previously established. Early on in the clinical trial, it became evident that there was a learning curve both with the use of the culture system technique and with the interpretation of culture results. Dairy producers indicated that colony identification was not always straight forward such as when colonies were too numerous to count or when clots in the milk turned color and were subsequently mistaken for colonies. During the summer months, it was also clear that the humidity of the air, especially in the milk house or parlour was enough to cause condensation of the Petrifilms such that they changed color. Recommendations then became to store OFCSs in the house or in offices where the humidity could be more easily controlled.

The sensitivity and specificity of the OFC system varied widely between farms according to the frequency of use. Overall, sensitivity and specificity were 63.8% and 48.4% respectively (n=334). Within herds using the culture system at least once per month for the duration of the clinical trial, sensitivity of the culture system reached 81.8% while specificity remained low at 45.6%. The negative predictive value (NPV) improved from 57.7% to 82.1% however the prevalence of gram positive cases dropped from 50% to 40% between the two groups analysed. The increase in NPV was influenced by the prevalence of gram positive infections on those herds. Still, NPV was improved on these herds (equivalent of 71.4% with 50% prevalence of gram positive infections) thus making those users more confident of a negative (non-treatment) test result. Experience in accurate quantification of colony numbers and culturing technique was identified as the primary limiting factor in the success of the system on farm based on validation of test results by technician and by the automated reader. Improved training regarding aseptic technique, incubator maintenance, attention to protocol and colony identification could improve the test characteristics of the culture system in the future.

### *Clinical outcomes*

In the present study, only cases diagnosed as gram positive infections were selected for treatment while all coliform and no-growth cases were left to self cure. Approximately 60% of cases were diagnosed by dairy producers as gram positive cases requiring treatment. This resulted in an initial reduction in antibiotic use in the OFC group of 40%. No significant differences in the risk of requiring additional antibiotic were detected between OFCS and TC groups. As the antibiotic preparation used in the study does not include a spectrum of activity which covers coliform infection, it was not expected that non-treatment would result in differences in cure probability. Based on the level of inaccuracy of the OFCS in the hands of the producers, however, cure probability became a greater concern. Initial analyses of the data looked at the effect of treatment group (culture versus control) on the odds of clinical and bacteriologic cure and on the number of days from mastitis onset until the producer indicated the milk returned to normal appearance. No significant differences in the odds of cases clinically or bacteriologically curing were detected between OFCS and TC groups, however, when treatment group was further divided into correct, false positive and false negative diagnosis, gram positive cases which were falsely diagnosed as non-treatment cases were more than 7 times more likely to fail to cure bacteriologically. Treatment group (OFCS versus TC) did significantly alter the number of days for cases to clinically cure despite the median number of days to cure being equal between groups. This was due to some cows in the OFCS group taking longer to cure. When treatment group was further divided according to accuracy of the diagnosis, this difference was entirely attributable to cases which were falsely diagnosed as non-treatment cases. The majority of cases were first time mastitis occurrences in a quarter since enrolment of the herd in the clinical trial. Five percent of cases were $2^{nd}$ occurrences but relatively few of those cases were recurrences with the same organism.

Cows were followed for a minimum of 4 months following enrolment into the clinical trial to monitor for CM recurrence. No differences in either the probability of recurrence of mastitis due to the causative organism or a different pathogen or in the days to that recurrence were detectable between treatment groups. Similarly, no significant differences in the risk of cows being culled were observed between OFCS and TC groups.

***Economic impact***

Use of the OFCS was expected to reduce the amount of milk discard in cases that were left un-treated as milk would be eligible to return to market as opposed to waiting out the mandatory withdrawal time when antibiotics were used. Allocation to the OFCS group significantly increased the odds of milk returning to market within the first 4 days due to a large number of non-treated cases spontaneously curing within a couple of days of CM onset. Mandatory milk withdrawal times of 96 hours for cephapirin sodium prevented cases in the TC group from returning to market any sooner and also caused cases diagnosed by the OFCS as treatment cases to be delayed in returning to market for an additional day pending culture results. Similarly, cases which were falsely diagnosed as treatment cases were delayed in returning to market by the mandatory milk withdrawal period following a 24 hour period pending OFCS results.

A number of factors influenced the cost of CM in the present study. In addition to the number of days that milk had to be discarded which was influenced by the causative organism and the accuracy of the diagnosis, the number of days in milk and milk production of the cow at CM onset were driving factors in the average cost. The pathogen distribution in herds also substantially impacted the average costs of CM selectively treated according to OFC results. Under default circumstances for pathogen distribution and accuracy of diagnosis previously reported across all herds, cases selectively treated according to OFCS results were estimated to have higher average costs of $44 per case. Accurate diagnosis of both treatment and non-treatment cases in the culture group resulted in an average savings of $16 per case. Cases caused by *Staphylococcus aureus* and other gram positive pathogens had higher average costs than control group cases due to increased duration of milk discard and associated labour costs regardless of the accuracy of the diagnosis with costs being highest in cases that were falsely diagnosed as non-treatment cases. Cases caused by coliforms and those with insignificant growth were estimated to have substantially reduced costs compared to control group cases which was most pronounced in those correctly diagnosed as non-treatment cases. The greatest potential for economic return in using an OFC system for selective treatment strategies is in herds with accurate diagnosis of treatment and non-treatment cases and in herds with a higher incidence of non-treatment cases.

## Discussion

The concept of on-farm culture and selective treatment was successfully introduced to dairy herds across Canada and was very well received by a large number of producers. While the culture system did not perform as well as expected, cure rates and long term health risks were not adversely affected in accurately diagnosed cases. Decreased probability of bacteriologic cure and a delay in clinical cure in non-treated gram positive cases was, however, evident in inaccurately diagnosed cases mostly attributable to classification of gram positive cases to the non-treatment group. As awareness of the importance of judicious antibiotic use continues to be emphasized, development of more accurate, rapid, and user friendly diagnostic tests will be required. While 3M Petrifilms have potential to be successfully utilized on the farm following adequate training on culture technique and interpretation of culture results, the 24 hour delay pending culture results will continue to result in additional milk discard in cases selected for treatment. Even with adequate training and improvement in the sensitivity of the OFCS in the hands of dairy producers, specificity is expected to remain relatively low resulting in continued over-treatment of some cases. For optimal diagnosis, treatment success and economic benefit, the ideal OFCS would provide results with high sensitivity and specificity within a few hours of CM onset so that treatment could be targeted quickly and appropriately.

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# Efficacy of the selective treatment of clinical mastitis based on on-farm culture results

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## Abstract

The objective of this clinical trial was to evaluate the efficacy of using on-farm culture to guide strategic treatment decisions in cows with clinical mastitis. A total of 422 cows affected with mild or moderate clinical mastitis in 449 quarters were randomly assigned to either a) a positive-control or b) an on-farm culture-based treatment group. Quarter cases assigned to the positive-control group received immediate on-label intramammary treatment with cephapirin sodium. Quarters assigned to the culture-based treatment group were treated with cephapirin sodium if incubation of milk using an on-far culture system for 18-24 hours showed Gram-positive growth or a mixed infection. The proportion of quarters that received intramammary antibiotic therapy because of study assignment or secondary (or extended) therapy was 100% and 51% for positive-control and culture-based groups, respectively. There was a tendency for a reduction in days in which milk was discarded from cows assigned to culture-based group *vs.* positive-control group (5.9 vs. 5.2 days). There was no difference between cases assigned to the positive-control vs. culture-based group for days to a clinical cure (2.7 vs. 3.2 days), bacteriological cure risk (71 vs. 60%) and risk for a new intramammary infection within 21 days of enrollment (50 vs. 50%). There was no difference in the risk and days for recurrence of a clinical mastitis event in the same quarter (35% and 78 days vs. 43% and 82 days), linear somatic cell count (4.2 vs. 4.4), daily milk production (30.0 vs. 30.7 kg), and risk and days for culling or death events (28% and 160 days vs. 32% and 137 days) for the rest of the lactation. In summary, the use of on-farm culture to guide the strategic treatment of clinical mastitis reduced intramammary antibiotic use by half and tended to reduce withholding time by one day, without affecting short or long-term health or production outcomes.

**Keywords:** clinical mastitis, selective treatment, on-farm culture, bi-plate

## Introduction

Mastitis has been recognized as the most frequent reason for antibiotic use in dairy cattle. In a study in 20 Wisconsin conventional dairies, 80% of all antimicrobial drugs used were used for treatment or prevention of mastitis (Pol and Ruegg, 2007). Fifty percent of all antimicrobial drugs used were solely for treatment of clinical mastitis. Concerns with the use of antibiotics in food animals include the risk for antibiotic residues and the potential for development of antibiotic resistance (Makovec and Ruegg, 2003; Pitkala *et al.*, 2004; Pol and Ruegg, 2007). Another concern is that the value of discarded milk following antibiotic treatment can exceed $100 per cow in the herd per year (Bartlett *et al.*, 1991).

It has been reported that 10 to 40% of cultures from clinical mastitis cases yield no bacterial growth, and so do not require antimicrobial therapy (Roberson, 2003). Another 40% of positive cultures (Gram-negatives, yeast) are not susceptible to most approved intramammary antimicrobial drugs. Also, a large proportion of Gram-negative infections are quickly cleared by the cow's own immune system, and so do not require antimicrobial therapy (Pyörälä *et al.*, 1994; Erskine *et al.*, 1992). Conversely, intramammary antibiotic therapy is routinely recommended for infections caused by Gram-positive organisms such as *Staphylococcus aureus*, *Streptococcus agalactiae*, and environmental streptococci species. Consequently, clinical mastitis treatment decisions should be based on culture results. However, laboratory culture has not been routinely utilized by many dairies because of the time delay between submission of milk samples and reporting of results. Adoption of rapid on-farm milk culture systems would allow producers to make strategic treatment decisions for clinical mastitis cases, based on knowing the type of pathogen involved. The objective of this study was to investigate the efficacy of using an on-farm milk culture system to guide strategic treatment decisions in cows with mild and moderate clinical mastitis, in regards to short and long-term health and performance outcomes.

## Methods

### *Study design*

A randomized controlled clinical trial was conducted between June 2005 and April 2007 in eight dairy herds. In each herd, cows were enrolled into the study during a period not longer than six months. These herds, two in Minnesota, five in Wisconsin and one in Ontario, were a convenience sample of commercial dairy farms from the North American Great Lakes Region. Herd size ranged from 144 to 1,795 cows, averaging 920 cows. On-farm culturing was done by a trained herdsperson.

### *Enrollment process*

All lactating cows in the herd were eligible for enrollment at the time of clinical mastitis occurrence when only the milk was abnormal (mild or grade one clinical mastitis) or when the milk and the quarter were affected (moderate or grade two clinical mastitis). Cows exhibiting severe (grade three) clinical mastitis or any cow with fewer than three functional quarters were ineligible for enrollment. If the cow met the designated inclusion criteria for enrollment, herd personnel aseptically collected a single milk sample from the affected quarter. For a first clinical mastitis episode (cow not previously enrolled into the study) eligible cows for enrollment were randomly assigned following a simple randomization schedule to either the positive-control group or culture-based treatment group. If more than one quarter was affected, all affected quarters were assigned to the same treatment group. For a second (or greater) clinical mastitis episode in the same cow (i.e. cow had been previously enrolled) in the same or in a different quarter, the quarter was assigned to the same treatment group as was previously assigned.

### *Positive-control group*

Immediately after enrollment affected quarter(s) were infused with one syringe (200 mg) of cephapirin sodium (Cefa-Lak®, Fort Dodge Animal Health, Fort Dodge, IA). The treatment was repeated once, 12 hours after the first treatment according to label directions. A milk-withdrawal period of 96 hours and a slaughter withdrawal period of 4 days were followed after the last treatment.

### *Culture-based treatment group*

The aseptically collected milk sample(s) from the affected quarter(s) was first cultured on-farm by trained herd personnel using the Minnesota Easy Culture System (University of Minnesota, St. Paul, MN). This on-farm milk culture system consists of a bi-plate which is a petri dish with two different types of agar, MacConkey agar on one half that selectively grows Gram-negative bacteria, while Factor media on the other half of the plate that selectively grows Gram-positive bacteria. A sterile cotton swab was dipped into the milk sample and then plated onto the Factor media half of the bi-plate, redipped into the milk, and then applied to the MacConkey media half of the bi-plate. The plate was placed in an on-farm incubator and incubated at approximately 37 °C for 18-24 hours. After inoculation of the swabbed media, the quarter milk sample was frozen on-farm at -20 °C. The next day the plate was examined for bacterial growth and interpreted by herd personnel according to guidelines provided by the Minnesota Easy Culture System II user's manual (University of Minnesota, Saint Paul, MN). If bacteria did not grow, the plate was returned to the incubator and re-read approximately 18-24 hours later. Final results for each sample plate were recorded as: (a) Gram-positive, when bacteria grew only in the Factor agar media of the bi-plate; (b) Gram-negative, when bacteria grew only in the MacConkey agar media of the bi-plate; (c) no growth, when bacteria did not grow on either media; or (d) mixed infection when bacteria grew on both media. The decision regarding initiation of intramammary antibiotic therapy the day after enrollment was based on the on-farm culture results. Quarters from which Gram-positive bacteria were isolated or had a mixed infection received the same intramammary antibiotic treatment following the same procedures as cases assigned to positive-control. If the on-farm culture result was Gram-negative or no growth, the quarter did not receive intramammary therapy.

### *Statistical analysis*

The treatment effect on the quarter risk for a bacteriological cure and for a new intramammary infection was analyzed by generalized linear mixed models using the GLIMMIX PROC of SAS version 9.1 (SAS Institute, Cary, NC). Binary responses with a 'time to event' component such as days to clinical cure, days out of the tank, quarter risk and days to a clinical mastitis recurrence or risk and days to removal from herd (culling/death) were modeled using the Cox's proportional hazards regression method (PROC TPHREG). Continuous outcome variables such as milk yield and linear somatic cell count were modeled as a function of explanatory variables the MIXED procedure of SAS by specifying a correlation structure among the repeated measurements of the same cow. The clustering of cows within herds, and of quarters within cows (when the outcome of interest was at the quarter level) was considered in all models.

## Results

### *Descriptive data*

A total of 422 cows affected with clinical mastitis in 449 quarters were enrolled into the study. Of these, 214 cows with 229 affected quarters were assigned to the positive-control group, and 208 cows with 220 affected quarters were assigned to the culture-based treatment group. The severity distribution of all clinical cases enrolled in the study was 68% for mild cases and 32% for moderate cases. Bacteria were isolated from 66% of quarters with clinical mastitis at enrollment. Coliform bacteria were the most commonly isolated pathogen (24% of clinical mastitis cases), followed by non-agalactiae streptococci (14%), coagulase-negative staphylococci (9%), *Staphylococcus aureus* (7%), and other infections (7%).

### *Risk to receive intramammary antibiotics because of primary or secondary therapy*

While 100% of cases assigned to the positive control group received antibiotic therapy, only 51% of cases assigned to culture-based treatment group received antibiotic therapy (44% because of study assignment and 7% because of secondary treatment of cases not treated initially with antibiotics). Model relative risk estimate of treatment effect using positive-control as reference ($RR_{PC}$), 95% confidence interval (95% CI) and P-value (P) were: [$RR_{PC}$ (95% CI) = 0.51 (0.44, 0.58); $P \leq 0.001$].

### *Days to clinical cure*

Herd personnel recorded the date and time when milk had returned to being visibly normal. There was no difference between treatment groups in days to return to visibly normal milk. Model hazard ratio estimate and significance of treatment effect using positive-control as reference were: [$HR_{PC}$ (95% CI) = 0.8 (0.6, 1.2); $P$=0.26] (Table 1).

*Table 1. Days to clinical cure and days out of the tank (adapted from Lago* et al.*, 2011a).*

| **Etiology**[1] | **Days to clinical cure (mean ± SD (n)**[2]**)** | | **Days out of the tank (mean ± SD (n)**[2]**)** | |
|---|---|---|---|---|
| | **Positive-control** | **Culture-based** | **Positive-control** | **Culture-based** |
| No growth | 2.7±1.3 (61) | 3.0±1.7 (51) | 5.5±2.6 (63) | 3.9±3.1 (58) |
| Gram-negatives | 3.1±2.0 (57) | 3.4±1.5 (39) | 6.2±2.5 (58) | 4.9±2.7 (41) |
| Gram-positives | 2.6±1.1 (54) | 3.5±1.6 (62) | 6.1±3.6 (62) | 6.5±3.7 (72) |
| All cases | 2.7±1.5 (196) | 3.2±1.7 (163) | 5.9±2.9 (183) | 5.2±3.5 (184) |

[1] Etiological classification was based on laboratory culture results.
[2] n is the population from which means and standard deviations were calculated.

### *Days out of the tank*

Herd staff recorded the date and time when milk was first marketed after enrollment. There was a tendency for fewer days of milk withheld from the market for cows assigned to the culture-based treatment group versus for cows assigned to positive-control group [$HR_{PC}$ (95% CI) = 1.2 (0.9, 1.4); $P$=0.08] (Table 1).

### *Bacteriological cure, new intramammary infection and treatment failure risk*

A quarter was considered infected when one or two bacterial species were isolated from a quarter milk sample. The isolation of two bacterial species was considered a mixed infection. A quarter sample was considered contaminated if 3 or more bacterial species were isolated. A bacteriological cure within a quarter was defined as the presence of one or two microorganisms in the enrollment milk sample, and the absence of the same specified microorganism(s) in milk samples collected at both day-14 and day-21 post-enrollment. A quarter was considered newly infected whenever a new bacterial species that was not previously present in the enrollment sample (d-0) was isolated either at day-14 or day-21 after enrollment. There was no difference in risk for a bacteriological cure and no difference in risk for new intramammary infection between the two treatment groups (Table 2). Model odd ratio estimate and significance of treatment effect using positive-control as reference were: a) [$OR_{PC}$ (95% CI) = 0.6 (0.3, 1.4); $P$=0.20] for bacteriological cure; and, b) [$OR_{PC}$ (95% CI) = 1.0 (0.6, 1.6); $P$=0.94] for new intramammary infection.

*Table 2. Quarter level bacteriological cure and new intramammary infection risk (adapted from Lago* et al.*, 2011a).*

| **Etiology**[1] | **Bacteriological cure risk (%**[2] **(n)**[3]**)** | | **New intramammary infection risk (%**[2] **(n)**[3]**)** | |
|---|---|---|---|---|
| | **Positive-control** | **Culture-based** | **Positive-control** | **Culture-based** |
| No growth | – | – | 50 (54) | 53 (62) |
| Gram-negatives | 86 (42) | 70 (37) | 52 (44) | 49 (41) |
| *Escherichia coli* | 83 (30) | 78 (22) | 43 (30) | 41 (22) |
| *Klebsiella* spp. | 86 (7) | 62 (13) | 43 (7) | 55 (11) |
| Gram-positives | 59 (46) | 52 (48) | 54 (54) | 55 (56) |
| Non-ag streptococci | 57 (14) | 61 (18) | 53 (19) | 63 (24) |
| *Staphylococcus* spp. | 53 (15) | 54 (13) | 55 (11) | 40 (10) |
| *Staph. aureus* | 43 (7) | 18 (11) | 14 (7) | 22 (9) |
| *Bacillus* spp. | 71 (7) | 75 (4) | 50 (6) | 33 (3) |
| All cases | 71 (97) | 60 (85) | 50 (163) | 50 (160) |

[1] Etiological classification was based on laboratory culture results.
[2] The fraction numerator was the number of quarters experiencing the outcome of interest and the denominator was the number of quarters in each category.
[3] n was the denominator of the fraction from which percentages were calculated.

### Recurrence of clinical mastitis

A recurrence was defined as detection of a new clinical mastitis case in the same quarter at least 14 days after enrollment of the previous case. Cows were followed until a new clinical mastitis event happened, the end of the current lactation or 12 months after enrollment (whichever came first). There was no difference in the risk and days to recurrence of a clinical mastitis event between the two treatment groups [$HR_{PC}$ (95% CI) = 1.2 (0.9, 1.6); $P$=0.20] (Table 3). Clinical mastitis recurrence data was not available for one herd.

### Removal from the herd

Cows were followed until culling/death, the end of the current lactation or up to 12 months after enrollment (whichever came first). There was no difference in risk for removal from the herd between the two treatment groups [$HR_{PC}$ (95% CI) = 1.1 (0.7, 1.6); $P$=0.560] (Table 3).

*Table 3. Clinical mastitis recurrence and removals from herd (adapted from Lago* et al.*, 2011b).*

| Etiology | Recurrence of clinical mastitis (%[1] (n)[2]) | | Removed from herd (culling/death) (%[1] (n)[2]) | |
|---|---|---|---|---|
| | **Positive-control** | **Culture-based** | **Positive-control** | **Culture-based** |
| No growth | 34 (68) | 48 (73) | 22 (58) | 26 (65) |
| Gram-negatives | 39 (56) | 52 (42) | 30 (50) | 25 (36) |
| Gram-positives | 29 (68) | 34 (79) | 37 (49) | 35 (62) |
| All cases | 35 (220) | 43 (210) | 28 (195) | 32 (195) |

[1] The fraction numerator was the number of quarters with clinical mastitis recurrence or the number of death cows and the denominator was the number of quarters or cows in each category.
[2] n is the denominator of the fraction from which percentage was calculated.

### *Somatic cell count and milk production*

Test records of performance were collected until the end of the current lactation or 12 months after enrollment (whichever came first). There was no difference in linear somatic cell count after enrollment between the treatment groups [$Diff_{PC}$ (95% CI) = 0.1 (-0.2, 0.5); $P$=0.44] (Table 4). Similarly, there was no significant difference in milk production after enrollment between the two treatment groups. Model difference estimate and significance of treatment effect using positive-control as reference were: [$Diff_{PC}$ (95% CI) = 0.7 (-0.9, 2.3); $P$=0.41] (Table 4).

In summary, the use of an on-farm culture system to guide the strategic treatment of clinical mastitis reduced intramammary antibiotic use by half and tended to reduce withholding

*Table 4. Somatic cell count and daily milk yield (adapted from Lago* et al.*, 2011b).*

| Etiology | Linear somatic cell count (mean ± SD (n)[1]) | | Daily milk yield (mean ± SD (n)[1]) | |
|---|---|---|---|---|
| | **Positive-control** | **Culture-based** | **Positive-control** | **Culture-based** |
| No growth | 3.9±0.2 (57) | 4.0±0.2 (60) | 32.2±1.0 (57) | 31.4±1.0 (60) |
| Gram-negatives | 4.3±0.3 (48) | 4.6±0.3 (44) | 30.0±1.1 (48) | 31.5±1.3 (44) |
| Gram-positives | 4.7±0.3 (52) | 4.9±0.2 (63) | 29.1±1.1 (52) | 28.6±1.1 (63) |
| All cases | 4.2±0.1 (178) | 4.4±0.1 (178) | 30.0±0.6 (178) | 30.7±0.6 (178) |

[1] n is the population from which means and standard deviations were calculated.

time by one day, without affecting future health or performance of the cow, including days to clinical cure, bacteriological cure risk, new infection risk within 21 days after the initial clinical mastitis event, risk for recurrence of clinical mastitis in the same quarter, somatic cell count, milk production, and cow survival for the rest of the lactation after the initial clinical mastitis event. General principles for the judicious use of antimicrobials emphasize the use of culture to aid in the selection of antimicrobials, confining the use of antimicrobials to appropriate clinical indications and limiting therapeutic antimicrobial treatment to the fewest animals indicated (FDA-Center for Veterinary Medicine, 2008). The selective treatment of clinical mastitis based in on-farm culture results implements those principles by reducing antibiotic use by half without a reduction in treatment efficacy and without affecting the future udder health and lactation performance of the cow.

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# Field study on acute mastitis with SIRS and different treatment regimes

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## Abstract

This field study focuses on additional therapy with non-steroidal anti-inflammatory drugs (NSAID) and infusions of parenteral NaCl solutions to parenteral antibiotic treatment in coliform mastitis. Fifty cows with typical inclusion criteria (clinical score) were involved in this study. All cows were treated with marbofloxacin (2 mg/kg once a day for three days). The cows were divided in three main groups (no infusion, 0.9% NaCl, 7.2% NaCl) and three sub groups (without and with tolfenamin acid (2 mg/kg)). Clinical examinations were performed at 0, 12, 24, 48, 72 hours and 3 weeks after mastitis occurrence. Milk samples at these times were used for bacterial diagnosis. Results of clinical examination were most influenced by the time. Significant differences in treatment could be seen in appetite, rectal temperature, udder inspection and udder palpation. The use of NSAID resulted in a temporary amelioration of the rectal temperature for 12 hours, and in improvement of the positive effects of infusions on appetite. The recovery of the udder was most influenced by the time and by infusions.

**Keywords:** *E. coli*, clinical recovery

## Introduction

Acute mastitis often is associated with severe clinical signs and with losses in milk production (Golodetz, 1985; Lohuis *et al.*, 1990; Pyörälä *et al.*, 1994). The so called bovine coliforme mastitis is mostly caused by *Escherichia coli* and occurs in the early lactation (Regenhard *et al.*, 2010). Only 30-50% of these cows return to full milk production (Shpigel *et al.*, 1997) even with antimicrobial or other therapy (Rantala *et al.,* 2002). Equivocal results of antimicrobial treatment of *E. coli* mastitis have been published in the last years (Pyörälä *et al.*, 1994; Rantala *et al.*, 2002; Poutrel *et al.*, 2008).

The aim of this study was to evaluate the efficacy of an additional therapy of infusions and/or administration of non steroidal anti-inflammatory drug (NSAID) to the antimicrobial therapy on clinical status and signs in the field.

## Material and methods

Fifty cows with typical inclusion criteria (rectal temperature: >39.3 °C, depression of general condition or appetite, changes in milk appearance (clots and flakes)) were involved in this study. All cows were treated with marbofloxacin (2 mg/kg once a day for three days). The allocation to the treatment groups can be seen in Table 1. Tolfenamin acid was used as NSAID and given 2 mg/kg body weight.

*Table 1. Treatment design.*

| | | **Infusion** | | |
|---|---|---|---|---|
| | | **No infusion** | **0.9% NaCl** | **7.2% NaCl** |
| NSAID | No | n=8 | n=9 | n=8 |
| | Yes | n=9 | n=8 | n=8 |
| antibiotic | | Marbofloxacin 2 mg/kg BW daily for three days | | |

Clinical examinations, as shown in Table 2, were performed at 0, 12, 24, 48, 72 hours and 3 weeks after mastitis occurrence. Milk samples at these times were used for california mastitis test and for bacterial diagnosis.

Depending on the response variable a gaussian model, a poisson model, a logistic regression or a cumulative logit model with ordinal response variable was used for the analysis. The unit for analysis was the cow. The repeated measurements over time within each cow were taken in consideration using an additional random intercept for each cow.

## Results

The results of the bacteriological examinations are shown in Table 3. The mastitis cases were mainly caused by *Escherichia coli.* In 5 cases all bacterial examinations were negative. At the end of the observation period all milk samples were negative, except one sample with *Streptococcus sp* and one with *Staphyoloccus aureus.*

Most parameters of the clinical examination were only influenced by the time, independent of the treatment. This occurred in general behaviour, temperature of ears, shoulders, gluteal region and claws, eye mucosa, heart rate, respiratory frequency, rumen motility and milk quality.

*Table 2. Clinical examination and encoding.*

| Parameter | | Encoding | | | |
|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** |
| General behaviour | | Normal | Slightly red. | Moderate red. | Comatose |
| Appetite | | Normal | Reduced | No appetite | |
| Temp. ear | | Warm | Hot-sweaty | Cold | |
| Temp. shoulder | | Warm | Hot-sweaty | Cold | |
| Temp. gluteal | | Warm | Hot-sweaty | Cold | |
| Temp. claws | | Warm | Hot | Cold | |
| Rectal temp. | Value | | | | |
| Eye mucosa | | Pale pink | Reddened | | |
| Heart rate | Value | | | | |
| Resp. frequency | Value | | | | |
| Rumen motility | Value | | | | |
| Milk quality | | Normal | Flakes | Serum/bloody/purulent | |
| Udder inspection | | Normal | Enlarged | | |
| Udder palpation | | Normal | Oedema | Hard | |

*Table 3. Bacteriological findings.*

| **Bacteria** | ***Escherichia coli*** | ***Klebsiella* sp.** | ***Streptococcus* sp.** | ***Staphyoloccus aureus*** | ***Arcanobacterium pyog*** | **Negative** |
|---|---|---|---|---|---|---|
| n cows | 28 | 5 | 6 | 4 | 2 | 5 |

The appetite is significantly influenced by the time, the infusions, the treatment with NSAID and interactions between infusion and NSAID. Resulting the fitted model the probability of no appetite is very small in all treatment groups after 12 hours (Figure 1). Combining infusion and NSAID results in a higher probability of normal appetite than infusions alone (Figure 2).

Time and interaction between time and NSAID have significant influence on rectal temperature. Comparing to the first examination the expected rectal temperature diminishes by 1.48 °C after 12 hours, 1.63 °C after 24 hours and 1.90 °C after 3 weeks. After administration of NSAID the expected rectal temperature falls to normal levels within 12 hours. This expected temperature reducing effect lasts only 12 hours; afterwards both groups show the same developing of the temperature (Figure 3).

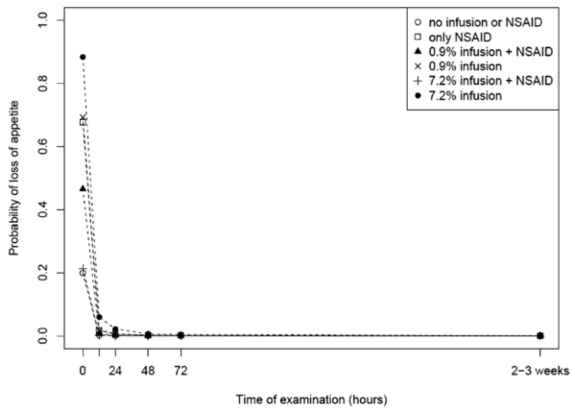


*Figure 1. Probability for loss of appetite.*

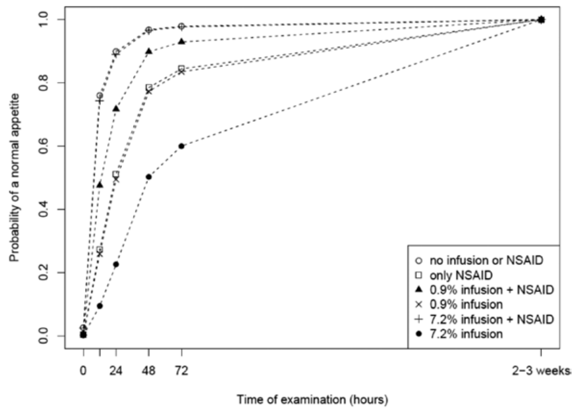


*Figure 2. Probability for normal appetite.*

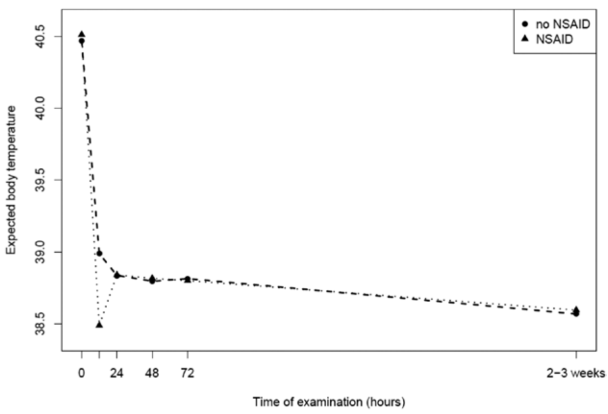


*Figure 3. Rectal temperature.*

In udder inspection the time and the interaction between time and infusion turned out to be relevant factors. No significant influence could be detected by the use of NSAID. As a result the probability for a normal udder inspection is significantly higher with the 7.2% NaCl infusion (Figure 4).

The udder palpation shows similar results as the udder inspection. The time and the interaction between time and infusion turned out to be relevant factors in the fitted model and the use of NSAID has no significant influence in udder palpation. The use of infusions causes a higher probability for a normal udder palpation (Figure 5).

In Table 4 and 5 the results of CMT and bacteriological healing of only *E. coli* caused mastitis cases are apparent. Somatic cell count showed slow recovery. After 3 weeks 75% of the cows with no infusion were still positive, in the infusion groups the values were 63.6% and 44.4%,

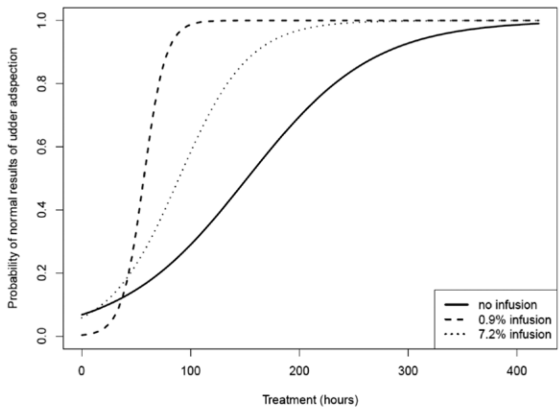


*Figure 4. Probability for a normal udder inspection.*

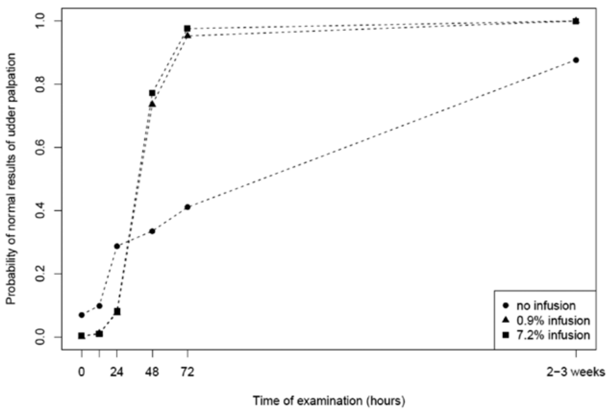


*Figure 5. Probability for a normal udder palpation.*

respectively (Table 4). 3 weeks after mastitis occurrence all cows with mastitis caused by *E. coli* were negative in BE, showing a delay in recovery with infusions and with NSAID (Table 5).

## Discussion and conclusion

Coliform mastitis has an important impact on the health of the cow. The major pathogen was *E. coli* as described in former literature. Following the recommendation of Grandemange and Davot (2002) parenteral antimicrobial therapy were administered to all cows. In this study three infusion treatment groups were allocated with no infusion, isotonic and hypertonic solutions as described by Roussel (1990). Furthermore the efficacy of NSAID was examined within these three infusion groups.

*Table 4. Number of CMT negative cows (CMT ≤1) with mastitis caused by* Escherichia coli.

| | No infusion | | 0.9% NaCl | | 7.2% NaCl | | No NSAID | | NSAID | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n=8 | % | n=11 | % | n=9 | % | n=14 | % | n=14 | % |
| 0 hrs | | | | | | | | | | |
| 12 hrs | | | | | | | | | | |
| 24 hrs | | | | | | | | | | |
| 48 hrs | | | | | | | | | | |
| 72 hrs | | | | | | | | | | |
| 3 we | 2 | 25 | 4 | 36.4 | 5 | 55.6 | 7 | 50 | 5 | 35.7 |
| CMT pos. at 3 we | 6 | 75 | 7 | 63.6 | 4 | 44.4 | 7 | 50 | 9 | 64.3 |

*Table 5. Number of BE negative cows with mastitis caused by* Escherichia coli.

| | No infusion | | 0.9% NaCl | | 7.2% NaCl | | No NSAID | | NSAID | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n=8 | % | n=11 | % | n=9 | % | n=14 | % | n=14 | % |
| 0 hrs | | | | | | | | | | |
| 12 hrs | 2 | 25.0 | 2 | 18.2 | | | 4 | 28.6 | | |
| 24 hrs | 3 | 37.5 | 4 | 36.4 | | | 5 | 35.7 | 2 | 14.3 |
| 48 hrs | 6 | 81.0 | 6 | 54.4 | 2 | 22.2 | 9 | 64.3 | 5 | 35.7 |
| 72 hrs | 6 | 81.0 | 9 | 81.8 | 4 | 44.4 | 11 | 78.6 | 8 | 57.1 |
| 3 we | 8 | 100 | 11 | 100 | 9 | 100 | 14 | 100 | 14 | 100 |
| BE pos. at 3 we | | | | | | | | | | |

Most clinical parameters in this study were influenced by the time. Differences caused by infusions could only be detected in appetite, udder inspection and udder palpation.

NSAID had influence in rectal temperature and in combination with infusion in appetite. The positive influence on rectal temperature lasted only 12 hours, 24 hours after mastitis occurrence the ongoing of rectal temperature were similar in both groups and significantly different to the initial examination. This is similar to the results of Dascanio *et al.* (1995), who examined the administration of saline solution, flunixin meglumine and phenylbutazon. In all three groups rectal temperature was significantly lower 24 hours after the initial examination. Contrary to the results of DeGraves and Anderson (1993), who examined the effect of ibuprofen treatment in endotoxin induced mastitis cows, tolfenamin acid had no influence on heart rate and respiratory frequency in this study. Beside this short time effect of reduced rectal temperature for 12 hours the administration of NSAID had positive influence on appetite when combined with infusions. Udder inspection and palpation were positively influenced only by infusion. The results of somatic cell count and BE agree with the results of Kutila *et al.* (2004), who showed a reduction of somatic cell count to prechallange level within 2 weeks and a reduction in bacteria in milk within 80 hours.

The positive effects of NSAID in general behaviour and clinical signs in this study is in agreement with the results of Hamann and Friton (2003). Taking into account the advances of nutritional influences on bovine health (Goff, 2006) the positive influence of the treatment with infusion and/or NSAID on appetite and subsequently on udder health can be assumed.

Besides these positive effects of NSAID on the general behaviour the results of BE in this study should be carefully interpreted because of small numbers of cow in each group and the tendency of different outcome comparative to the results in clinical recovery. All examined parameter of this study were significantly influenced by the time. Furthermore clinical udder recovery additionally was positive influenced by infusions. In appetite a combination of infusions and treatment with NSAID was positive.

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# Efficacy of two fresh cow subclinical mastitis treatment programs

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The objective of this clinical trial was to investigate the efficacy of using the California Mastitis Test (CMT) alone, or the CMT and an on-farm culture test in series, to diagnose and guide treatment decisions in cows with subclinical mastitis at the time of parturition. A total of 1,885 cows were screened using the CMT at 1-4 days after parturition. Of those, 717 cows with at least one CMT-positive quarter were randomly assigned to either (a) a negative-control; (b) a CMT-based treatment; or (c) to a culture-based treatment given a CMT-positive result. Quarters from cows assigned to negative-control did not receive antibiotic treatment. CMT-positive quarters from cows assigned to CMT-based received immediate on-label intramammary treatment with cephapirin sodium. Quarters from cows assigned to culture-based|CMT-positive were treated after 18-24 h of incubation only if had Gram-positive growth. There was an increase in the days of milk withheld for cows assigned to CMT-based (6.3 days) and to culture-based|CMT-positive (4.4 days), as compared to negative-control (1.7 days). Bacteriological cure was greater for quarters assigned to CMT-based (59%) and tended to be greater for quarters assigned to culture-based CMT-positive (50%), as compared to controls (42%). The risk for clinical mastitis during lactation was lower for quarters assigned to CMT-based (10%) and to culture-based CMT-positive (8%), as compared to controls (12%). Similarly, the LSCC was lower for cows assigned to CMT-based (2.9) than for cows assigned to control (3.3). However, LSCC was not significantly lower for culture-based|CMT-positive (3.1). There were no significant differences in milk production, pregnancy risk and risk for removal from the herd among treatments. In summary, intramammary treatment resulted in less clinical mastitis for both treatment groups, and lower SCC during lactation for cows assigned to CMT-based treatment.

# Effect of the combination of Tylan 200® & Penicillin G in the treatment of mastitis caused by *Staphylococcus aureus* and/or *Streptococcus uberis*

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In cattle, Tylan 200® is used to treat mastitis, caused by Gram positive pathogens such as *Staphylococcus aureus* and *Streptococcus uberis*. Typically Tylan 200® is used in combination with penicillin G. Although it is well known that these antibiotics activity is dose dependant, concerns have been raised that a bacteriostatic/bactericidal combination may be antagonistic i.e. the combination effect is less than each drug administered alone. The aim of the study was to determine if Tylan 200® + Penicillin G combination work in synergy or antagonise each other. The Minimum Inhibitory Concentrations (MICs) of Tylan 200® and Penicillin G were determined against a *S. aureus* and *S. uberis* strain using broth microdilution methodology in accordance with Clinical Laboratory Standards Institute (CLSI) guidelines M7-A8 and M31-A3. The Fractional Inhibitory Concentrations (FICs) of Tylan 200® and Penicillin G in combination were determined. For FIC determinations, the concentrations tested for each test article were zero, 1/8 MIC, 1/4 MIC, 1/2 MIC, MIC, 2×MIC, 4×MIC and 8×MIC using the 'checkerboard' technique. Interpreting the FIC results according to standard published criteria, the combination of Tylan 200® and Penicillin G demonstrated no effect (indifference) against the two test strains used in these experiments. It could be concluded that when Tylan 200® and Penicillin G are used in combination there is a neutral effect between the two compounds (neither synergism nor antagonism). Although no synergy was identified, this study clearly demonstrates that the use of Tylan 200® and Penicillin G in combination does not act antagonistically either.

# Use of Tylan 200® for the treatment of mastitis caused by *Staphylococcus aureus* and/or *Streptococcus uberis*

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*Staphylococcus aureus* and *Streptococcus uberis* are leading causes of cattle mastitis. In the field these pathogens are typically treated with the macrolide tylosin, in the form of Tylan 200®. The aim of the study was to determine the Minimum Inhibitory Concentration (MIC) of Tylosin against *S. aureus* and *S. uberis* using the methodology recommended by the Clinical and Laboratory Standards Institute (CLSI). A total of 50 isolates each of *S. aureus* and *S. uberis* were collected from cattle with clinical mastitis and subjected to antibiotic susceptibility testing. *S. aureus* ATCC 29213 and *Enterococcus faecalis* ATCC 29212 served as quality control isolates. Tylosin MICs against *S. aureus* ranged from 0.25-2 μg/ml while the tylosin MICs against *S. uberis* ranged from 0.125->256 μg/ml. Elanco Animal Health has recently developed tentative clinical breakpoints for tylosin against *S. aureus* and *S. uberis* of ≤2 μg/ml = susceptible and ≥4 μg/ml = resistant. Applying these breakpoints no tylosin resistance was detected in *S. aureus* while 12% of *S. uberis* were found to be resistant to tylosin. Applying the recently developed tentative tylosin clinical breakpoints against *S. aureus* and *S. uberis* of ≤2 μg/ml = susceptible and ≥4 μg/ml = resistant, no tylosin resistance was detected in *S. aureus* of cattle origin, while 12% of *S. uberis* of cattle origin were found to be resistant to tylosin. The data agrees with previously published data and confirms that despite over 40 years of tylosin use tylosin resistance in *S. aureus* of cattle origin has not emerged and in *S. uberis* of cattle origin has remained stable. This study confirms that Tylan 200® remains efficacious in the field for the treatment of mastitis caused by *S. aureus* and *S. uberis*.

# Therapeutic effects of lactation treatment of bovine subclinical *Staphylococcus aureus* mastitis with penicillin

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Treatment of subclinical *Staphylococcus aureus* mastitis is often delayed to dry-off, increasing the risk for chronic infection. The aim was to evaluate cure after lactation treatment of subclinical mastitis caused by penicillin-susceptible *S. aureus* with penicillin. Ninety cows from seven herds were given either a combination of intramammary (IMM) benzylpenicillin and intramuscular (IM) penethamate hydroiodide, sole IMM benzylpenicillin or no treatment. Treatment efficacy was evaluated based on bacteriology on day 7, 14, 28 and 56 after treatment, daily milk yield and inline measurement of either composite somatic cell count (ICSCC), measured with Delaval Online Cell Counter (OCC) or Lactate Dehydrogenase (LDH) measured with DeLaval Herd Navigator®, until 56 days after treatment. Cows receiving combined treatment had higher cure rates (73%) in comparison to IMM treatment (54%) and no treatment (6%). Treatment resulted in a significantly lower ICSCC until day 56 for combined and until day 28 for sole IMM treatment compared to untreated cows, whereas for sole IMM treatment, the ICSCC was only significantly lower until day 28. After day 31, cows receiving only IMM treatment had a significantly lower LDH compared to untreated cows. Finally, cows receiving combined treatment had a significantly higher milk yield compared to cows receiving IMM or no treatment, whereas IMM treatment alone resulted in a significantly lower milk yield compared to cows receiving no treatment. In conclusion, penicillin treatment in lactation therapy of subclinical S. aureus mastitis can have a beneficial effect on infection load, inflammatory status and milk yield.

# *In vitro* activity profile of a kanamycin and cefalexin combination against coagulase-negative staphylococci and correlation between MIC and disk zone sizes

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The feasibility of using a disk containing both kanamycin and cefalexin for *in vitro* susceptibility testing of the combination against major mastitis pathogens (*Staphylococcus aureus*, *Streptococcus uberis*, *Escherichia coli*) has been previously established. However, it is unkown how well the disk result correlates with broth MIC when testing Coagulase-negative staphylococci (CNS). This study evaluated the overall activity profile of the combination by broth microdilution and disk diffusion against 148 recent isolates of CNS (from bovine mastitis field cases). The overall correlation of broth MIC to disk zone size was determined against these isolates by testing by broth microdilution and disk diffusion in parallel per CLSI guidelines. In addition, 8 isolates known to be resistant to kanamycin and/or cefalexin were included to challenge the performance of the disk test. The proposed interpretive criteria previously described by Pillar *et al.* (<8/0.8 mg/l, >20 mm = susceptible; 16/1.6 mg/l, 18-19 mm = intermediate; >32/3.2 mg/l, <17 mm = resistant) were subjected to error rate bounding per CLSI to determine whether these criteria are suitable for use when testing CNS. CNS isolates show a high degree of susceptibility to the kanamycin/cefalexin combination, with minimal resistance to either agent alone. It was concluded that the combined disk concentration of 30µg kanamycin and 15µg cefalexin currently used for testing the susceptibility of bovine mastitis isolates of *S. aureus*, *S. uberis*, and *E. coli*, is also reliable for use in the testing of CNS, as disk results correlated with broth MICs. Furthermore, the interpretive criteria published for interpreting broth and disk results for this combination also can be applied when testing CNS, as there were minimal error rates detected when using these criteria.

# Part 9
# Treatment evaluation

# Monitoring treatment outcomes: understanding and managing expectations

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## Abstract

Original aspects: There are a number of ways to assess the outcome of mastitis therapy, from the simple use of the California Milk Test, through assessment of somatic cell counts (SCC), to bacterial culture. Each of these methods has inherent advantages and disadvantages. However, only analysis of SCC responses, combined with lack of recurrence of clinical disease, offer the ability to perform such assessments in a large scale, cost effective and ongoing way. Clinical mastitis and SCC data have been collated from over 600 UK farms. These data have been analysed to establish the range of outcomes that might be expected for treatment of clinical and sub-clinical mastitis in different farm situations and suggest that rates of 'successful' treatment of clinical mastitis vary from less than 10% to greater than 70% on different units. This analysis will provide useful information to farmers and advisors when trying to establish and communicate herd performance. This approach is being incorporated into management software widely available in the UK (TotalVet) and internationally (UNIFORM & Dairy Data WareHouse). Communication: Whilst the solution to mastitis control on an individual unit is unlikely to reside in treatment alone, a key aspect of mastitis management is being able to communicate and manage farmer expectations of treatment. As part of the DairyCo Mastitis Control Initiative, software in addition to that outlined above, and based on published research evidence, has been developed to help farmers and their advisers understand the likely outcome of treating sub-clinically affected cows. Analysis of clinical mastitis outcomes on a large number of farms will also help inform farmers and consultants of realistic expectations when treating clinical mastitis.

**Keywords:** clinical mastitis, dry period, cure

## Introduction

Mastitis remains a significant financial drain on the dairy industry and is recognised as the most costly of all the production disease affecting dairy cows (Kossaibati and Esslemont, 1997). Whilst sub-optimal production is undoubtedly the single largest cause of financial loss associated with mastitis, treatment costs can also be significant and on many units antibiotics for the treatment of mastitis can constitute a significant part of the overall veterinary costs.

As well as the financial costs, mastitis is a major reason for the use of antibiotics on farm, both for treatment in lactation and the dry period and prophylaxis in the dry period. In 2009, in the UK, approximately 3 tonnes of intramammary antibiotic (active ingredients) was used in the treatment and control of bovine mastitis (VMD, 2010). This represented approximately 30% of all antibiotic use that could be directly attributed to cattle, suggesting that mastitis is probably the single most significant reason for antibiotic use in the dairy sector. Moreover these figures do not include systemic antibiotic use in the control of mastitis which will undoubtedly increase the mass and proportion of active ingredient directed at mastitis control. Whilst one might argue that the use of intramammary antibiotics *per se* does not pose a significant risk for the development of antimicrobial resistance (NMC, 2004), the same cannot be said of systemic use or the implications that may arise from subsequent use of milk collected from cows under treatment (*ie* feeding to calves).

As outlined above, both the financial implications of mastitis, the cost of treatment and the need for prudent antimicrobial use demand that both the farmer and veterinarian alike put in place systems and methods for monitoring the efficacy of mastitis treatment. Historically this has been difficult is not impossible to undertake in a systematic and ongoing way. This paper discusses approaches to monitoring mastitis treatment outcomes, outlines one approach developed by the authors and written into analysis software (TotalVet©, QMMS and SUM-IT Computer Systems) and reviews the range of results that might be expected by examining the outcomes from a large cohort of UK dairy farms.

## Approaches to monitoring mastitis treatment outcomes

Effective treatment of intra-mammary infection (IMI) remains a cornerstone of any mastitis plan to prevent the build up of infected cows within the herd. However, the interaction between resolution of clinical symptoms, sustained reduction in somatic cell count and a bacteriological cure is complex. Following infection of the gland and treatment, we have to understand the difference between an 'apparent' failure to cure (a new IMI following bacteriological cure of the original IMI) and a 'true' failure to cure (persistence of the original IMI despite treatment or recurrence of clinical signs following a clinical but not bacteriological cure of the original IMI). The effect of 'true' failures to cure is often over-played in many dairy herds; for example the largest influence on apparent dry period cure rate is the rate at which NEW IMI's occur, with the dry period new infection rate responsible for approximately 20% of the variation seen in dry period cure rate in a recent UK study (Bradley and Green, 2006). This means that for many dairy herds, the most cost effective way (and the most appropriate way) to enhance apparent cure rates is to therefore minimise the rate of *new* IMI, when the latter is poorly controlled and above target. It is also important to remember that this same scenario also exists with lactation based treatment outcomes; a recent meta-analysis of clinical mastitis treatment outcomes demonstrated that 22% of treated quarters acquired a new coagulase negative *Staphylococcus* IMI within the subsequent 28 days (Bradley and Green, 2009).

In order to make rational decisions regarding treatment for individual herds, it important to assess treatment outcomes, measure cure rates and *communicate* this data back to the farm team. Currently, decisions regarding therapeutic strategies are rarely based on an understanding of the current dry period or clinical case cure rate in the herd, but these are essential parameters to include in routine herd health monitoring. This is clearly dependant on effective methods to determine the outcome of treatment across the dry period and treatment of clinical cases of mastitis. From the farmer's perspective, these may be based on cow-side tests such as the California Mastitis Test (CMT) to assess the number of quarters likely to be infected at drying-off and calving and on resolution of clinical symptoms of IMI in lactation (clots in the milk, swelling of the udder, signs of systemic illness in the cow etc) following intra-mammary therapy. Routine bacteriology of quarters before and after a dry period and of clinical cases pre- and post-treatment in lactation is expensive, and is compromised by the variable sensitivity for detecting different organisms. Using individual cow somatic cell counts (SCC) offers a cheaper method. Individual cow SCCs have been shown to be a good proxy for IMI and can be collated over time to allow assessment of cures – a number of different approaches can be used and could for instance incorporate both the level and duration of any decrease below a threshold over a certain period of time. In practice, a reduction in SCC from above 200,000 cells/ml to below 200,000 cells/ml across the dry period could constitute a 'cure' for existing IMI at drying-off, although consideration should be given to allow for cows that are missed at first test-day due to clinical mastitis and cows that are milk recorded within the first week of lactation (and therefore a higher threshold for IMI should be set, for example 400,000 cells/ml) (Bradley and Green, 2005). When considering cure rates for the treatment of clinical mastitis in lactation, a reduction in SCC that is sustained below a threshold of 200,000 cells/ml for several test-days with no recurrence of clinical symptoms of IMI within that time could also be used to constitute a cure.

Software has been developed in the UK (TotalVet©, QMMS and SUM-IT Computer Systems) and also overseas (Dairy Data Warehouse, Uniform Agri) to facilitate the calculation of cure and new intramammary infections rates in a herd. Dry period cures are calculated based on the movement of cows around the 200,000 cells/ml threshold. Clinical mastitis cure rates are calculated based on SCC responses and lack of recurrence of clinical signs; high SCCs within 14 days of a clinical case are ignored, but otherwise a cure is assumed to have occurred when following the clinical case the subsequent 3 test day SCCs are <200,000 cells/ml or 2 test day SCCs are <100,000 cells/ml and there is no recurrence of clinical signs.

## Results and discussion of analysis of data from UK dairy herds

Data were collated from 653 herds enrolled in a national mastitis control program to enable calculation of both clinical mastitis and somatic cell count parameters using the principles outlined above. The results of these analyses are summarised in Table 1.

Analysis revealed substantial variation in all parameters between farms and provides a useful benchmark for what one can expected to achieve in the average herd. Whilst the minimum values for some of the clinical mastitis parameters may seem anomalously low, they have been included for the sake of completeness.

Preliminary exploration of the data found no relationship between herd size or yield with any of the measures of clinical mastitis or dry period cure. However, as illustrated in Figure 1 there is a clear trend for a reduction in apparent cure rates, both in the dry period and lactation as bulk milk SCC rises. This is unsurprising and probably reflects both a shift to more persistent pathogens in the herd as well as a higher prevalence of infection in the herd and therefore infectious pressure on recently cured quarters/cows.

The role of infectious pressure and therefore new intramammary infection and the impact this has on apparent cure rates is illustrated in Figure 2. This figure demonstrates a clear relationship between new infection and cure rate with cure rates declining in both the dry and lactating periods when the rate of new infection increases. This is a key point that needs to be conveyed to farmers and dairy professionals alike as it has a significant impact on apparent cure rates and needs to factored into client expectations. More importantly this relationship between cure and new infection needs to be explained and understood when making decisions about antimicrobial use.

## Presenting data on farm

Whilst software allows us to manipulate large amounts of data and calculate a huge number of parameters, this is all in vain if we cannot use this to monitor disease and performance effectively on farm and convey key messages to our clients. There are undoubtedly many ways to present and convey such information and this goes well beyond what can be presented in a short paper such as this. Depending on herd size and disease incidence, it may be possible to monitor outcomes effectively on a monthly or even weekly basis. However, in many cases and in smaller herds rolling quarterly or even annual figures allowing evaluation of long term trends may be more appropriate.

Data from one large herd (500 cows) is illustrated in Figures 3 and 4. Whilst in this herd the authors monitor performance closely on a month by month basis, when reviewing the impact of a mastitis control plan and discussing cure rates rolling 12 month indices may be more appropriate. Figure 3 illustrates the change in the rolling 12 month cure rates in the herd

*Table 1. Clinical mastitis and SCC parameters for UK dairy herds enrolled in a mastitis control program (12 month rolling figures).*

| **n=653** | **Mean** | **Min** | **25th percentile** | **Median** | **75th percentile** | **95th percentile** | **Max** |
|---|---|---|---|---|---|---|---|
| Herd Size | 218 | 47 | 134 | 187 | 264 | 484 | 903 |
| 305 Day yield (L) | 9,093 | 4,538 | 8,322 | 9,178 | 10,010 | 11,301 | 13,649 |
| Somatic cell count parameters | | | | | | | |
| Bulk milk SCC[1] | 233 | 71 | 177 | 225 | 273 | 364 | 743 |
| % >200K[2] | 24 | 6 | 19 | 24 | 29 | 38 | 59 |
| New lactation IMI (%)[3] | 10 | 0.2 | 8 | 10 | 12 | 16 | 26 |
| Fresh calver IMI (%)[4] | 22 | 4.1 | 17 | 22 | 27 | 35 | 76 |
| Dry period new IMI (%)[5] | 19 | 1.5 | 14 | 18 | 23 | 32 | 67 |
| Dry period cure (%)[6] | 72 | 16.1 | 66 | 73 | 80 | 89 | 100 |
| Chronic infection (%)[7] | 16 | 2 | 12 | 15 | 20 | 27 | 47 |
| Clinical mastitis parameters | | | | | | | |
| 1st quarter case rate[8] | 53 | 3 | 32 | 48 | 68 | 108 | 173 |
| Quarter case rate[9] | 76 | 3 | 42 | 67 | 101 | 169 | 287 |
| 1st cow case rate[10] | 38 | 3 | 27 | 38 | 49 | 65 | 88 |
| Cow case rate[11] | 68 | 3 | 40 | 62 | 90 | 144 | 229 |
| 1st case cure rate (%)[12] | 41 | 2 | 32 | 40 | 50 | 65 | 81 |
| All mastitis cure rate (%)[13] | 31 | 1 | 24 | 30 | 39 | 52 | 75 |

[1] 12 month rolling geometric mean calculated bulk milk SCC.

[2] Proportion of cows apparently infected, as measured by an SCC being above the 200,000 cells/m threshold.

[3] Proportion of cows apparently developing a new intramammary infection between milk recordings, based on movements around the 200,000 cells/ml threshold.

[4] Proportion apparently calving with an intramammary infection based on recordings occurring in the 1st 30 days of lactation and the 200,000 cells/ml threshold.

[5] Proportion of cows apparently developing a new intramammary infection during the dry period, based on movements around the 200,000 cells/ml threshold.

[6] Proportion of cows apparently curing (*ie* removing an intramammary infection) during the dry period based on movements around the 200,000 cells/ml threshold.

[7] Proportion of cows chronically infected, as measured by 2 of 3 consecutive somatic cell counts being above the 200,000 cells/ml threshold.

[8] Number of quarters affected with clinical mastitis on one or more occasions/100 cows in the past 12 months.

[9] Total number of quarter cases of clinical mastitis/100 cows in the past 12 months.

[10] Number of cows affected with clinical mastitis on one or more occasions/100 cows in the past 12 months. *ie* the proportion of the herd affected.

[11] Total number of cow cases of clinical mastitis/100 cows in the past 12 months.

[12] The proportion of 1st cases of clinical mastitis apparently curing in the past 12 months.

[13] The proportion of all cases of clinical mastitis apparently curing in the past 12 months.

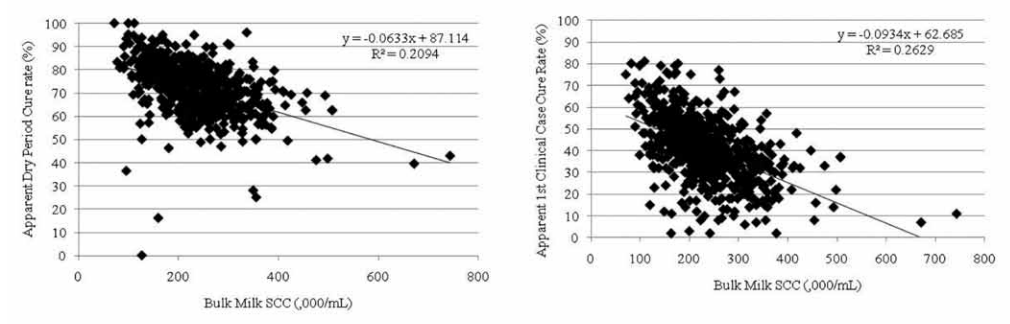


*Figure 1. An illustration of the relationship between apparent cure rates in the dry period (left panel) and the lactating period (right panel) and bulk milk SCC.*

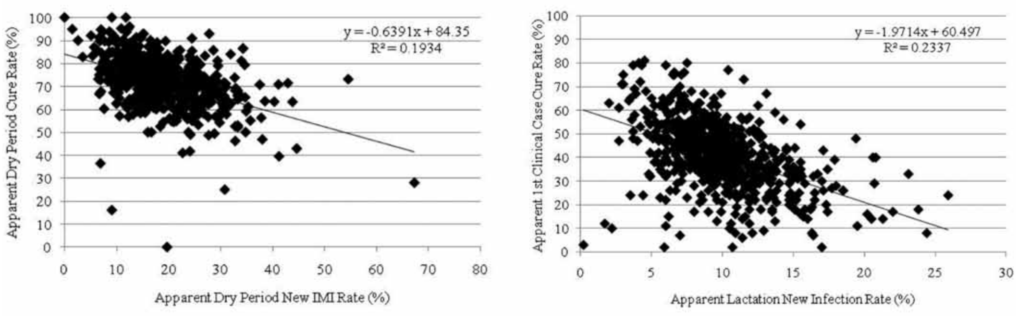


*Figure 2. An illustration of the relationship between apparent new infection rates and apparent cure rates in the dry period (left panel) and the lactating period (right panel).*

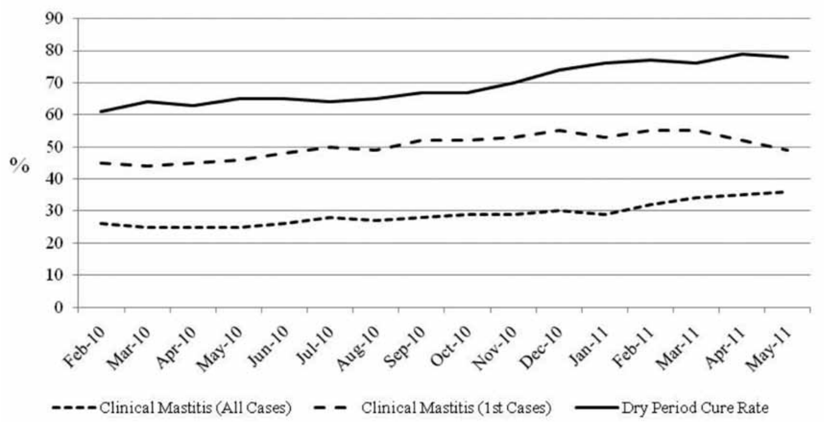


*Figure 3. An illustration of the relationship between the 12 month rolling average clinical mastitis and dry period cure rates over time in a herd implementing a mastitis control plan.*

over an 18 month period – this enables an overview of the impact of changes in treatment approach, but also clearly demonstrates the increased efficacy of dry period compared to lactating period therapy and that treatment of the 1st case of clinical mastitis in a lactation cycle is far more likely to result in a successful outcome that treatment of subsequent case.

Meanwhile Figure 4 illustrates the relationship between cure and new intramammary infection in the herd over the same timeframe. This graph clearly illustrates the improvement in dry period management as measured by a decrease in the proportion of cows calving with an elevated SCC. This improvement has been driven by changes in environmental management, resulting in a decrease in the rate of new infection allowing the apparent cure rate to increase. This is of particular interest in this herd as the exceptional improvement has been made without significant changes in therapy and in the absence of the use of an internal sealant (its use being precluded as the milk is used in mature cheddar cheese production).

## Conclusion

Using data that is widely available and already present on many dairy farms it is possible to put in place mechanisms to calculate and monitor cure of intramammary infection, both in the dry period and in lactation, for both clinical and sub-clinical infections. In an era of increasing concern over antimicrobial use in food producing animals it is incumbent on both prescribing veterinarians and farmers to monitor the success of treatment regimes so as to minimise and ensure prudent use of antibiotics. Moreover, given the ongoing financial pressures facing the industry, irrespective of prudent use it makes clear economic sense to better understand the financial return on any investments made in treatment.

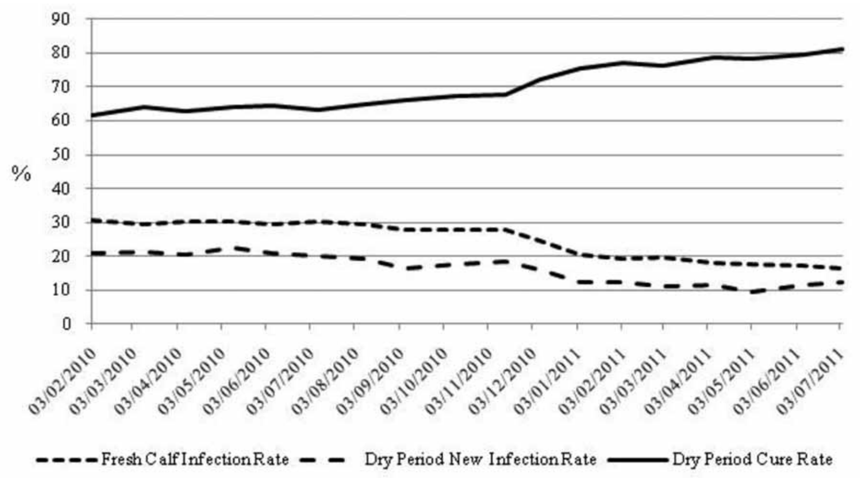


*Figure 4. An illustration of the relationship between the 12 month rolling average fresh calver infection rates and dry period cure and new infection rates over time in a herd implementing a mastitis control plan.*

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# Use of in-line measurements of somatic cell count to evaluate treatment efficacy of subclinical bovine Staphylococcus aureus mastitis

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## Abstract

Automatic milking systems using in-line measurements of markers for mastitis offer new possibilities for cheap and readily assessment of mastitis treatment efficacy. The aim was to evaluate the potential of daily measurements of in-line composite somatic cell count, using DeLaval Online Cell Counter (OCC), to assess treatment efficacy in cows with subclinical *Staphylococcus aureus* mastitis. 34 cows infected with *S. aureus* were randomly allocated to one of three treatment regimens. A cow was only classified as cured if no *S. aureus* was present in any of the quarters on day 7, 14, 28 and 56 after treatment. Daily measurements of OCC were compared between cured and non-cured cows, using summarization of the measurements over different time periods. Eighteen cows were classified as cured and sixteen as not cured based on bacteriology. The OCC of cured cows (101,000 cells/ml) were significantly lower than for cows not cured (262,000 cells/ml) ($P$<0,001). Using a three day average of OCC with a cut off value at 200,000 cells/ml was a reliable tool to predict bacteriological cure at day 56 from day 13 and onwards. The sensitivity compared to the four repeated bacteriological tests were 1.00, the specificity 0.86 and the accuracy 84%. However this was not reliable if the OCC of the cow before treatment was below 200,000 cells/ml. The study indicates that calculating a three day average with a cut off value at 200,000 cells/ml and visual inspection of the individual OCC plots can be used as cheap and readily available methods to evaluate treatment efficacy soon after treatment.

## Introduction

The Somatic Cell Count (SCC) is a measure of the content of inflammatory cells in the milk. A high SCC indicates the presence of mastitis (International Dairy Federation, 1987) and thus, this measure is often used as a diagnostic tool to select animals prone to have an intramammary infection. However, the accuracy of a single sample SCC can be questioned due to day-to-day and diurnal variation as well as individual variations (Harmon, 1994). Using repeated measurements has been suggested as a more accurate approach to detect changes in SCC (Forsbäck *et al.,* 2010). The use of SCC also requires the definition of a threshold for when the cow is cured. Pyörälä (1988) claimed that SCC in quarters which are bacteriologically cured after treatment returned to normal within three weeks. Thus, using common cut-off values for subclinical mastitis in the first weeks after treatment will probably misclassify a cow as not being cured if the quarter is still in a recovery stage (Pyörälä, 1988). The increased use of automatic milking systems has resulted in the development of systems that measure in-line somatic cell count, such as DeLaval Online Cell Counter (OCC). This progress makes it possible to follow and visualize the dynamics of SCC on a daily basis probably decreasing the demands for a threshold value (Lusis *et al.,* 2010). A previous study showed that the OCC accurately identified cows with SCC over 200,000 cells/ml, which indicates that OCC-meassures is a fairly reliable tool for measuring SCC (Lusis *et al.,* 2010). Bacteriolology is the preferred method for the evaluation of treatment success but this method is expensive and time-consuming. If in-line measurements of SCC also accurately determine whether the cow is bacteriologically cured, this measure can serve as an applicable and cheap tool to evaluate treatment success that could replace bacteriology in many cases.

The aim was to evaluate the potential and accuracy of daily measurements of in-line composite somatic cell count, using the DeLaval Online Cell Counter, to assess treatment efficacy in cows with subclinical *Staphylococcus aureus* mastitis. The study was conducted as part of a clinical trial evaluating the effect of penicillin treatment of subclinical mastitis caused by *S. aureus* (unpublished data). The results from the trial can be seen on the poster 'Therapeutic effects of lactation treatment of bovine subclinical *S. aureus* mastitis with penicillin.'

## Materials and methods

Three conventional Danish dairy herds with a DeLaval Online Cell Counter installed on their voluntary milking systems, were enrolled in July to October 2010 and the data collection ended between October and December 2010. All cows were housed in free stall barns with cubicles. Holstein was the predominant breed, one herd had mainly Jersey, one mainly Holsteins and one had both Holstein and Jersey.

To be included in the study, the cows had to meet the following criteria; at least one OCC >150,000 cells/ml during the last 14 days and no systemic or intramammary antimicrobial during the preceding 11 days. Only cows with an inflammatory reaction according to the above criteria and with penicillin-susceptible *S. aureus* cultured in two pretreatment samples in the same udder quarter(s) were included in the treatment protocols. Cows were excluded if they were expected to be culled, sold or dried off during the trial, had less than three lactating quarters, or had over 250 days in milk.

Selected cows were randomly allocated to one of the following treatment protocols; 20 mg of Penethamate hydriodide (Mammyzin, Boehringer Ingelheim, Denmark) per kg body weight, delivered IM in combination with IMM administration of 600.000 IE Benzylpenicillinprocaine

(Carepen, Boehringer Ingelheim, Denmark) in all udder quarters, once daily for five days, IMM administration of 600.000 IE Benzylpenicillinprocaine in all udder quarters, once daily for five days or no treatment. The farmer or the farm employee administered all the treatments.

Before treatment, milk samples from each quarter of the included cows were collected twice or, if necessary for confirmation, three times for bacteriological examination (aseptic sampling): 14 and seven days before treatment (day zero). For follow-up, milk samples were collected on day seven, 14, 28, and 56 after treatment for bacterial examination.

The samples were stored in a freezer at -18 °C until they were thawed for culturing. From each quarter sample, an inoculum of 0.02 ml milk was cultured on blood agar plates containing 5% equine blood, supplemented with aesculin and on chromID *S. aureus* (SAID) medium (Biomérieux, Marcy l'Etoile, France). The plates were incubated at 37 °C for 18-24 hours. Identification was based on colony morphology and biochemical tests. Strains producing double hemolysis were presumably identified as *S. aureus* and confirmed if the strain produced a green staining on SAID medium. If not, confirmation was done using Slidex® Staph Plus test (Biomérieux, Marcy l'Etoile, France) or, if still negative, a tube coagulase test was used for final confirmation. The quarter was considered infected when growth of at least one colony forming unit of *S. aureus* was detected. Susceptibility to penicillin was tested on all isolated strains of *S. aureus* using blood agar plates containing 1.0 IE penicillin per ml.

OCC-data from 14 days prior to treatment to 56 days after treatment were available via online connections to the farms and collected continuously during the trial period.

Bacteriological cure of the cow was defined as no isolation of *S. aureus* in any of the previously infected quarters at day seven, 14, 28 and 56. Missing results from any of the bacteriological cultures resulted in exclusion of the cow from the trial. Furthermore, cows that had been treated or culled for *S. aureus* mastitis during the study period were considered as treatment failures.

### *Statistical analysis*

Data from the DeLaval Online Cell Counter was available in all three herds. From day 1 to day 56 a total of 4423 cell count measurements were available from 34 cows (average 2.3 measurements per day). Mean, maximum (Max), 90 percentile (p90) and standard deviation (SD) was calculated for individual cows in different length of time periods and ROC curves was produced plotting sensitivity and false positive compared to bacteriological culture up to day 7, 14, 28 and 56. The ROC curves were evaluated using the AUC (area under curve) calculated using PROC LOGISTIC in SAS 9.2 (SAS institute, Cary, USA) to select the best time interval and the best parameter for evaluating the infection status based on the OCC measurements.

The initial analysis showed that cows with an average cell count below 200,000 cells/ml in the last five days before treatment did not have any significant changes in cell counts whether the *S. aureus* infection was cured or not. Therefore the data set was divided in to two datasets consisting of cows with a pre-treatment cell count below or above 200,000 cells/ml.

Based on the evaluation of the ROC curves a three day average of OCC was found to be the best parameter and the sensitivity, specificity and accuracy of this parameter was calculated compared to the infectious status up day 7, 14, 28 and 56. Furthermore the sensitivity and specificity of the three day average of OCC with a cut off value of 200,000 cells/ml at different time points between day 8 and 56 to predict the bacteriological status at day 56 was evaluated.

## Results

The plots of OCC differed according to if the cow was cured or not, where cured cows either showed an obvious decrease in OCC, a decreased day-to-day-variation or both soon after treatment was initiated, compared to cows considered not cured.

Twelve out of 18 cows was cured based on bacteriology in the group of cows with online somatic cell count above 200,000 cells/ml before treatment. The AUC for the four parameters; mean, p90, Max and SD did not differ significantly (0.96, 0.94, 0.94 and 0.90) based on measurements from day 54 to day 56 (Figure 1). The three day mean was used for the evaluation of OCC as

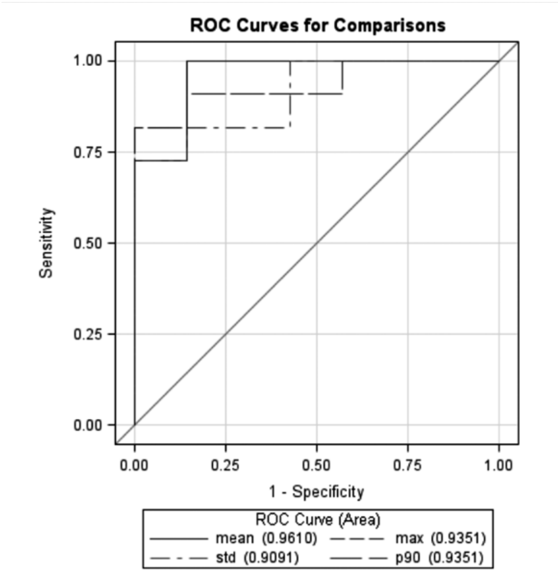


*Figure 1. ROC curves of three day mean (mean), maximum (max), standard deviation (std) and 90 percentile (p90) of online cell counts from day 54 to 56 compared to bacteriology at day 56. The curves for max and p90 are overlapping.*

indicator of cure AUC= 0.96 [0.88;1.00]. Based on the ROC curve a cut off value of 200,000 cells/ml was used for the evaluation. Table 1 presents the sensitivity, specificity and accuracy of the three day mean at different times in the study period compared to the first following milk sample (day 7, 14, 28 or 56) or compared to the status at day 56. In Figure 2 the sensitivity and specificity of the three day average compared to the bacteriological status at day 56 are presented. From day 13 and onward to day 55 the three day average is just as good as the average at day 56 to predict the bacteriological status of the cows (AUC between 0.93 and 0.98).

## Discussion

Evaluating the effect of a treatment for mastitis is essential both for veterinarians and farmers to monitor if the used treatment protocol is effective and cost efficient. Guidelines for estimating efficacy of intramammary antibiotics recommend bacteriology and in case of subclinical mastitis also the use of SCC (EMEA, 1999), but the bacteriology would be convenient to avoid since it is costly and time-consuming and not always readily available for the farmer and finally, the sensitivity of a single milk sample is rather low. The timing for bacteriology and

*Table 1. Sensitivity, specificity and accuracy of the average three day online cell count with a cut off value at 200,000 cells/ml compared to bacteriological culture for* Staphylococcus aureus *at day 7, 14, 28 and 56.*

| Cell count before day 0 | Day | No. cows | Cured at day 56 | Sensitivity | Specificity | Accuracy | Mean OCC, cured cows[1] | Mean OCC, Non cured cows[1] |
|---|---|---|---|---|---|---|---|---|
| High | Day 0 | 18 | 11 | | | | 448 | 516 |
| | Day 7 | 18 | 11 | 0.82 [0.48;1.00] | 0.86 [0.42;1.00] | 0.83 [0.66;1.00] | 157[a] | 332[b] |
| | Day 14 | 18 | 11 | 1 [0.72;1.00] | 0.86 [0.42;1.00] | 0.84 [0.66;1.00] | 57[a] | 559[b] |
| | Day 28 | 18 | 11 | 1 [0.72;1.00] | 0.86 [0.42;1.00] | 0.84 [0.66;1.00] | 57[a] | 380[b] |
| | Day 56 | 18 | 11 | 1 [0.72;1.00] | 0.86 [0.42;1.00] | 0.84 [0.66;1.00] | 98[a] | 443[b] |
| Low | Day 0 | 17 | 7 | | | | 134 | 110 |
| | Day 56 | 17 | 7 | 0.84 [0.42;1.00] | 0.22 [0.03;1.60] | 0.5 [0.27;0.77] | 110 | 120 |

[1] ×1000 cells/ml.

[a,b] Different letters in the same row indicates significant difference (*P*<0.05).

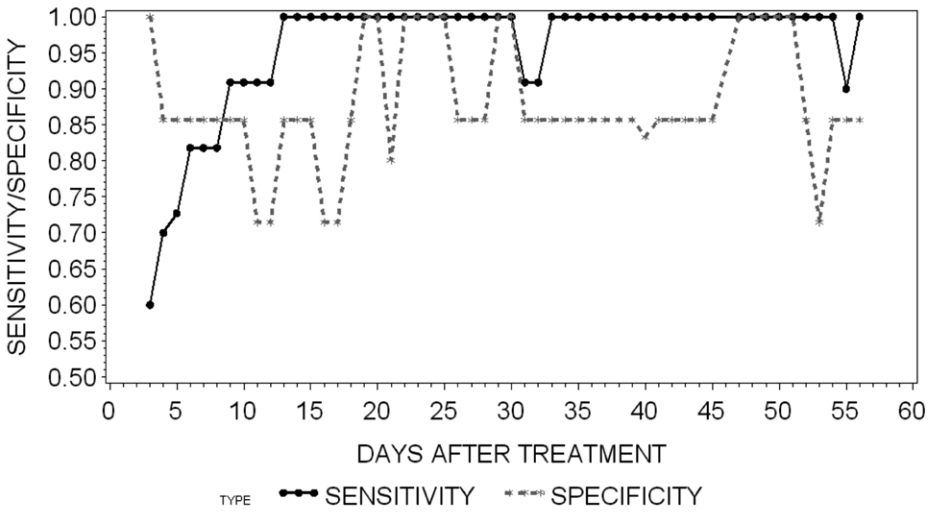


*Figure 2. Sensitivity and specificity of the three day average of online cell counts to predict bacteriological cure at day 56 of cows with average cell count above 200,000 at day 0 (cure = all samples at day 7, 14, 28 and 56 free of* Staphylococcus aureus*). N=18.*

evaluation on SCC must be taken into consideration. If the intramammary infection is cured, the SCC will in most cases return to a normal level as the udder recovers after inflammation. This process can take two to four weeks (Pyörälä and Pyörälä, 1997). During this period, there is a risk that the udder gets reinfected which cannot be distinguished from a flare up of the original infection. Bacteriology was performed at four occasions (day 7, 14, 28 and 56) and a cow was considered cured only if all the milk samples were free of *S. aureus*, a kind of parallel testing which increases the sensitivity of the test method. compared to if only a single sample was analysed.

When the cow has a SCC above 200,000 cells/ml before treatment is initiated, the average SCC over a three day period is an accurate method to evaluate whether the cow has been cured or not after treatment. However, this method was not suitable for evaluation of treatment when a cow started out with a SCC below 200,000 cells/ml. Based on the results from this study, treatment success can be accurately evaluated already from day 13 and the conclusion is not indifferent from an evaluation on a later stage e.g. day 54-56. The results of this study indicates that cows with somatic cell count below 200,000 cells/ml at day 13 were not likely to get re-infected in the first two month after treatment.

With a threshold of 200,000 cells/ml it was possible to get an overall accuracy with repeated bacteriology at 84%. This threshold has been widely used in veterinary practice to divide cow populations in healthy and mastitic cows (Dohoo and Leslie, 1991).

For cows with an average somatic cell count below 200,000 cells/ml before treatment both mean SCC and SD seemed unchanged regardless of whether the cow where treated or not and whether she was cured or not. One thing that could have explained the lack of change is that these cows seem do not to seem react on the *S. aureus* infection with elevated cell counts and nor will they have a decreased SCC if they clear the infection. Whether this missing reaction was due to properties of the bacteria or the cows is not known.

## Conclusion

If the OCC of a cow is above 200,000 cells/ ml before treatment for subclinical *S. aureus* mastitis, OCC is an accurate tool to assess the treatment efficacy. However, if the cow had a low initial start OCC (below 200,000 cells/ml), OCC is not accurate enough to decide whether the treatment was successful. A three day average OCC seemed to be the most useful measure to correctly differentiate between cows as cured and as treatment failures when four consecutive days of bacteriology analysis was used as the gold standard test and thus was superior to the standard deviation, 90 percentile and the maximum OCC-value. Regardless of measure the OCC provides a readily available and accurate method to evaluate treatment success.

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# ‘Therapy evaluation’: a useful tool for practitioners

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## Abstract

Public opinion and upcoming regulations ask for a responsible use of antibiotics. Veterinarians play a prominent role in communication with dairy farmers and have an important role with regard to responsible use of antibiotics. They give advice on animal health and farm management, with udder health being one of the main issues. Veterinarians are not only responsible for a responsible prescription of antibiotics, but also by actively evaluate treatments together with the farmer. Currently, possibilities/supporting programs to do this are limited. Digital recording of diagnoses and treatments regarding animal health eases the insight in antibiotic use on the farm. Main motivations for farmers to digital record animal health data is to fulfil requirements of quality control, but also to get insight in the medicines used and animal health status of the farm. A pilot is conducted with 5 veterinary practices with in total 36 farmers participating. Goal of this pilot was to develop and test the techniques, educate veterinarians and farmers, and prepare for national implementation of a supporting program for therapy evaluation, ‘Therapy-evaluation’. ‘Therapy-evaluation’ is a tool developed to support veterinarians in their advice regarding animal health. With this tool a veterinarian can get insight in the efficacy of treatment, incidences on farm level, the amount of (antibiotic) treatments given and can communicate this to the farmer by easy overviews. ‘Therapy evaluation’ is connected to the farmers management program to register animal health diagnoses and treatments. The veterinarian is able to get insight in this information to monitor, evaluate, and actively work on a responsible use of antibiotics, together with the farmer. By means of ‘Therapy-evaluation’ decision support for sustainable antibiotic use and improved animal health is made possible for all veterinarians and farmers.

**Keywords:** advice, communication, support, antibiotics, treatment

## Introduction

Antibiotic resistance is an upcoming problem gaining more and more attention. Not only veterinarians and farmers take part in this discussion, but also political and social issues play a more and more prominent role. To reduce the resistance problems, the Dutch government set goals for the agricultural sector to reduce the use of antibiotics with 50% in 2013 (with 2009 as reference). Veterinarians, but also farmers, play a very important role and are responsible to reach this goal. To reach this goal, three measures are set up by the dairy industry, starting January 2012. First, a farm specific health plan will be introduced. To set up this plan, the farmer and veterinarian have to work together to get insight in the antibiotic use and possible risks for animal health. Secondly, farm specific treatment protocols have to be present on each farm. And thirdly, a farmer has to work together with a certified veterinarian. This certified veterinarian is, amongst other things, obliged to register prescribed antibiotics in a central database. By doing so, the amount of antibiotics used by a farmer and/or veterinarian is transparent and can be used for control measures.

A farmer is obliged to take these measures to be able to deliver milk (quality obligation). Digital recording of diagnoses and treatments regarding animal health eases the insight in antibiotic use on the farm. A farmer can choose to give the veterinarian access to his management information, which the veterinarian can use for management support. To support veterinarians with this animal health management support, no general available tools are available. A tool enabling a veterinarian to monitor medicine use on farm level and evaluate and actively work on responsible medicine use would help veterinarians to show their added value to farmers. By doing so, this can stimulate (paid) farm support and help veterinarians to further improve their relation with customers and improve image of the sector.

This study consists of two parts. The first gives insight in the motivations that influence the recording of data by the farmer. The second describes a pilot conducted to develop a tool to support veterinarians in their animal health farm support based on data recorded by the farmers and by the veterinarian.

## Materials and methods

### *Farmers motivation to record data*

Data is collected by interviewing 28 farmers. These farmers were selected from 2 different groups. The first group were participants who indicated to be willing to participate in further studies during a previous study on animal health recording (Maatman, 2010). The second group were participants in a pilot study. The interview was based on 24 questions, divided into questions about general farm features, questions about the use of the animal health module and questions about features of data recording. Results were analysed in a descriptive way and graphically presented using Excel.

### *Therapy evaluation*

From 2008 till 2010 a pilot group of veterinarians and farmers worked on a system for therapy evaluation for veterinarians. During this period, 5 veterinary practices, with in total 36 dairy farmers, participated. Veterinary practices were selected based on interest and motivation to participate. With the group of veterinarians, discussion meetings were held to discuss the requirements. The veterinarians discussed the results and the set up of the program with their participating dairy farmers. At the end of the pilot a working tool for therapy evaluation was finished and veterinary practices can use this tool now in their daily farm management support.

## Results

The general attention given to a responsible use of antibiotics in society results in a growing number of farmers registering their diagnoses and treatment data digitally. Farmer recorded data is not always complete, but registered data is mostly correct. Especially data on udder health (subclinical and clinical mastitis) is registered complete and correct (Maatman, 2010).

### *Farmers motivation to record data*

Farmers participating in the interviews had on average 88 dairy cows (with a variation between 38 and 174). Most farmers indicated to have to wish to grow and improve compared to the current situation. Most farmers (81%) record their animal health data to meet the quality regulations (Figure 1). The next reason was to have insight in the history of animal health and to have insight in the used medicines.

Only a couple of farmers indicated to find data recording annoying, most farmers think it's just part of the business, and some like it. The data of farmers who use a PDA, is significantly more accurate than the data of farmers who record there animal health data in another way. 67% of the farmers who use a PDA record their data daily (Figure 2).

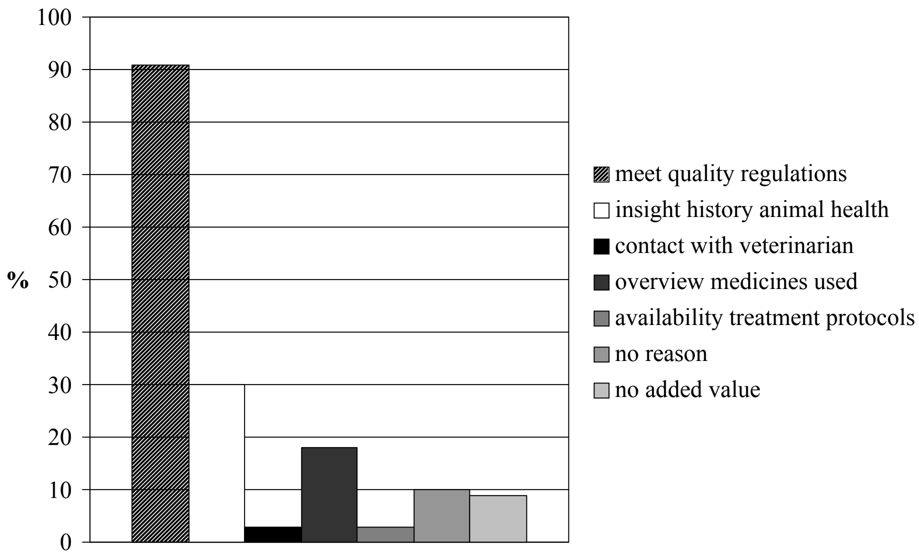


*Figure 1. Farmers motivation to record animal health data.*

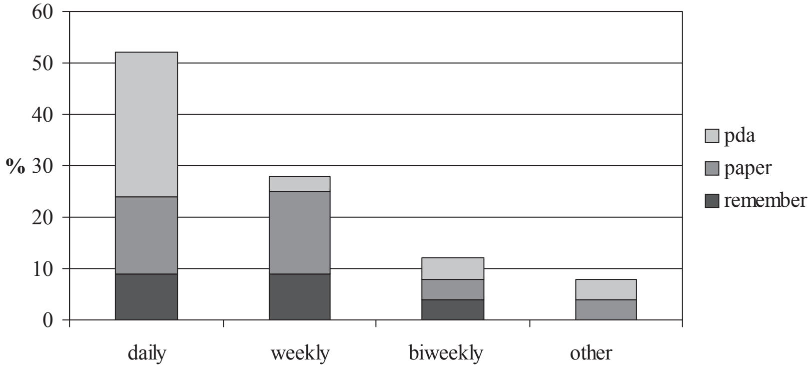


*Figure 2. Recording behaviour of farmers using pda, paper, or remember data by head.*

### *Therapy evaluation*

Together with veterinarians and farmers a program is set up to be able to combine data from veterinarians and farmers. The main structure of the program is presented in Figure 3.

Most important requirements of a supporting tool for animal health management were user friendliness and complete data availability. Further a high need of simple opportunities to include treatment protocols was valued high. It is difficult for farmers to set up treatment protocols themselves. Therefore, the veterinarian should be able to do this for the farmer(s).

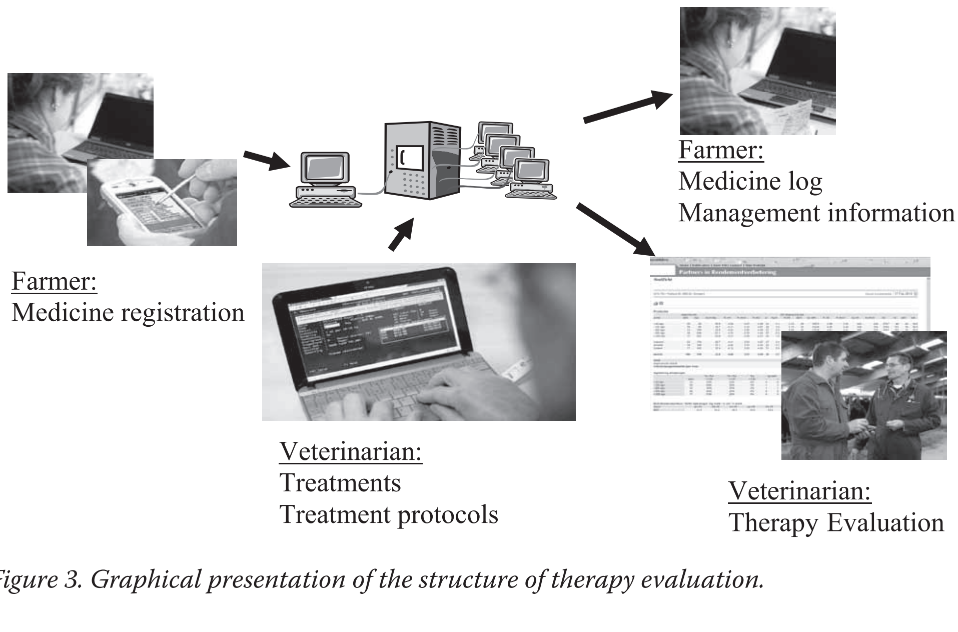


*Figure 3. Graphical presentation of the structure of therapy evaluation.*

The use of treatment protocols is important to obtain consistency between treatments and between staff (if staff is working on the farm). The tool contains modules regarding therapy-evaluation on udder health, metabolic disorders, fertility, claw health, drying off, vaccinations, young stock, and other health issues. The tool was set up including analyses of the effectiveness of treatment, analyses of incidences of different health issues, insight in farm goals, national averages and cow information.

Main reasons for veterinarians to participate in the pilot were image (to farmers and other practices), wanting to be a pioneer (prestige towards other practices, add value for farmers), and the financial compensation for participating. The practices who are connected to the tool after the pilot (it is available for every veterinary practice now), are motivated by the first two reasons (image and pioneer).

## Conclusion and discussion

Digital farmer data on animal health are increasing. Although the data are not complete, registered data seems to be correct. Especially mastitis data is registered more frequently. In the future it is expected that more data will be collected digitally because of the regulations. A tool like 'therapy-evaluation' can help the sector to be able to reach the targets set by the Dutch government (50% reduction in 2015). Next, the tool can contribute to improve awareness and responsibility of antibiotic use and helps to identify problem areas. By doing so, veterinarians can use the tool to add value to their farm support.

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# Dynamics of udder infection and effect of dry cow therapy validated by test day samples

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For many years individual cow cell counts has been measured at all control dates in Denmark. Due to limited use of the existing presentation of the measurements a new simpler system is now introduced with grouping cows as healthy or infected based on a cutoff value of 200.000 cells/ml independent on stage of lactation or lactation number. By this subdivision we were able to validate data from all 535.000 Danish cows in the herd control system in 2010 On average 23% of all heifers were infected at first control after calving. On average 30% of all cows were infected at each control day in 2010. Infection rate were reduced by 2% in 2010 compared with 2009. Infection rate were constantly lower in 2010 with a higher difference from august correlating a lower BTSCC and a lower mastitis incidence in Denmark. Average infection rate related highly to lactation number with 18% in 1$^{st}$ lactation 32% in 2$^{nd}$ lactation and 44% in older lactations. Changes between two test days within lactation were: Newinfection rate 10%,16% and 21% of cows with low cell counts, chronically infected 10%, 21% and 32% and cure rate were 44%, 31% and 22% of cows with high cell counts in respectively 1, 2 and older lactations In the dry period new infection rate were 30% and 37% of cows with low cell counts, chronically infected were 11% and 25% and cure rate were 56% and 50% of cows with high cell counts in respectively 1 and older dry periods. In all 282.162 dry periods received no therapy whereas 51.834 received dry cow therapy. Infection at first control day after calving were 40% and 31% for respectively no therapy and antibiotic therapy at dry off with a cure rate of 47% and 63% during the dry period. The presentation will focus on variation in the different udder health indicators in relation to dry cow treatment and variation between herds

# Part 10
# Infectious pressure

# Subclinical mastitis in Dutch dairy heifers in early lactation and associated risk factors

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## Abstract

Heifer mastitis is a problem and risk factors may differ between heifers and older cows. The aim of this study was to estimate subclinical heifer mastitis (HSCM) incidence based on elevated somatic cell count (SCC) in the first 100 days in lactation and associated risk factors in Dutch dairy herds. In 2008, 173 farmers filled in a questionnaire regarding housing and herd management factors potentially related to udder health. In addition, monthly milk production and SCC data from all cattle were provided by the Dutch Royal Cattle Syndicate (CRV). On average, 25.5% (95% CI: 23.9-27.0%) of the heifers per herd had subclinical mastitis. Housing heifers together with lactating cows close to calving, was protective for HSCM compared to separate housing. In addition, farmers that removed super-numerous teats of calves had a lower HSCM incidence and day and night grazing was also protective. Herds that were milked with an automatic milking system had a higher HSCM and submitting milk samples for mastitis culturing was also associated with a higher HSCM incidence.

**Keywords:** heifers, subclinical mastitis, incidence, risk factors

## Introduction

Udder health is highly correlated to productivity, antibiotic use and animal welfare and is therefore important for the dairy industry. Subclinical mastitis (SCM) is an indicator for udder health and has been associated with production losses, higher probabilities of clinical mastitis and culling (De Vliegher *et al.*, 2005; Whist *et al.*, 2007; Steeneveld *et al.*, 2008).

In the Netherlands, more than 20% of heifers have a somatic cell count (SCC) above 150,000 cells/ml at the first test-day, and 16% of heifers have clinical mastitis, of which 40% occurred in the first month of lactation (Miltenburg *et al.*, 1996; Barkema *et al.*, 1998).

Because heifers differ from multiparous cows with respect to dry period, production level and nutrition before calving, risk factors for subclinical mastitis in multiparous cows may not apply for heifers. Therefore heifers may require other management measures to prevent mastitis than older cows.

The aim of this study was to identify the incidence of subclinical mastitis in heifers (HSCM) in the first 100 days in milk in the Netherlands based on test-day records and associated risk factors.

## Material and methods

In the spring of 2008, 380 dairy farmers that participated in a national udder health program were asked to participate and complete a questionnaire in a study to determine risk factors for HSCM. In total 189 out of the 380 farmers completed the questionnaire that was sent to them by mail or that was e-mailed between May and September 2008. Results of the questionnaire were entered in Net Q (Net Q, 2008), a program for preparation of questionnaire data.

In addition, four-weekly test-day records from all the cows that were present in the period January until December 2008 in the 189 studied herds were provided by the Dutch Royal Cattle Syndicate (CRV) and contained the following cow and milk quality data:

- date;
- herd level: unique herd identification (UHI);
- cow level: ID number, date of calving, parity;
- test-day level: number of days in lactation, delivered kg milk, fat and protein, SCC, predicted kg milk, fat and protein.

The data provided by CRV was aggregated to herd level and combined with the results of the questionnaire. The items included in the questionnaire are summarized in seven categories of management practices namely, general information, raising young stock, grazing management, feeding management, milking process and technique, mastitis and dry cow treatment.

The diagnosis HSCM was based on individual SCC results in heifers between 4 and 100 days in lactation and was defined as SCC >150,000 cells/ml at one or more of the regular test-days (CRV, 2010; Sampimon *et al.*, 2010). For the analyses if the risk factors, the test-day data were aggregated to HSCM incidence per herd and was calculated as the number of cases of HSCM in the first 100 days after calving divided by the total number of heifers in the first 100 days of lactation that were present on the farm.

In the risk factor analyses management factors in the questionnaire that were hypothesized to be associated with HSCM and potentially gave the farmer the possibility to intervene in order to reduce HSCM were included. The HSCM incidence followed a normal distribution and therefore general linear models in SAS 9.1 (SAS, 2006) were used for analyses. First, the variables derived from the questionnaire were subjected to univariable analyses. Variables with a $P \leq 0.20$ were kept for the final multivariable model. The multivariable analysis was done using a backward elimination procedure. After each run, the variable with the highest *P*-value was excluded from the model until all variables had a $P \leq 0.05$. In the final model, all possible two-way interactions were tested, normality was checked and the $r^2$ was calculated.

## Results

From the 189 farmers that completed the questionnaire, data from 173 was complete and remained for the analyses. The average HSCM incidence in the first 100 days of lactation in the study herds was 25.5% (95% CI: 23.9%-27.0%). Per herd, the HSCM incidence varied between 0% and 60.3% (Figure 1).

In the univariable model, 25 variables were related to HSCM ($P \leq 0.20$) and therefore entered the multivariable model. In the final multivariable model, 5 factors remained and explained 24% of the variation in HSCM incidence between herds (Table 1).

Herds that housed heifers that are close to calving together with lactating cows had a lower HSCM incidence (-4.5%; 95% CI: -8.7% to -0.2%) than herds in which heifers were housed separately (Table 1). Herds in which supernumerous teats of calves were removed at the same time as dehorning had a lower HSCM incidence (-7.0%; 95 CI: -11.3% to -2.8%) compared to herds in which supernumerous teats were not removed. Furthermore, day and night grazing of lactating cows also was protective for HSCM incidence (-5.9%; 95% CI: -5.9% to -1.3%) compared to keeping the cows inside. Milking with an automatic milking system was found to be a risk factor for HSCM incidence. Heifers in herds with an automatic milking system (AMS) had a significant higher incidence of HSCM (6.9%; 95% CI: 2.2% to 11.5%). Finally,

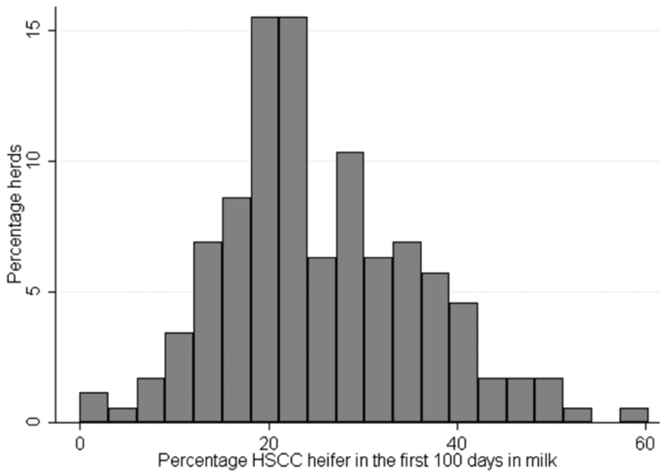


*Figure 1. Frequency distribution of heifer subclinical mastitis incidence in the first 100 days in lactation in 173 Dutch dairy herds in 2008.*

*Table 1. Risk factors associated with the incidence of subclinical heifer mastitis up to 100 days in lactation in 173 Dutch dairy farms.*

| Variable | Category | N observations | Model estimate (95% CI) | *P*-value |
|---|---|---|---|---|
| Intercept | | | 26.5% (22.3 to 30.7) | <0.01 |
| Location close-to-calving heifers | Separate | 48 | Reference | |
| | Dry cows | 78 | 1.1% (-2.4 to 4.6) | 0.53 |
| | Lactating cows | 34 | -4.5% (-8.7 to -0.2) | 0.04 |
| | Other | 13 | -2.0% (-8.3 to 4.2) | 0.52 |
| Removing supernumerous teats at early age[1] | No | 24 | Reference | |
| | Yes | 147 | -7.0% (-11.3 to -2.8) | <0.01 |
| Lactating cows on pasture | No | 45 | Reference | |
| | During the day | 96 | 0.7% (-2.8 to 4.2) | 0.70 |
| | Day and night | 32 | -5.9% (-10.6 to -1.3) | 0.01 |
| Number of milkers | ≥1 | 107 | Reference | |
| | 1 | 45 | 0.8% (-2.7 to 4.2) | 0.66 |
| | Automatic milking system | 21 | 6.9% (2.2 to 11.5) | <0.01 |
| Culturing of mastitis milk samples in the previous year[2] | No | 77 | Reference | |
| | Yes | 95 | 4.1% (1.1 to 7.1) | <0.01 |

[1] Two observations were missing and were included as a separate category, these results did not differ significantly from the reference category and were not presented.
[2] One observation was missing and was included as a separate category, the result of this category did not differ significantly from the reference category and was not presented.

heifers from farmers that submitted milk samples for mastitis culturing in the previous year had a higher HSCM incidence (Table 1).

## Discussion

In this study, the average HSCM incidence was 25.5% (95% CI: 23.9-27.0%) in the first 100 days after calving. Five factors were associated with HSCM. One of these factors was 'Culturing of mastitis samples in the previous year'. It is likely that this factor represented herds with prolonged mastitis problems instead of being a risk factor for a HSCM. In addition, keeping close-to-calving heifers with the lactating cows appeared to work protective for the incidence of HSCM. It is known that the first calving and the transition into lactation has a large impact on heifers (Fox, 2009). It is possible that this transition is even more difficult when influenced by stress of transferring the heifer to the lactating cows. Transferring heifers into the group of lactating cows earlier, may lead to more adjustment time, probably less stress, and getting used to the lactation ration in an earlier stage compared to transferring after calving. The removal of super-numerous teats in calves was also found to reduce the incidence rate of HSCM. This factor might be directly related to a lower HSCM incidence because inflammation of these super-numerous teats is prevented. It may, however, also be an indirect relation. Farmers that remove super-numerous teats may be more precise and have a more hygienic management style or may have more focus on udder health and therefore have lower HSCM incidence (Barkema *et al.*, 1999). Herds in which the lactating cows were grazed day and night had less HSCM than herds in which all lactating cows remained indoors. The infection pressure in the field may be lower than in the barn, possibly leading to less new infections and subclinical mastitis in heifers.

The last factor that was found to be associated with subclinical heifer mastitis incidence was the number of milkers. The negative effect of an automatic milking system might be associated with the hierarchy in the herd. Optimal cow traffic is necessary if an automatic milking system is used, to obtain an optimal number of milkings (Svennersten-Sjaunja and Petterson, 2008). Furthermore, the heifers have to get used to the automatic milking system, which might lead to incomplete milkings and prolonged intervals between milkings that negatively affect the udder health. Finally the infection pressure might be higher in herds with automatic milking stables. An automatic milking system cleans the teats automatically and there is no method available to monitor the effectiveness of cleaning like a visual control of the milker in non automated milking systems (Mottram, 1997).

## Conclusion

Subclinical heifer mastitis incidence occurs in almost all herds, in on average 25.5% of the heifers in the first 100 days of lactation. A higher HSCM incidence rate was found in herds that submitted milk samples for bacterial culturing in the year prior to this study and in herds that were milked with an automatic milking system. In addition, there were three management factors i.e. removing super-numerous teats, housing heifers that are close to calving together with lactating cows and day and night grazing of lactating cows on which intervention can be performed to reduce HSCM.

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# Risk factors associated with bacteriological quality of bulk tank milk in the Netherlands

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## Abstract

Bulk tank milk culture can be used to evaluate farm hygiene practices and the prevalence of mastitis pathogens. The objective of this study was to determine associations between some risk factors and concentrations of selected bacteria in bulk tank milk of Dutch dairy farms. A questionnaire was conducted in December 2010 on 904 Dutch dairy farms which have participated for at least one year in the GD Animal Health Service bulk tank milk culturing program. Bulk tank milk was tested for counts of *Staphylococcus aureus*, streptococci and streptococci-like organisms (SSLO), and coliform bacteria as well as the presence of *Streptococcus agalactiae, Streptococcus uberis*, and *Klebsiella* spp. Complete questionnaire data and bulk tank milk culture results were available from all 904 Dutch dairy farms. For each bacteria species a stepwise backward multivariate analysis was performed. Farms using an automated milking system had higher counts of SSLO, coliforms, and *S. aureus* in BTM than farms with tie-stall or conventional milking systems. Teat cleaning by an automated milking system appeared to be less effective than manual cleaning. Tie-stall barns had higher *S. aureus* counts in the bulk tank milk. Farms with deep-bedding stalls tended to have fewer *S. uberis* and more often a low count of SSLO and *S. aureus* when compared with those farms using rubber mats or mattresses as bedding material. Barn type, bedding type, milking system, and pasturing were all associated with one or more bacterial counts in bulk tank milk.

**Keywords:** bulk tank culture, milk quality, management

## Introduction

Periodic examination of bulk tank milk (BTM) is useful for monitoring and evaluating milk quality. The production of milk with low bacterial counts starts at the farm and is influenced by many procedures related to on-farm management practices (Elmoslemany *et al.*, 2010). Bacteria in BTM are present as a result of milking infected mammary quarters, contamination from the environment during milking, dirty milking equipment, and growth during milk storage. Because different types of bacteria can contaminate BTM through various and multiple sources, it is not always straightforward to determine the cause of high bacterial count in milk (Murphy and Boor, 2000). However, the majority of bacteria present in milk are a result of contamination from the environment and dirty equipment (Schroeder, 2010). High bacterial counts in raw milk can affect the quality of pasteurized milk and milk products, resulting in lowered shelf life and reduced consumer acceptance of milk and milk products (Barbano *et al.*, 2006). Estimation of the type and number of bacteria in BTM is valuable in understanding and troubleshooting issues related to udder health, milk harvest hygiene, cleaning practices, and milk storage conditions (Elmoslemany *et al.*, 2009). Isolation of contagious mastitis pathogens from BTM is an indicator of an intramammary infection in one or more cows in the herd (Jayarao and Wolfgang, 2003; Olde Riekerink *et al.*, 2009).

Although it is well recognized that good quality raw milk is essential for producing quality milk and milk products, limited information is available on the influence of management factors on BTM bacterial counts. Elmoslemany *et al.* (2009) identified the relationship between cow hygiene or teat-end cleanliness score and bacterial count in BTM, with high hygiene scores (dirty) being associated with increased risk of having a high bacterial count in BTM. Other factors, such as using a milking robot play an important role in the Netherlands.

The objective of this study was to determine associations between some risk factors and concentrations of selected bacteria in bulk tank milk.

## Materials and methods

A questionnaire was send to 2,727 Dutch dairy farmers that were participating in a commercial BTM culture programme in 2010. Questionnaires were sent both by e-mail (n=1,867) and mail (n=860). For the digital version of the questionnaire the programme Net-Q was used. Gathered data was transferred to a spreadsheet (Microsoft Excel 2000) and checked for missing values and errors. Questionnaire data were merged with laboratory results and farms with less than 10 test results were excluded. The questionnaire consisted of questions related to general management of milking, hygiene of animals and environment, and mastitis management. The questions were set up to be as closed as possible to avoid different interpretation between farmers. The questionnaire was tested on 2 farms prior to send-out to assess if the questions were interpreted correctly and easily. After that, farmers were asked to return the questionnaire within 3 weeks by post or fill it in via a website. Farmers that did not respond within 1.5 week were reminded to fill in the questionnaire by sending a reminder by email. Farmers that received the questionnaire by mail were not reminded.

Three different culture media were used to detect *Staphylococcus aureus*, *Streptococcus agalactiae*, streptococci and streptococci-like organisms (SSLO), coliforms, and *Klebsiella* spp. These were: (1) a medium selective for staphylococci; (2) a medium selective for streptococci; and (3) MacConkey agar. After mixing the milk sample on a vortex shaker for 5 s, 50 µl was dispensed by pipette onto the plates. The milk was spread evenly and allowed to air dry before incubation. Plates were incubated at 37 °C aerobically for 48 h. These plates

were examined after 24 and 48 h of incubation. Streptococci and streptococci-like organisms were counted from the streptococci-selective medium as were coliforms from the MacConkey agar. *S. aureus* was identified by specific colorization on the staphylococci-selective medium, by Gram stain, a positive catalase test, and a positive tube coagulase test. *S. agalactiae* was identified by typical appearance, gram-positive staining, a negative catalase test, and a positive CAMP test. *Klebsiella* spp. and *Streptococcus uberis* were identified by their typical appearance on MacConkey agar and streptococci-selective media and were not further confirmed.

Unconditional association between the outcome of interest and the management factors was examined using simple logistic regression. *S. uberis, S. agalactiae,* and *Klebsiella* spp. were classified as positive or negative. Variables with a $P \leq 0.25$ in the unconditional analyses were offered into multivariable logistic regression model. All analyses were carried out using Stata 11.1 statistical software (College Station, Texas 77845 USA).

## Results and discussion

The majority of participating farms had free-stall barns using a conventional milking system and pastured the lactating cows part of the day (Table 1). The farm population in this study is most likely not totally representative for the Dutch dairy industry because the BTM culture program is more geared towards larger farms (approximately more than 80 cows).

*Table 1. Distribution of risk factors for bacteriological quality of bulk tank milk in 904 Dutch dairy herds.*

| **Risk factor** | | **Distribution (%)** |
|---|---|---|
| Barn type | Free-stall | 95 |
| | Tie-stall | 4 |
| | Other | 1 |
| Milking system | Parlor | 77 |
| | Milking robot | 19 |
| | Tie-stall | 4 |
| Pasturing | Part of the day | 51 |
| | Day and night | 25 |
| | None (confined) | 24 |
| Stall type (bottom) | Soft (rubber mat or mattress) | 68 |
| | Deep | 18 |
| | Other | 14 |
| Bedding material | Sawdust | 66 |
| | Straw | 16 |
| | Other | 18 |

*S. agalactiae* was isolated from BTM from 12 farms (1.3%) and was therefore not further analysed. All farms had a yearly geometric mean average of 20 cfu/ml (95%CI: 1 - 360), 549 cfu/ml (95%CI: 105 - 2,870), and 4 cfu/ml (95%CI: 0 - 47) of respectively *S. aureus,* SSLO, and coliforms in their BTM. *Klebsiella* spp. and *S. uberis* was recovered at least once on 35% and 11% of the farms, respectively.

High SSLO BTM counts were associated with farms that milk with robots and those farms which had straw as bedding material. Farms with deep-bedded boxes had lower SSLO counts. Farms with robotic milkers had also a higher geometric mean coliform count in the BTM. No other risk factor in this study could be identified as being associated with coliform counts. Teat cleaning by an automated milking system appears to be less effective than manual cleaning. Cow cleanliness can also affect the efficiency of teat preparation before milking. Cleanliness of the udder and teats can be influenced by several factors, including transition from summer grazing to winter housing (with housed cows being dirtier than grazing cows; Ellis *et al.*, 2007), faecal consistency (where increasingly fluid faecal consistency correlated with dirtier cows), frequency of bedding change and quality of bedding (Ward *et al.*, 2002), and stage of lactation (Reneau *et al.*, 2005).

*S. aureus* counts in BTM of free-stall barns with conventional milking systems were lower than BTM of farms with robot milkers and tie-stall barns. In addition, herds that were confined all year round and herds that had soft material in the boxes (i.e. mattresses and rubber mats) had on average higher *S. aureus* concentrations in BTM than farms that pastured the cows in the summer and herds that were kept on deep-bedded boxes. Using rubber mats or mattresses has been associated with *S. aureus* in BTM before in Canadian dairy herds (Olde Riekerink *et al.*, 2010). Presence of *Klebsiella* spp. in BTM was clearly associated with the use of sawdust bedding material. Additionally, the use of deep-bedded boxes and robotic milking system tended to be associated with *Klebsiella* spp. presence in BTM, but deep-bedded boxes were associated with lower odds of presence of *S. uberis* in BTM.

## Conclusions

Barn type, bedding type and material, milking system, and pasturing were all associated with one or more bacterial counts in bulk tank milk.

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# The efficacy of two iodine teat dips based on naturally occurring new intramammary infections

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## Abstract

Based on proving non-inferiority of one product compared to another, this study was designed to compare the efficacy of an experimental pre-milking teat dip against a positive control in reducing naturally occurring intramammary infections (IMI). To test this methodology in the field, 199 cows were randomly allocated to two groups (Control, CG; n=100 and Experimental, EG; n=99) in Spring/Summer 2010. Personnel were blinded as to the origin of the product. Cows were milked two times per day following standard pre-milking procedures. Quarters of CG and EG cows were pre dipped for 30 sec with the control product and experimental products, respectively. Both different products were 0.5% iodine and 5% emollient. After milking, both groups were dipped with the control product. Quarter milk samples were collected for SCC analysis, at the beginning of the trial and afterwards every two weeks until 70 d. Quarter-level bacteriological status was established in all quarters at the beginning of the study. Milk samples collected thereafter were cultured only if SCC was >100,000 cells/ml in heifers and >200,000 cells/ml in cows. Logistic and linear regressions were used for data analysis. Overall, 148 CG (7.1%) and 130 EG (6.3%) milk samples were bacteriologically positive. *Staphylococcus* spp. (3.6% of tested samples tested), and *Staphylococcus aureus* (1.2% of tested samples) were commonly isolated in both groups. *Streptococcus uberis* was frequently isolated in CG (0.9% vs. 0.2% in EG). SCC geometric means were 32,000 (CG) and 25,000 (EG) cells/ml. No differences between groups in the log odds of having either an IMI or a new IMI (NIMI) were observed. The critical difference in the NIMI rate between both products was set at 0.03. The observed difference in NIMI rate was negligible, showing a non-inferiority of the experimental product vs. control. This study provided evidence of a valid and field-tested methodology to evaluate the efficacy of teat disinfectants under the assumption of non-inferiority.

**Keywords:** disinfectant, iodine, udder infection, non-inferiority, pre-milking

## Introduction

A vast number of publications referring to the effectiveness of pre and postmilking products are available, documenting the importance of teat disinfection as a management tool in preventing new intramammary infections (IMI) in dairy cows (Farnsworth *et al.*, 1980, Pankey *et al.*, 1984). As a consequence, the success of teat disinfection has resulted in the emergence of numerous germicidal products marketed as teat dips.

Iodine-based teat dips have proved to be effective for reducing the spread of mastitis-causing pathogens (NMC, 2009). Nevertheless, governmental agencies require supportive clinical trials for approving and registering these teat dip disinfectants, but the requirements for those studies are inconsistent among countries. One mission of the National Mastitis Council (NMC) is to monitor the development of protocols that determine effectiveness of mastitis control products, such as teat disinfectant solutions. Although the Teat Health Committee of the NMC has reviewed and developed a protocol for evaluating the efficacy of postmilking teat dips (Nickerson *et al.*, 2004); these recommendations did not include a standard procedure for evaluating pre-milking teat disinfectants. Additionally, the recommended protocol for evaluating pre-milking teat disinfectants has not been reviewed since 1991 (NMC, 1991), while the results on the evaluation of the efficacy of pre-milking and postmilking teat disinfectants has been reviewed recently (NMC, 2009). Therefore, a new protocol to compare the efficacy of an experimental teat dip with that of a positive control product in reducing naturally occurring IMI is described. We hypothesized that there are no differences in either prevalence or incidence of IMI between a control and test pre-milking iodine-based teat dip in reducing naturally occurring infections.

The objective of this study was to describe a new protocol to compare the efficacy of an experimental iodine pre-milking teat dip to reduce naturally occurring new intramammary infections (NIMI) with that of an iodine control product, based on proving non-inferiority of the experimental disinfectant relative to the positive control.

## Material and methods

Cows from a dairy herd in Western New York were selected for a 10-wk trial between July and September 2010. Two groups of lactating cows with 100 and 99 animals each were selected for the trial. Cows were in good health at the time of recruitment, had not been treated with antibiotics or anti-inflammatory products in the 30 d prior to recruitment. They were housed in free-stall barns with no differences in feeding and management. Cows were milked twice daily following standard pre-milking milking procedures.

Selected cows were allocated to two groups (Control; n=100 and Experimental n=99). Cows were allocated to the study groups in such a way to balance parity and stage of lactation of between groups. Study personnel were blinded as to the origin of the products and treatment allocation. Control group (CG) received Theratec® Plus (GEA Farm Technologies, Inc. Naperville, IL), and experimental group (EG) received F-2326 (DeLaval Inc. Kansas City, MO) as pre-milking teat disinfectants. Both products were ready-to-use 0.5% iodine teat dips with 5% emollients, and applied with non-return dip cups. Color-coded dip cups and leg bands were provided to the farm to ensure proper treatment application during the trial.

The efficacy of F-2326 compared to Theratec® Plus was measured by defining the number of NIMI in each study group. At the start of the study, and whenever a cow entered the study, all quarters from each cow were aseptically sampled for somatic cell count (SCC) and aerobic culture. This was used to confirm that cows entering the study were not previously infected and that subsequent infections could be attributed to the success or failure of study treatments in preventing NIMI. Further, two milk samples were aseptically collected biweekly from each quarter. One sample was used for SCC analysis, using those results as a screening tool to detect the quarters that were most likely to be culture-positive. If SCC was >100.000 cells/ml in first lactation heifers, or >200.000 cells/ml in cows, then the second sample was cultured (Laevens *et al.*, 1997, Schepers *et al.*, 1997). Additionally, over the course of the study, any quarter with a clinical mastitis case was sampled before treatment for bacterial culture of milk to identify the causative pathogen. Aerobic cultures were conducted at Quality Milk Production Services of Cornell University, following standard protocols established by the NMC (Oliver *et al.*, 2004), and SCC analyses were conducted at Dairy One using automated equipment (Fossomatic®, Foss, Hillerød, Denmark).

The quarter was the unit of analysis. The initial bacteriological status of each quarter was established at the beginning of the trial using a single sample to set the eligibility of each quarter. Once a quarter is identified as being infected with a particular organism, any repeat infection of the same quarter with the pathogen in question was not counted as a new infection. Therefore a NIMI was defined based on the presence of a microorganism in a single quarter sample that was not identified in that quarter previously. Samples from clinical cases were also eligible for identifying IMI. Samples containing more than two bacterial species were considered as contaminated, and were not informative of IMI status.

### *Statistical analysis*

The prevalence of any IMI during the whole study period was calculated as the number of IMI divided by the number of quarters sampled at that specific time. A logistic regression model combined with generalized estimating equations to account for within-cow clustering was used to evaluate any differences between both groups (i.e. quarters dipped with control or experimental teat dips). The coefficients of the regression model were expressed as population-averaged odds ratios, which give the effect of dipping teats before milking with the experimental product on having an IMI across all cows (Dohoo *et al.*, 2009).

The model used was:

$$\text{Ln}\,[P/(1-P)] = \text{intercept} + \text{treatment} + \text{time} + \text{treatment} \times \text{time} + \text{Re} \qquad (1)$$

where treatment is either product tested (control or experimental), and time corresponds to milk sample collection (0, 14, 28, 56 and 70 days after start of treatment), Re is a complex error structure allowing for within-cow correlation.

The incidence risk of having a NIMI was calculated as the probability that an individual quarter had a NIMI during the 70-d study period considering only quarters free of an IMI with the pathogen of interest at the beginning of the study. The quarter was the unit of interest accounting for within-cow clustering by fitting a generalized linear mixed model with a first order autoregressive correlation structure, and including fixed effects of time, as categorical variable. The analyses were carried out using the GLIMMIX procedure of SAS version 9.2 (SAS Institute Inc, Cary, NC, USA).

The SCC for the six composite samples per cow (0, 14, 28, 42, 56 and 70 days after start of treatment) was analysed by linear mixed models (Dohoo *et al.*, 2009). Fixed effects of treatment group, time, and their interaction were included. The final analysis was carried out on natural log scale for SCC (LnSCC), and was carried out using the MIXED procedure of SAS version 9.2 (SAS Institute Inc, Cary, NC, USA).

## Results and discussion

The effect of the two pre-milking disinfectants (F-2326 and Theratec® Plus) was evaluated using the information available from 4,167 quarters. Of these, 718 (CG) and 643 (EG) quarter milk samples met the qualifying requirements for bacteriological culture (i.e. only quarters having a SCC >100,000 cells/ml in heifers, or 200,000 cells/ml in cows). A total of 1,375 (66% CG) and 1,431 (69% EG) milk samples did not meet these specifications.

### *Prevalence of infection*

Bacteria were isolated in 21% of CG (148 out of 712), and 21% of EG (130 out of 628) (6.3%) quarter milk samples, with *Staphylococcus* spp. being the most common pathogen isolated (CG=26.4%; EG=26.9%), followed by *Staphylococcus aureus* (CG=8.1%; EG=10.0%). *Streptococcus uberis* was frequently isolated in the CG (12.8% of isolations), but not in the EG (3.1% of isolations).

The overall risk of having an IMI during the 70-d study period was 0.083 and 0.086 for the CG and EG (*P*=0.89), respectively. The experimental product (F-2326) did not increase the log odds of having an IMI during the study period compared to the control (Theratec® Plus) (*P*=0.84). The log odds of having an IMI after dipping with the experimental product was reduced by 30% after controlling for the effect of time, but remained not statistically significant (*P*=0.89). The intraclass correlation was ($\rho$) 0.25, which corresponds to the correlation between observations on two units in the same cluster (cow). This value is indicating a moderate cow clustering (Dohoo *et al.*, 2009).

### *Incidence risk of new intramammary infection*

The effect of two pre-milking teat disinfectants on the risk of NIMI was evaluated based on the information collected from 1,195 quarters (Table 1). The difference (Δ) between groups was 0.004 (CI 95%: -0.015, 0.024). The odds of having a NIMI during lactation, although numerically higher in the CG, were not different between treatment groups (*P*=0.68).

The detectable difference in the risk of NIMI between both products was set at 0.03, based on the anticipated change of the NMC teat dip protocol (Nickerson *et al.*, 2004). Thus our objective was to demonstrate that F-2326 was at least not substantially inferior to the control product, based on preventing naturally occurring NIMI. Consequently, based on the Δ observed these results indicate that EG was non-inferior than CG but not shown to be superior.

Non-inferiority trials have been described in an international guideline authored by regulatory agencies, as a method to evaluate the efficacy of an investigational product (FDA, 1998). The interpretation is based on where the confidence interval for the treatment effect lies relative to both the margin of non-inferiority Δ (e.g. 0.03 for our study) and a null effect (Piaggio *et al.*, 2006). Thus the position of the upper confidence limit is not of primary interest in non-inferiority trials. Consequently, this non-inferiority trial is designed as a one-sided study (Piaggio *et al.*, 2006, Christensen, 2007). For that reason the necessary sample size would be less than that needed for an equivalence trial. In our study, the claim of non-inferiority was based on a proper power calculation. As mentioned, the sample size was calculated assuming a NIMI rate of 0.03 for the CG and a detectable difference of 0.03 (i.e. effectively a doubling of NIMI). Using this detectable difference, the statistical power with the current sample size of 600 quarter-months was then approximately 0.7. Regarding to SCC, no differences were observed between CG and EG, based on 3,960 quarter milk samples.

*Table 1. Frequency of no new cases and new intramammary infections in 1,195 quarter milk samples collected from 199 cows treated with two different pre-milking teat disinfectants[1].*

| Quarter status | Theratec® plus (control product) | | F-2326 (experimental product) | |
|---|---|---|---|---|
| | **No.** | **%** | **No.** | **%** |
| No cases | 601 | 96.8 | 558 | 97.2 |
| New intramammary infections | 20 | 3.2 | 16 | 2.8 |
| Total | 621 | 100 | 574 | 100 |

[1] A total of 159 quarters from 16 cows did not match the criteria for their inclusion in the analysis of the incidence risk of new IMI.

## Conclusions

These results showed a negligible difference in NIMI between both dipping products. Therefore, the experimental product (F-2326) was not inferior to the control product (Theratec® Plus), concluding this with a power of approximately 70%. Methods used in this study allowed testing for evaluating the efficacy of teat dipping products based using non-inferiority trials based on: (a) An initial bacteriological status of all quarters using single milk samples; (b) Biweekly sampling of all quarters; (c) Using SCC thresholds for defining whether bacteriological culture of milk samples were to be performed; and (d) Adequate statistical methodology.

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# Manageable risk factors associated with incidence and elimination of *Staphylococcus aureus* intramammary infections

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*Staphylococcus aureus* is a major cause of mastitis worldwide. Because of the chronic nature of these intramammary infections (IMI), focus must be made on preventing acquisition of these IMI or, alternatively, on reducing their duration. The objective of this study was to identify practices that are not widely adopted by Canadian dairy producers but that could reduce the incidence or increase the elimination of *S. aureus* IMI. A cohort of 90 Canadian dairy herds was recruited and followed in 2007-2008. Management practices used on these farms were measured and series of quarter-milk samples were collected at three-week intervals on a selection of cows from participating herds. Routine bacteriologic culture was used to identify occurrence and elimination of *S. aureus* IMI. Hierarchical cross-classified logistic regression was used to estimate the effect of manageable risk factors on odds of acquiring and eliminating an IMI while taking into account important confounders. The median herd *S. aureus* IMI incidence and elimination rates were 0.08 IMI/quarter-year and 0.39 IMI/quarter-month respectively. Using pre-milking teat disinfection, wearing gloves during milking, adequate teat end condition, optimization of stall dimensions, managing calcium in diet at calving, and fly control were all significantly associated with lower IMI incidence or increased elimination. Herd and cow initial *S. aureus* prevalence were associated with higher subsequent incidence. In terms of a Canadian control program, efforts should be directed toward promotion of glove use by milkers and pre-milking teat disinfection which could theoretically be linked to 26% and 19% of new *S. aureus* IMI respectively (population attributable fraction).

# Factors influencing average herd somatic cell count in France in 2005 and 2006

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To describe factors affecting composite weight mean cow SCC (CMSCC) in France, 5 models were used with yearly or monthly CMSCC (YE-CMSCC; MO-CMSCC) as explanatory variables: 2 linear models (2005 and 2006), a monthly static panel data model (24 months) and 2 dynamic panel data models (2005 and 2006). The average CMSCC was 266,000 cells/ml. The correlation between 2005 and 2006 CMSCC was 0.69. 50, 33 and 10% of the units had a CMSCC >250, 300 and 400,000 cells/ml in 2005 or 2006, respectively. In linear and static panel data models, number of cows, having a beef or fattening unit, number of days in milk (DIM), age at first calving, purchased cow proportion, proportion of cows at risk for subacute ruminal acidosis (SARA) and negative energy balance (NEB), average calving interval and having at least one dead cow were positively associated with CMSCC, whereas the association was negative for a predominant breed other than Holstein, milk production, dry-period length, first calving cow proportion, having an autumnal calving peak, being a good-breeding practices member, the previous-year culling rate, the municipal cattle density and the municipality grass utilization. In the dynamic panel data models, MO-CMSCC was positively associated with previous and penultimate MO-CMSCC, penultimate SARA, previous milk production and current number of cows, DIM and NEB. A negative association was described for the 3rd previous month MO-CMSCC, current milk production and current proportion of first calving cows. This study showed the impact of SARA and NEB on CMSCC and the high importance of farmer's motivations for udder health issues, among them the specialization of farmers into dairy production. The contextual factors including farming system, local milk payment conditions and cattle intensification had also an important effect on CMSCC. Dynamic approach appeared as a promising tool for both research and farm surveys.

# Risk factors associated with intramammary infections caused by the more pathogenic CNS-species

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Coagulase-negative staphylococci (CNS) are the most frequently isolated mastitis pathogens from cows with and without a high somatic cell count (SCC). The bacteria within this heterogeneous group have traditionally been regarded as minor pathogens. We recently reported that *Staphylococcus chromogenes*, *Staphylococcus xylosus*, *Staphylococcus simulans* and *Staphylococcus cohnii* were the four most frequently isolated CNS-species capable of causing intramammary infections (IMI). *S. chromogenes*, *S. xylosus* and *S. simulans* even cause IMI characterized by elevated quarter milk SCC to a level that is not different from IMI due to *Staphylococcus aureus*. These CNS-species are therefore considered to be more pathogenic than other CNS-species. *S. cohnii*, on the other hand, only caused a very moderate increase in SCC, not different from non-infected quarters. Research is needed to get more insight in how to prevent and control IMI with the more pathogenic CNS-species. The main objective of this study is to identify risk factors for both existing and new IMI specifically caused by the three more pathogenic CNS-species. Potential cow-, quarter- and observation-level risk factors for IMI during lactation were collected in a longitudinal study. In order to identify risk factors associated with existing IMI, multivariable, logistic mixed regression models were fit with cow and quarter as random effects (MLwiN 2.16). Preliminary analyses indicate that heifers (versus older cows) and teats with some evidence of scaling are more likely to be infected with one of the three pathogenic CNS-species. Also, distribution of the more pathogenic CNS-species seems to be herd-dependent.

# Management of udder-thigh dermatitis on dairy cattle: epidemiological and bacteriological data

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Udder-thigh dermatitis (UTD) is a common illness in cattle but few descriptions are reported. UTD is a more-or-less symmetrical lesion of the groin skin, between the medial thigh and the lateral udder. Five clinical stages can successively occur from an erythema to a necrotic dermatitis. Recovery always takes a long time (at least three weeks), especially in the final stage, with pain and increased recumbency. This study aims at defining incidence, risk factors and involved pathogens of UTD in France. Firstly, a survey was conducted among 74 dairy farms (4,393 cows) randomly selected in a defined area (Cantal, France) in which general practices, breeds, levels of production, feeding and housing were very variable. Secondly, bacterial investigations were conducted from swabs obtained on UTD lesions (n=14). Epidemiological data showed a high herd prevalence (97%) and annual cow incidence (6%) of UTD in the studied population. Relative risk of primiparous affection compared to multiparous was 15.3. Breed and season were not associated with UTD occurrence ($P>0.05$) whereas moving (non tied animal) has a preventive effect ($P<0.05$, linear model). Udder oedema was the major risk factor of UTD. Bacterial cultures showed the presence of several aerobic and anaerobic bacteria. Some of them were considered as opportunist pathogens but *Fusobacterium* spp was commonly isolated from affected skins: *Fusobacterium nucleatum* and *Fusobacterium necrophorum* were regularly identified, suggesting their particular involvement in UTD. According to the epidemiological results, management of UTD should include prevention and cure of udder oedema (especially in heifers) and increasing moving. For affected cows and before apparition of extended lesions, UTD therapy should also include local disinfection to avoid development of *Fusobacterium* spp. and to limit the use of systemic antibiotics.

# Survey of bulk tank milk from all Danish dairy herds in 2009 and 2010 with real-time PCR

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The objective of this research was to evaluate the use of results from real-time PCR on BTM as indicator of udder infections and milking hygiene in all Danish dairy herds. In 2009 BTM samples from all 4,258 Danish dairy herds were tested by real-time PCR and also cultured for *Streptococcus agalactiae* (GBS). In 2010 BTM samples from all 4093 dairy herds were tested by real-time PCR and only samples positive for GBS by PCR were cultured for GBS. Results from BTM real-time PCR were distributed directly to farmers and advisors and a roughly grouping of results as problems with contagious mastitis, environmental mastitis and milking hygiene was introduced. Results from 2009 showed NoCt reaction in BTM for *Streptococcus uberis*, *Staphylococcus aureus, Escherichia coli* and GBS, in respectively 5, 9, 39 and, 93% of the herds. For the 12 different genes mean Ct values and Ct percentile 10, 25, 50, 75 and 90 were calculated. Real-time PCR were found to be more sensitive than culture for GBS. Real-time PCR identified 53% more herds as GBS-herds in 2009. The risk of a positive culture was markedly reduced with increasing Ct-value (weaker PCR reaction). The relation between Ct-value and culture sensitivity and the importance for identification of GBS infected herds will be described and discussed.

# Bedding conditioners for reduction of infectious pressure by mastitis pathogens – does their use make sense?

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The use of bedding conditioners is recommended within mastitis control programmes by some udder health services. The intention is to alter pH and moisture content and thus reduce infectious pressure caused by mastitis pathogens in bedding material. Although previous studies showed limited effects, even new conditioners are developed and placed in the market, supported by reports on reduction of bacterial counts under laboratory conditions and increase of pH in bedding material. Therefore, in our study two commercially available conditioners were tested with regard to their effects on pH, dry matter and bacterial counts in chopped straw and on bacterial contamination of teats in a free stall barn. For each experiment two groups of 25 cows were allocated in a cross-over design: one group served as control, in the other group bedding material was treated according to manufacturer's instructions. Treatments were changed after 3 weeks. Teats were sampled by swabbing 1 $cm^2$ of two teats per cow at the beginning of the study, and after 3 and 6 weeks each. Counts of coliforms, staphylococci, and streptococci were determined by use of selective media and related to visual contamination. Bedding samples were collected from 8 boxes per group in weekly intervals and tested for pH, dry matter and bacterial counts. Results were related to stall usage, which was observed 4 times per day. The results are currently evaluated but first evaluations show only small effects of the tested conditioners on the parameters determined. Our study may contribute to the discussion how to communicate results to farmers and to ensure that only measures based on scientific evidence are applied.

# Epidemiological and microbiological characteristics of *Streptococcus uberis* as mastitis pathogen in Swiss dairy herds

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Although *Streptococcus uberis* is a common cause of bovine mastitis, the epidemiology still is not fully understood and increasing rates of treatment failures are reported. To get a general idea about the situation in Switzerland 4 farms with *S. uberis* mastitis problems were examined by sampling all cows in lactation on two or three occasions. The microbiological analysis of the quarter foremilk samples were performed using standard procedures and a newly developed agar plate to identified *S. uberis*. In the 4 farms 103 S. uberis isolates from 69 quarters of 45 cows were found and further typed with the Multilocus Sequence Typing method (MLST). They belonged to 41 different sequence types (ST). Thereof 36 ST were found only in one cow each, three ST were found in two cows and one ST was detected in three cows, respectively. But one single ST was found in 25 quarters of 13 cows. None ST was found in more than one herd. The minimum inhibitory concentrations (MIC) of 15 antimicrobial agents against 62 *S. uberis* isolates were determined using custom made sensititre susceptibility plates. Six isolates showed a slightly decreased susceptibility against penicillin (MIC: 0.125 mg/l – 0.5 mg/l). 23 of the isolates were resistant to erythromycin and clindamycin, 22 of these isolates were additionally resistant against tetracycline. Five isolates were resistant against tetracycline and two isolates against clindamycin and tetracycline. *S. uberis* still must be mainly regarded as an environmental pathogen, but if conditions or cofactors promote infections, *S. uberis* seems to be able to spread like a contagious mastitis pathogen.According to the *in vitro* susceptibility results, penicillin remains the first choice of antimicrobial agent to treat *S. uberis* intramammary infections.

# Part 11
# Host resistance

# Immunological response to an experimental intramammary inoculation with a killed *Staphylococcus aureus* strain in vaccinated and non-vaccinated lactating dairy cows

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## Abstract

The objective of this study is to unravel the innate immunological response after administration of a novel vaccine (Startvac®, HIPRA, S.A., Amer, Spain), containing the inactivated *Escherichia coli* J5 strain and the *Staphylococcus aureus* SP 140 strain expressing Slime Associated Antigenic Complex (SAAC). In a challenge trial, the effect of vaccination on milk neutrophil viability and concentration was determined and several clinical parameters were observed. Six animals were included of which three were immunized at 45 days before the expected calving date followed by a second vaccination 35 days later. The other three cows serve as non-vaccinated controls. Fifteen days after calving, two contralateral quarters of each cow were inoculated with an inactive *S. aureus* isolate. Phosphate buffered saline was administered to the two control quarters. Quarter milk samples were collected at 2 hours before, and at 4, 12, 24 and 48 hours after challenge. Preliminary results indicate vaccinated cows develop a less severe inflammatory reaction after inoculation compared to non-vaccinated animals.

**Keywords:** mastitis, vaccine, immunity

## Introduction

Mastitis accounts for the largest proportion of antibiotic drug use in the dairy industry (Heringstad *et al.*, 2000). Ongoing political debates and public concerns about the emergence of antimicrobial resistance and drug residues in milk stress the need for alternatives to antibiotic therapy. In particular, the prophylactic use of antimicrobials is coming under scrutiny. One such use of antibiotics is dry cow therapy. As a consequence, there is an increasing interest in the possibilities to boost the host immune responses.

Both heifers and multiparous cows suffer from immune suppression around parturition, characterized by a higher proportion of less viable blood and milk polymorphonuclear neutrophils (PMN) (Van Oostveldt *et al.*, 2001; Mehrzad *et al.*, 2002). This phenomenon most probably explains the high incidence and increased severity of clinical mastitis in early lactation (Barkema *et al.*, 1998) as PMN play a key role in the elimination of bacteria in the early stages of intramammary infection (IMI) (Paape *et al.*, 2002).

Enhancement of the immunological response by vaccination is an attractive alternative approach for mastitis prevention and control. Prepartum vaccination did reduce the severity and duration of clinical disease post-challenge in one study (Middleton *et al.*, 2006), and had a positive effect on milk production in another study (Pellegrino *et al.*, 2008). However, little is known about the effect of vaccination on the functionality of PMN.

The aim of this study was to evaluate the effect of administration of the Startvac vaccine® (HIPRA, S.A., Amer, Spain) on milk PMN concentration and viability. Preliminary results of six cows are presented.

## Materials and methods

Six clinically healthy cows and heifers were selected at the research dairy farm of the Faculty of Veterinary Medicine, Ghent University, Belgium (Agri-Vet). Three animals were vaccinated intramuscularly at 45 days and 10 days before the expected calving date with the Startvac® vaccine (HIPRA, S.A., Amer, Spain) containing the inactivated *Escherichia coli* J5 strain and the *Staphylococcus aureus* SP 140 strain expressing Slime Associated Antigenic Complex (SAAC) (Prenafeta *et al.*, 2010). At 15 days in milk (DIM), two contra-lateral quarters of each of the six cows were inoculated with the formaldehyde killed *S. aureus* C 195 strain (HIPRA, S.A., Amer, Spain) 2 hours after morning milking. The two other quarters were inoculated with phosphate buffered saline (PBS) and served as control quarters. Duplicate quarter milk samples (5 ml) were aseptically collected for bacteriological culturing and determination of the somatic cell count (SCC) at different time points before and after inoculation (Table 1). Bacteriological culturing was performed at several time points to exclude interference with naturally occurring IMIs. Additionally, quarter milk samples (200 ml) were collected for the quantification of PMN viability at different time points between 15 and 17 DIM (Table 1).

Bacteriological culture was done as previously described (Piepers *et al.*, 2007) and performed at the lab of the Mastitis and Milk Quality Research Unit (Merelbeke, Belgium). Quarter milk SCC (qSCC) was quantified by electronic counting (Direct Cell Counter, De Laval, Gent, Belgium).

The milk used to isolate PMN was divided into several 50 ml Falcon-tubes and diluted 1:1 with PBS. All tubes were centrifuged (600×g) during 15 minutes, the cream layer and supernatant were removed, and each pellet was suspended into 10 ml PBS. Two pellets were merged together and again centrifuged (200×g) during 10 minutes, this was repeated two more times. Subsequently, milk PMN were differentiated from other milk cells by a two-step fluorescent immunolabeling using a primary anti bovine monoclonal granulocyte antibody (CH138A)

*Table 1. Sample overview.*

| Tasks | Days before calving | | Days into milk | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 45d | 10d | 2-6d | 10-14d | 15d –2h | 15d | 15d +4h | 15d +12h | 16d | 17d |
| Vaccination [1] | × | × | | | | | | | | |
| Challenge | | | | | | × | | | | |
| Collection of milk samples: | | | | | | | | | | |
| Somatic cell count | | | × | × | × | | × | × | × | × |
| Bacterial culture | | | × | × | × | | × | × | × | × |
| PMN[2] | | | | | × | | × | × | × | × |

[1] Three of the six cows were vaccinated.

[2] Polymorphonuclear neutrophils.

(VMRD Inc., Pullman, WA, USA) and an Alexa 647 labeled goat anti mouse IgM secondary antibody (Molecular Probes, Invitrogen, Nederland) as previously described (Piepers *et al.*, 2009). To identify apoptotic and necrotic PMN, a double fluorescein isothiocyanate (FITC)-annexin-V (Roche, Indianapolis, IN, USA) and propidium iodide (PI) (Sigma-Aldrich, Bornem, Belgium) staining was used. PMN that were positive for FITC and negative for PI were considered as (early) apoptotic whereas PMN that were positive for both FITC and PI were considered necrotic. Polymorphonuclear neutrophilic leukocytes that were negative for both stains were considered viable (Piepers *et al.*, 2009; Van Oostveldt *et al.*, 2001).

Linear mixed regression models adjusting for clustering of repeated measurements within quarters as well as for clustering of quarters within cows were fit to evaluate the association between the cows' vaccination status before calving and the evolution of qSCC, milk PMN concentration ($Log_{10}$PMN), and milk PMN viability (expressed as the proportion of viable PMN), respectively, in both the inoculated and control quarters.

## Results

All animals remained clinical healthy during the trial period. Challenge did not affect clinical parameters such as heartbeat rate, respiration rate, manure consistence or appetite. The average body temperature 2 hours before inoculation was 38.4 °C and 38.8 °C for the vaccinated and non-vaccinated animals, respectively, and did not significantly differ between both groups. In both groups, body temperature slightly increased between 15 and 17 DIM (Figure 1).

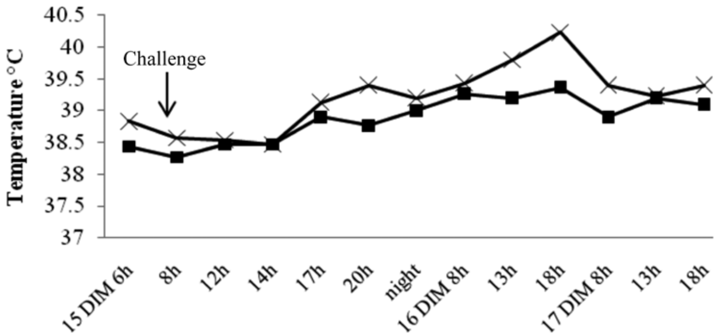


*Figure 1. Temperature (°C) from the vaccinated (■) and non-vaccinated (×) group starting from 15 DIM until 17 DIM.*

The average daily milk yield (MY) per cow was 33.1 liter at the onset of the trial. In the non-vaccinated group average daily MY decreased from 32.3 liter/day at 15 DIM to 27.3 liter/day at 16 DIM ($P$=0.06). In the vaccinated group, no significant differences in average daily MY were observed over time. In both groups of animals, the qSCC of the challenged quarters increased over time. The difference in qSCC between the control and inoculated quarters was substantially higher in the non-vaccinated animals compared with difference in vaccinated animals ($P$<0.001). Interestingly, in the vaccinated group the increase of the qSCC in the infected quarters was not significantly different from the qSCC in the control quarters ($P$=0.21) (Figure 2). Similar results were obtained for the milk PMN concentration (Figure 3). The preliminary results on average daily MY and qSCC correspond well with the findings of other studies (Nickerson *et al.*, 1999; Middleton *et al.*, 2006). The difference in PMN viability between inoculated and control quarters during the trial period did not depend on the vaccination status of the animal.

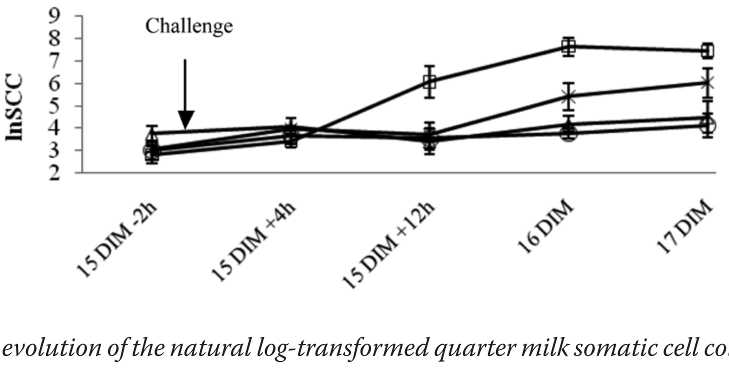


*Figure 2. The evolution of the natural log-transformed quarter milk somatic cell count (qLnSCC) (± standard error) from non-vaccinated control quarters (○),vaccinated control quarters (▲), vaccinated challenged quarters (×), and non-vaccinated challenged quarters (■).*

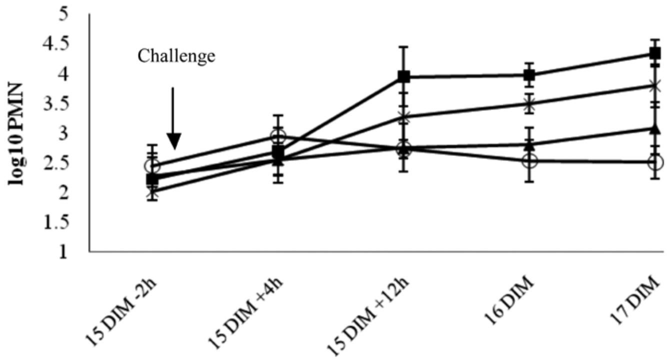


*Figure 3. The evolution of the milk PMN concentration ($Log_{10}$PMN) (± standard error) from non-vaccinated control quarters (○),vaccinated control quarters (▲), vaccinated challenged quarters (×), and non-vaccinated challenged quarters (■).*

## Conclusions

Based on these preliminary results, vaccinated cows seem to undergo a less severe inflammatory reaction after inoculation compared to non-vaccinated animals. This could possibly explain why no change in daily MY was observed in the vaccinated animals, while the non-vaccinated animals suffered from a substantial drop in milk production in the days after challenge. Further research is definitely needed before final conclusions on the impact of prepartum vaccination on the cows' innate immune response shortly after calving can be drawn.

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# Feasibility of high immune response (HIR) technology as a health management tool to characterize immune response profiles of dairy cattle

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## Abstract

High Immune Response (HIR) is a patented evaluation technology that has the potential to improve the health and food quality of dairy cattle through the reduction of antibiotics and enhanced resistance to economically important diseases such as mastitis. The test includes a blood sample to evaluate antibody-mediated immune response (AMIR) and a skin thickness measurement to evaluate cell-mediated immune response (CMIR). Dairy cattle with a high immune response to test antigens are at a lower risk for developing disease compared to average and low responding animals. Focus groups conducted in two Ontario dairy regions indicated significant interest in HIR (75% of producers) for culling, grouping, treating, and breeding animals. Pre-commercialization activities are underway to conduct: (1) a quantitative market assessment of interest in HIR throughout Ontario (n=128 producers, 3% of Ontario herds) to confirm qualitative focus group data; (2) HIR testing of Ontario AI cull-sires as an application of HIR and to demonstrate no cross-reactivity with governmental health testing; (3) a validation study of previous research to rank cattle based on antibody from milk in lieu of blood (n=21 cows); and (4) beta-testing of HIR on one to two Ontario dairy herds to demonstrate the economic value of HIR (n=250-350 animals per herd). Knowledge transfer and communication research of the HIR technology are also being conducted by attending dairy symposia throughout Ontario to speak to producers and veterinarians, to provide information media, and to recruit participants for educational workshops about HIR.

**Keywords:** disease, resistance, sustainability, knowledge transfer

## Introduction and background

Genetic selection, mainly focussed to improve dairy milk production traits with minimal emphasis for health traits, has gradually led to an increase in the incidence of disease among dairy animals. Recently, the dairy industry has been diligently working to provide genetic and management solutions for improved health in order to correct this problem, particularly in light of the increase in emerging disease and antibiotic resistance in livestock. Dairy cattle face challenge by diverse bacterial, viral, and other pathogens. The immune system provides host defense via genetically and environmentally regulated cells and molecules that respond to pathogens. The immune system can be characterized as having two interconnected systems - the innate system which includes physical barriers and some enzymes and cells that have the ability to respond to a first encounter with a pathogen, and the adaptive immune system which has the hallmark characteristics of memory, diversity, specificity and self/non-self recognition. These features allow the system to respond to an invader on second exposure more rapidly to remove that pathogen swiftly and effectively. The adaptive immune system can be further characterized by its ability to respond to different pathogens as a result of the activation of T helper cells. T helper 1 (Th1) cells predominately produce cytokines that generate a cell-mediated immune response (CMIR) to respond to intra- cellular pathogens like *Mycobacterium avium paratuberculosis* that cause Johne's disease, whereas T helper (Th2) cells produce cytokines that tend to generate an antibody-mediated immune response (AMIR) towards extra-cellular pathogens like *Escherichia coli* known to cause mastitis. For selection of broad-based disease resistance to be effective, the individuals selected for breeding subsequent generations must demonstrate a favourable AMIR and CMIR response to both extra-and intra-cellular organisms, respectively.

Genetic regulation of immune response and selection for disease resistance is well documented and considered a preventative method to improve animal health (Stear *et al.,* 2001). There is solid evidence that selective breeding for high (H) or low (L) immune response influences resistance to infectious disease (Kelm *et al.,* 2001) and heritability of AMIR and CMIR are stable and moderate to high, indicating that genetic selection is feasible. In fact, identification of H immune responders is associated with lower disease risk and improved response to vaccines in dairy cattle (Wagter *et al.,* 2000; Hernandez-Heriazon, 2007; DeLaPaz, 2008). Work by Wagter *et al.* (2000) demonstrated that dairy cattle could be classified based on their antibody response profile to ovalbumin and when evaluated for disease occurrence, cows that had a H antibody response, were found to have no mastitis in 2 of the 3 herds investigated. Recent work done by DeLaPaz *et al.* (2008), on a large US Florida herd to evaluate HIR response profiles on approximately 875 cows and evaluate health data, indicated that cows that had a H immune response to antigens for both CMIR and AMIR had significantly lower odds ratio risk for developing mastitis, metritis, ketosis, and retained fetal membranes compared to those having an average (A) or a L immune response.

HIR technology may be useful as a management tool for the prevention or reduction of diseases like mastitis, which is the disease of most significant economic importance to the dairy industry. As well, the application of HIR may result in a reduction of a broad range of diseases. This will result in improved food quality, and a decreased dependence on antibiotics to treat disease. After several years of research, the HIR technology is now ready to be transferred to the dairy marketplace. Feasibility research must be conducted to test the hypothesis that the High Immune Response (HIR) technology is economically beneficial to the dairy industry and is ready for commercial application. Feasibility research will address the following sub-hypotheses: (1) the dairy industry is interested in HIR as management tool for disease control; (2a) Immune Response (IR) estimated breeding values (EBV) can be used to identify sires and their daughters with improved health; (2b) sires can be IR tested without any adverse reactions or cross-reactivity with the required federal diagnostic tests; (3) milk whey in lieu of sera can be used to rank cows for IR and milk samples are readily obtained through dairy herd improvement programs; (4) beta-testing can help estimate the economic value of HIR; and (5) knowledge transfer research is useful for evaluating awareness of HIR.

## Methods

### *Quantitative market assessment of HIR*

Over 1000 Ontario dairy producers were contacted to participate in an on-line survey to provide information on their dairy operation, management priorities and attitudes towards health management. They were presented with the HIR concept including the features of the test (Figure 1), and their interest and willingness to try HIR was evaluated. One hundred twenty eight producers (3% of Ontario dairy herds) completed the survey on-line (n=117) and by letter mail (n=11). Results obtained with this sample size were accurate within ±10% nineteen times out of twenty (95% CI).

### *Sire testing*

Ten proven sires scheduled for removal were HIR tested in 2 groups of 5 sires in October 2010 and January 2011. All sires were housed in a separate barn at the sire testing facility. Sires were immunized with specified antigens that stimulate immune response according to the patented test protocol, to evaluate AMIR by ELISA test, and CMIR by a skin thickness increase measurement (Figure 1). The HIR test was conducted after sires were determined to be negative for all Canadian Food Inspection Agency (CFIA) disease testing, including tuberculosis (Tb). They were then further tested by CFIA one week after HIR testing was complete.

### *Validation study*

Twenty one cows from the University of Guelph Elora Dairy Research station were immunized with antigens that stimulate AMIR and CMIR immune responses. Blood was collected 14 days

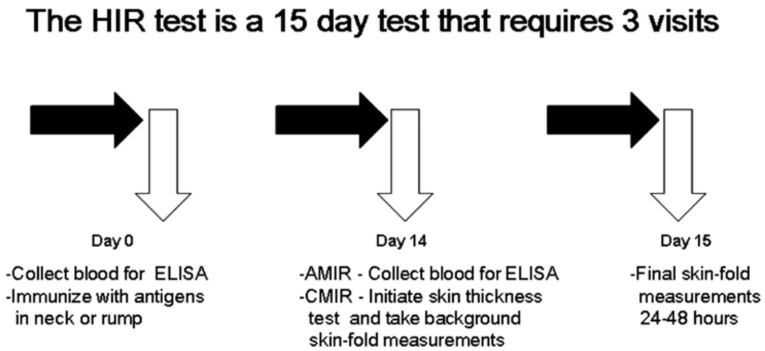


*Figure 1. Features of the high immune response test in dairy cattle.*

before calving (day 0), and at calving blood and colostrum were collected. Both blood and milk were collected on days 1, 2, 3, 4, 5 after calving. Cows received another immunization on days 3, 4, or 5, and another blood and milk sample were collected 7 days later. A sub-sample of 9 cows were further immunized in late lactation, and two weeks later were evaluated for their AMIR responses in whey and sera. This study will validate previous research by Wagter *et al.,* 2000, which demonstrated that cattle ranked high for serum antibody to ovalbumin in sera also have high antibody in colostrum and milk whey.

### Beta-testing HIR

Two Ontario dairy producers have had their herds tested using the HIR patented test protocol (Figure 1). After CMIR and AMIR data are compiled, animals will be ranked based on their IR EBV profile. Disease and health management costs will be collected and interpreted with the assistance of the producer to establish the value of the test relative to costs associated with treating and preventing disease.

Development of communications media and a training workshop to raise awareness of HIR to assist with improving knowledge transfer of a health technology

A USB drive containing a video about HIR will be handed out to producers and veterinarians at various dairy and veterinary symposia throughout Ontario and the US. It will contain supporting documentation and contact information with a link to social media about HIR. Producers and bovine practitioners will be invited to participate in a workshop about HIR at a later date. A preliminary Knowledge Attitudes and Behaviour (KAB) survey given before and after the workshop to assess the knowledge transfer of HIR. Workshops will be organized in 2012, and results will be presented in late 2012.

## Results

### *Quantitative market assessment of HIR in Ontario dairy herds*

Producers were asked to respond by applying a level of importance to a list of the benefits and concerns cited by dairy producers that participated in qualitative HIR focus groups. The major benefits cited include the ability to cull animals early, HIR would lead to a more productive herd, and the reduced need for antibiotics. The major concerns include: expense, accuracy of test, and the inconvenience of a blood versus milk test. Eighty nine percent of producers surveyed indicated an interest in HIR (Figure 2). When asked how they would use HIR if they tried it and were satisfied with how it worked, the majority of producers (59%) indicated they would use it on their entire herd, 31% on their milking cows only, 4% on their calves, and 6% would try it on some of their animals. (Figure 3).

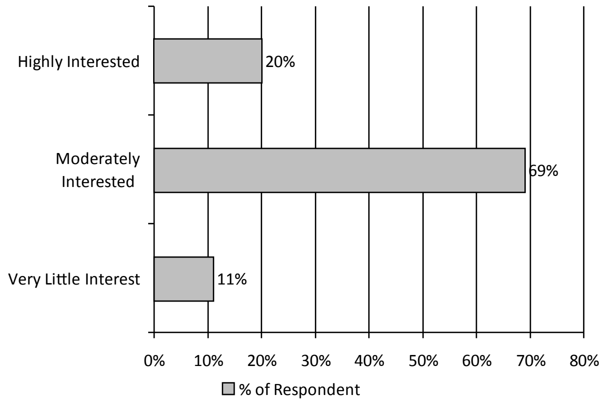


*Figure 2. Producer interest in HIR.*

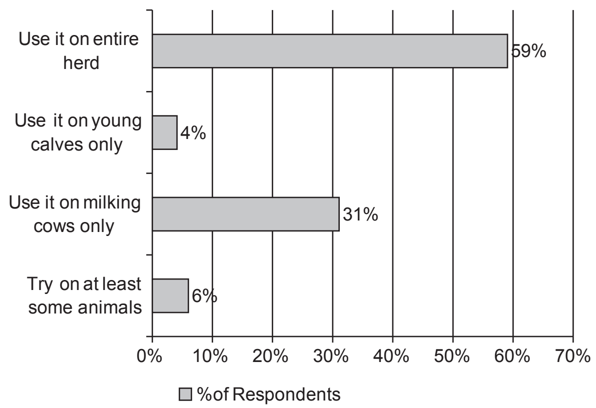


*Figure 3. Producer uses of HIR.*

### *Sire testing*

Sires tested showed variation in AMIR and CMIR. There are sires that are high for CMIR and AMIR, some that are low for both, and some that are high for one or the other response. No adverse reactions were noted with the test and all sires were negative for CFIA health testing, including Tb, before the HIR test and following the HIR test.

### *Validation study*

Analysis of variance and correlation analysis are underway to validate that antibody response in sera ranks similarly in whey during early and late lactation. Visual inspection of individual graphs for each cow during the peripartum period indicates that animals, that are high or low for antibody in sera, have a high or low response in colostrum and whey, respectively.

### *Beta-testing HIR*

Both herds have completed HIR testing and AMIR responses are currently being assessed in the lab. General linear model analysis will be conducted, and estimated breeding values will be calculated. After the animals are ranked producers will assist in providing a perspective on the economic value of HIR.

## Discussion

The dairy industry is looking for sustainable approaches to minimize disease and therapeutic treatment, while at the same time optimize production in dairy cattle. Before the HIR concept and its features were presented in the market survey, producers were asked the following: (1) if they could identify disease prone animals within their herd, and were then asked to (2) express how valuable it would be to be able to confirm this using a diagnostic test. Producers indicated that it would be extremely (28%) or somewhat valuable (65%) to have a way of identifying a disease prone animal. Preliminary results of the quantitative market research of HIR indicated that 89% of Ontario producers surveyed are interested in the HIR technology and only 11% are not (Figure 2). Approximately 59% of 128 producers indicated that they would try it on their entire herd (Figure 3). These results are very promising for HIR as this indicates the majority surveyed would use the technology to test both their lactating cattle and young stock. Some producers (31%) indicated that they would only test their milking cows. Although there may be benefit in identifying IR of calves early to determine which animals will be the better investment for better health, few data points of information are available on calves in contrast to that collected on a lactating cow. With information on lactating cattle readily available from management software and dairy herd improvement reports, a producer can better evaluate the value of HIR to them. This group of producers may proceed to test calves after the milking herd is tested and are sufficiently satisfied with the technology and its claims. The quantitative market survey indicated that the top three major benefits of HIR include identifying animals for culling, increased productivity in herds, and the reduced use of antibiotics. The top 3 concerns include: expense, accuracy, and the inconvenience of a blood test over a milk test. The market assessment further indicated that producers understand HIR and its purpose. They see the value in the test and this evaluation has given the developers insight and direction on how to position HIR in the marketplace. The information provided by this market assessment was extremely valuable to understand producer attitudes and potential willingness to try the HIR technology. It was instrumental in identifying concerns and while valid, some of these concerns are not supported by previous research on HIR. These concerns can be addressed through marketing campaigns at dairy and veterinary symposia, and technology transfer events. This knowledge transfer and communication strategy may help overcome some of the possible barriers to understanding and adopting HIR.

Phenotypic variation in HIR response in sires was evident in this feasibility study, and did not interfere with federal government health testing. While detailed statistical analysis is not yet available, variation in AMIR and CMIR results are expected to support that HIR will be useful for identifying sires and their daughters with improved health.

Validation data will be evaluated to confirm that cattle that are high for antibody response in sera, will also be high in colostral and milk whey in early and late lactation. A complete statistical analysis is required to confirm this correlation. This information will be extremely valuable to dairy herd improvement programs that currently provide management services through the regular collection of milk for component analysis and diagnostic ELISA testing for pathogens causing disease. As milk is more readily obtained than a blood sample, the evaluation of a milk sample in a herd improvement testing lab will offer a convenient option for assessing the AMIR part of the HIR test.

Beta-testing is a marketing application to test a product in the real world. It has allowed the developers to apply the procedure in different testing scenarios, to aid in understanding how best to apply the business model particularly in large herds. Although HIR test results for beta-testing for each herd are still being evaluated statistically and EBV calculated, we expect to complete these by the fall of 2011. Producers will give their opinion on the value of knowing which animals are H, A and L responders, and what it means to them in terms of savings or losses in their health management program. Taken together, beta-testing results and the market assessment will be very useful resources for developing a business model for HIR that will be feasible for the dairy marketplace.

Finally, a knowledge transfer communications study of HIR is expected to help dairy producers and veterinarians better understand and support HIR. The results of this knowledge transfer assessment will be evaluated and presented in late 2012.

## Acknowledgements

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# Polymorphism screening and association study of *CXCR1* with udder health in dairy heifers

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## Abstract

Similar to other countries, heifer mastitis is highly prevalent in Belgium. Marker assisted genetic selection against certain disadvantageous genotypes could offer possibilities to enhance host resistance. The main objective of this study was to screen *CXCR1* for polymorphisms and to analyze their association with udder health during first lactation. This potential candidate gene encodes the homonymous receptor binding interleukin 8, a crucial chemokine in the innate immunity of the mammary gland. Eighty-six heifers originating from 20 Belgian farms were genotyped for the entire coding region. Fifteen single nucleotide polymorphisms (SNPs) were detected of which 10 have not been described before. Four distinct haplotypes were detected. The association between SNP at position +735 relative to the start codon (c.735C>G) and subclinical mastitis which has already been reported by other research groups could not be confirmed in our study. Instead, SNP c.642G>A was found to be associated with udder health. Prevalence of intramammary infection (IMI) in early lactation was significantly lower in heifers expressing genotype AA compared to heifers expressing genotype AG or GG. Additionally, SNP c.982A>G tended to be associated with pathogen group specific IMI. Heifers with genotype GG on this locus were more susceptible specifically to major pathogens compared to those expressing genotype AG or AA. Numerical differences in somatic cell count in early lactation and throughout lactation by *CXCR1* genotype were observed but were not statistically significant. Results in this study are promising and stimulate to further elucidate the role of *CXCR1* in mastitis susceptibility.

**Keywords:** *CXCR1* polymorphisms, heifer mastitis, genetic resistance

## Introduction

Mastitis threatens udder health and milk quality of both pluriparous cows and heifers. Even before first milking, a large proportion of dairy heifers suffer from intramammary infection (IMI) (Fox, 2009). Resistance towards IMI is partly genetically determined (Nash *et al.*, 2003). Selection of heifers less susceptible to mastitis might hence offer a durable and sustainable approach in the prevention of heifer mastitis and fits perfectly with the policy to limit antimicrobial drug use in veterinary medicine. Identification of genetic polymorphisms linked with (heifer) mastitis resistance would allow evaluation of genetic make-up of breeding animals for udder health, even before their offspring is born. For this reason, genetic markers associated with udder health are searched for (Ogorevc *et al.*, 2009).

Migration of neutrophils from peripheral blood to the milk is a key event in the immune defense of the mammary gland against invading bacteria (Paape *et al.*, 2000). Interleukin 8 (IL8) is the main chemoattractant in this process (Barber and Yang, 1998; Caswell *et al.*, 1999) and binds on two receptors, namely IL-8 receptor-α (CXCR1) and IL-8 receptor-β (CXCR2). Polymorphisms in the encoding genes (*CXCR1* and *CXCR2*) might affect expression or functionality of the receptor causing variability in the innate immune responses subsequent to the contact with a mastitis pathogen. Until now, 5 polymorphisms in the coding region of *CXCR1* have been identified (Grosse *et al.*, 1999; Pighetti and Rambeaud, 2006; Youngerman *et al.*, 2004b) of which some seem to explain part of the existing variability in udder health (Galvao *et al.*, 2011; Youngerman *et al.*, 2004a).

It is reasonable to believe that *CXCR1* polymorphisms might play a key role in the host resistance of periparturient heifers as well and could hypothetically explain part of the variation in prevalence and incidence of heifer mastitis. However, *CXCR1* polymorphisms have yet not been studied as potential risk factors for heifer mastitis. The objectives of this study were to screen the entire coding region of *CXCR1* for polymorphisms and to analyze potential associations between *CXCR1* polymorphisms and subclinical mastitis phenotype (quarter milk SCC in early lactation, IMI status in early lactation, and composite milk SCC during first lactation) in Belgian dairy heifers.

## Materials and methods

### *Herds and heifers*

The dataset for current research consisted of phenotypic records (Piepers *et al.*, 2010, 2011) combined with data on the *CXCR1* genotype. In total, 86 Holstein-Friesian heifers originating from 20 commercial dairy farms were included. To avoid bias of additive effects by background genes, only one heifer per sire was selected.

### *Mastitis phenotype*

Intramammary infection status in early lactation was determined on the outcome of bacteriological culture of two consecutive milk samples collected between 1- 4 DIM, and 5-8 DIM, respectively (Piepers *et al.*, 2011). Quarter milk SCC at both samplings was determined at the Milk Control Centre (MCC) Flanders (Lier, Belgium). As it was decided to specifically focus on subclinical mastitis, records on quarters reported to be clinically infected (n=4) were considered as missing values. Composite milk SCC throughout first lactation was determined on milk samples collected on a four- to six-weekly basis as part of the dairy herd improvement program.

### *CXCR1 genotyping and polymorphism screening*

DNA was released from blood samples and used as a template to amplify simultaneously both copies of the complete *CXCR1* coding region in a single polymerase chain reaction (PCR). The PCR product of each heifer was sequenced by direct sequencing using the primers designed for the PCR as sequencing primer. Sequences were compared with the reference sequence (GenBank Gene ID: 281863) and with each other to identify polymorphisms. Haplotypes were identified based on homozygous genotypes, present in a number of animals.

### *Statistics*

The associations between the different polymorphisms and presence of IMI in early lactation were determined using logistic mixed regression models including heifers' genotype at the position of the polymorphism as categorical fixed effect. Different models were fit separately for three different binary outcome variables: (1) 'CNS IMI' (0 = non-infected quarter versus 1 = quarter infected with coagulase-negative staphylococci); (2) 'Major pathogen IMI' (0 = non-infected quarter versus 1 = quarter infected with *Staphylococcus aureus*, *Streptococcus agalactiae*, *Streptococcus dysgalactiae* or esculine-positive streptococci); and (3) 'all IMI' (0 = non-infected quarter versus 1 = quarter infected with CNS, *Corynebacterium bovis*, *S. aureus*, *S. agalactiae*, *S. dysgalactiae* or esculine-positive streptococci).

Associations between the different polymorphisms and quarter milk somatic cell count (SCC) in early lactation and composite milk SCC during lactation, respectively, were tested using linear mixed regression models also including heifers' genotype at the position of the polymorphism as categorical fixed effect. To obtain a normal distribution, a natural logarithmic transformation of all SCC data was performed.

## Results

### *Descriptive statistics*

In total, 39% of the quarters and 9% of the heifers were non-infected. Approximately 41% of the quarters and 76% of the heifers were subclinically infected with the vast majority of these IMI being caused by CNS. Infections by major pathogens were detected in 18 quarters of 13 heifers. Esculine-positive streptococci were the most frequently isolated major pathogens, followed by *S. aureus*.

Infected quarters had higher geometric mean quarter milk SCC (229,000 cells/ml) than healthy quarters (118,000 cells/ml) ($P<0.001$). During lactation, the composite milk SCC followed a quadratic curve. The geometric mean was 94,000 cells/ml between 14 and 45 DIM, declined to 63,000 cells/ml between 76 and 105 DIM and rose again till 114,000 cells/ml between 256 and 285 DIM.

### *Polymorphisms*

Fifteen polymorphisms were detected of which 8 are silent and 7 are non-silent. Many were in complete linkage disequilibrium with each other. Consequently, only 4 distinct haplotypes were found. Associations with polymorphisms c.642G>A, c.735C>G, c.816C>A, and c.980A>G were studied. All others were in complete linkage disequilibrium with either one of abovementioned polymorphisms.

### *Associations*

Intramammary infection status in early lactating heifers was found to be associated with *CXCR1* polymorphisms c.642G>A and c.980A>G, respectively. Quarters from heifers with genotype AA on position 642 were less likely to have IMI by whatever pathogen and IMI by CNS compared to quarters from heifers with genotype AG or GG on position 642 ($P<0.05$). Additionally, quarters from heifers expressing genotype GG on position 980 were more likely to be infected than quarters from heifers expressing genotype AG on position 980 ($P=0.06$). No associations were detected between *CXCR1* polymorphisms and quarter milk SCC in early lactation or composite milk SCC during first lactation.

## Discussion and conclusions

To further improve prevention and control of heifer mastitis, identification of more risk factors is requested. Previous studies stress the importance of host-specific factors (De Vliegher *et al.*, 2004; Piepers *et al.*, 2011) and heifer mastitis has shown to be partly genetically determined (Nash *et al.*, 2003). Although many genes influence host resistance, a few major genes affecting mastitis susceptibility might exist (Detilleux, 2009). In current research, *CXCR1* was selected as study object because of the crucial role of the encoded protein in the innate immunity of the udder (Caswell *et al.*, 1999) and its recently demonstrated relevance in mastitis resistance (Galvao *et al.*, 2011; Leyva-Baca *et al.*, 2008; Youngerman *et al.*, 2004a). Novel polymorphisms were detected and associations with subclinical mastitis phenotype of Belgian dairy heifers were found.

Our research differed from previous research in the way that the whole coding region rather than a segment of the coding region of *CXCR1* was screened for polymorphisms. This resulted in the discovery of 10 novel polymorphisms that have to the best of our knowledge yet not been described in literature.

Intramammary infection status at quarter level by bacteriological culture is usually not available on large scale, although it is interesting to study as it is a direct parameter for udder health. Not all pathogens have the same impact on udder health and milk production of early lactating heifers (Piepers *et al.*, 2010). Selection should mainly aim at reducing IMI by major pathogens rather than reducing IMI by minor pathogens known to be more prevalent but having only moderate impact on production and udder health. Although complicating the analysis, we studied associations with both IMI by all pathogens and pathogen-group specific IMI (IMI by CNS and IMI by major pathogens). This allowed us to show an association between novel polymorphism c.980A>G and IMI caused by major pathogens while this association was observed neither with IMI caused by all pathogens nor with IMI caused by CNS. Besides polymorphism c.980A>G, polymorphism c.642G>A was found to be associated with IMI status in early lactation. Both IMI by all pathogens and IMI by CNS were less prevalent in quarters from heifers expressing genotype GG compared to quarters from heifers expressing genotype GA and AA. Differences in quarter milk SCC in early lactation or composite milk SCC during first lactation by *CXCR1* genotype were observed but not significant.

Current results indicate selection against certain *CXCR1* genotypes could offer possibilities for prevention and control of heifer mastitis. However, more research is required to further unravel the impact of *CXCR1* polymorphisms on innate immunity and pathogen-specific resistance of the mammary gland.

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# Genomic regions associated with somatic cell score in dairy cattle

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## Abstract

The EU project RobustMilk combines unique data from research dairy herds located in four European countries. The dataset contains detailed recordings on somatic cell score (SCS), with up to 50 SCS test-days per cow per lactation. Variation in SCS can be due to genetic and environmental factors. The aim of the present study was to identify regions on the genome that contribute to genetic variation in lactation-average SCS (LASCS) and the standard deviation of SCS (SCS-SD). The standard deviation of SCS aims to capture temporary increases in SCS associated with infection. First lactation SCS records and DNA of 1,484 cows were analysed. Cows were genotyped for 50,000 markers. Each individual marker was tested for its detection of variation in LASCS or SCS-SD. One marker on chromosome (BTA) 18 detected variation in both LASCS and SCS-SD. One marker on BTA4 detected variation in LASCS, and one marker on BTA6 detected variation in SCS-SD. The present study identified genomic regions on BTA4, BTA6 and BTA18 contributing to genetic variation in LASCS and SCS-SD. More knowledge on genetic control of LASCS and SCS-SD may not only enable more accurate breeding value estimations that allow farmers and the dairy industry to reassess their selection decisions, but also helps to find genes for mastitis resistance which is relevant for understanding the genetic mechanisms leading to mastitis.

**Keywords:** single nucleotide polymorphism, genome-wide, mastitis, loci, somatic cell count

## Introduction

The EU funded project 'RobustMilk' (www.robustmilk.eu) is a collaboration between six European research institutes that are actively working in dairy cattle breeding and that have close relations with the dairy industry. This collaboration has the aim to develop new technologies to enable dairy farmers and the dairy industry to reconsider their selection decisions, with a focus on milk quality and dairy cow robustness. The project combines unique data on Holstein dairy cows from research dairy herds located in four European countries; Ireland, the Netherlands, Scotland and Sweden. These data not only contain detailed recordings on somatic cell score (SCS), with up to 50 individual test-days per lactation, but also genomic information on cows.

Genome-wide association studies (GWAS) use a dense set of DNA markers distributed across the genome to survey the genome for regions contributing to genetic variation that exists within a trait (Hirschhorn and Daly, 2005). Essentially, GWAS compare frequencies of allelic or genotypic variants within each marker with the phenotypes of animals that carry these variants (Hirschhorn and Daly, 2005). By locating markers that detect genetic variation for a trait, GWAS may not only provide a better understanding of genetic control of somatic cell score through identification of genes, but also enable more accurate estimation of genetic merit of animals (e.g. Pryce *et al.*, 2010).

Traditional genetic selection for SCS, relying on phenotypic and pedigree information, is difficult (Baes *et al.*, 2009), mainly due to a negative genetic correlation between SCS and production traits (e.g. Rupp and Boichard, 1999) and a relatively low heritability for SCS (e.g. Rupp and Boichard, 2003). Further, SCS can only be measured on cows and not on bulls. As such, selection for SCS may be enhanced by genomic information.

Generally, lactation-average somatic cell score (LASCS) is used as indicator for mastitis and used in genetic selection for mastitis resistance (Miglior *et al.*, 2005). The LASCS captures variation in the average SCS level of a lactation between cows. Variation in SCS levels during lactation within cows, however, is not captured by LASCS (De Haas *et al.*, 2003). The standard deviation of test-day SCS (SCS-SD) largely reflects this variation and aims to capture temporary elevations in SCS levels associated with mastitis (Urioste *et al.*, 2010). The SCS-SD is genetically variable and strongly positively correlated with clinical mastitis which makes SCS-SD, in addition to LASCS, an interesting candidate for genetic selection for mastitis resistance (Urioste *et al.*, 2010).

The present study aims to identify regions on the genome that contribute to genetic variation in LASCS and SCS-SD through a GWAS using combined data on Holstein cows from four different European research herds.

## Materials and methods

The RobustMilk project combines data from research dairy herds located in four European countries; Ireland, the Netherlands, Scotland and Sweden. Within each country, cows were located in different herds; this study includes three Irish, two Dutch and one Swedish herd. The Scottish cows were part of two genetic lines. One line was selected for kilograms of milk fat plus protein and the other line was selected to resemble the average genetic merit for milk fat plus protein for all UK evaluated cows (Veerkamp *et al.*, 1994). The present study treats these lines as two separate herds. At the time of data recording some cows in the RobustMilk project were subjected to dietary treatment as part of other studies. Data were recorded between 1989 and 2009.

### Genotypes

DNA was extracted from blood samples. Cows were subsequently genotyped for approximately 50,000 markers by a commercial genotyping company (ServiceXS, Leiden, The Netherlands) using the Illumina BovineSNP50 BeadChip (Illumina Inc., San Diego, CA, USA). A quality control on the markers was performed as reported by Wijga *et al.* (2010). All cows genotyped within the RobustMilk project were checked for pedigree inconsistencies using the methodology outlined by Calus *et al.* (unpublished data).

### Animals and phenotypes

The phenotypic dataset consisted of 81,408 first lactation records on 1,816 genotyped and pedigree checked Holstein cows. Only test-day records with somatic cell count (SCC) above zero and that were recorded before 350 days in lactation were retained. Cows that had fewer than ten SCC test-day records were removed from the data to have adequate records for estimating mean and standard deviations of SCC. The edited data used for analyses consisted of 46,882 first lactation records from 1,484 Holstein cows located in four countries; Ireland (n=329 cows; 8,795 test-day records), the Netherlands (n=574 cows; 17,024 test-day records), Scotland (n=390 cows; 13,312; test-day records) and Sweden (191 cows; 7,751 test-day records). The LASCS and SCS-SD were calculated for each cow based on her test-day records. Lactation SCC measurements were log-transformed (Ali and Shook, 1980) to LASCS, where

$$LASCS = \log_2\left(\frac{\Sigma SCC}{n}\right) \quad (1)$$

The standard deviation of first lactation test-day SCC was log-transformed to SCS-SD where

$$SCS - SD = \log_2\left(\frac{\Sigma(SCC - \mu)^2}{n-1}\right) \quad (2)$$

### Statistical analyses

Each individual marker was tested for its detection of genetic variation in LASCS or SCS-SD using a linear animal model in the software package ASReml (Version 3; Gilmour *et al.*, 2009), which accounted for genetic relationships between animals. Data were analysed according to the model

$$y_{ijkl} = \mu + CHYST_i + Birthyear_j + Marker_k + Animal_l + e_{ijkl} \quad (3)$$

where $y_{ijkl}$ was the response variable corresponding to SCS or SCS-SD of cow $l$ from CHYST-group $i$ born in year $j$ with marker genotype $k$, the fixed effect $CHYST_i$ accounted for effects of management through the combination $i$ of country (C) and herd (H) in which the record was produced, the year (Y) and season (S) of calving of the cow producing the record and the treatment (T) the cow received during lactation ($i$ = 1 to 146). Seasons were defined as calendar quarters (January to March, April to June, July to September and October to December). The CHYST groups that contained less than five individuals were merged with adjacent CHYST groups. $Birthyear_j$ was the fixed effect correcting for the year of birth $j$ of the cow ($j$ = 1 to 23), the fixed effect $Marker_k$ accounted for the effect of marker genotype $k$, $Animal_l$ was the random additive genetic effect of cow $l$ and $e_{ijkl}$ was the random residual effect. The pedigree consisted of 9,368 individuals over 19 generations.

Analysis of each marker separately, so-called multiple testing, increases the risk of false positive associations of the marker with the phenotype. To account for these false positives, a false discovery rate (FDR) set at 0.20 was applied. The P-value corresponding to an FDR of 0.20 was calculated using the package 'qvalue' (Storey and Tibshirani, 2003), available in the statistical environment R.

## Results

The GWAS identified two markers that detected genetic variation in LASCS: marker BTB-01841922 located on chromosome (BTA) 4 and marker ARS-BFGL-NGS-101491 located on BTA18. Furthermore, the GWAS identified two markers that detected variation in SCS-SD: marker BTB-02087354 located on BTA6 and marker ARS-BFGL-NGS-101491, located on BTA18, which was also found to detect variation in LASCS (Figure 1).

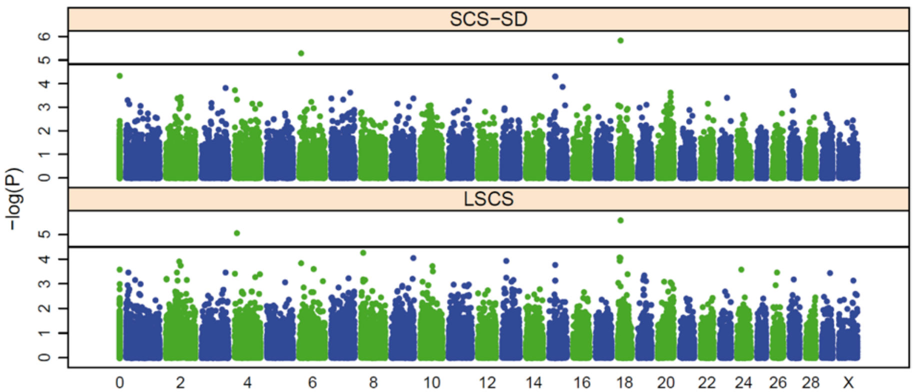


*Figure 1. –$log_{10}$ P-values from individual marker analysis for lactation-average somatic cell score (LASCS) and test-day somatic cell score standard deviation(SCS-SD). Chromosomes are arranged from left to right from chromosome 0 (unassigned markers) to chromosome X. Markers above the black horizontal line passed the 0.20 false discovery rate threshold.*

Analysis of the untransformed SCC data showed that for marker ARS-BFGL-NGS-101491 the smallest homozygous genotype class resulted in an increase of 87,000 cells/ml compared to the largest homozygous genotype class. This genotype class effect was in the same direction for SCS-SD where the difference between the genotype classes was an increase in SCS-SD of 197,000 cells/ml in the smallest homozygous genotype class.

For marker BTB-01841922, the implication of the heterozygous genotype was an additional 51,000 cells/ml, compared to both homozygous genotypes.

The quality criterion that markers should have a minor allele frequency of at least 1% could not prevent that the smallest homozygote genotype class of marker BTB-02087354 consisted of one cow. Therefore analyses for this marker were repeated without this cow. The $-\log_{10}$ P-value increased from 5.3 to 6.1. The SCS-SD for the heterozygote genotype class was approximately 235,000 cells/ml higher compared to the SCS-SD for the homozygote genotype class.

## Discussion

The present study had the aim to identify genomic regions that contribute to variation in LASCS and SCS-SD through a GWAS using phenotypic and genomic information on cows from experimental dairy herds. For these cows detailed SCS recordings were available, with up to 50 individual test-days per lactation. In commercial dairy herds, monthly SCC recordings are common practice. Monthly recordings are, however, limited in detecting elevated SCC caused by clinical mastitis (Rupp and Boichard, 1999), given that mastitis can arise and the animal restored to health between two adjacent recordings (Vaarst and Enevoldsen, 1997). The detailed SCS recordings available for the present study increase the probability that elevations in SCC levels caused by infections of short duration, as is the case in clinical mastitis caused by *Escherichia coli* (De Haas, 2002), were included and as such, provide a more accurate representation of the phenotype.

The present study identified two markers that detected variation in LASCS and two markers that detected variation in SCS-SD. A window of 200,000 base pairs around the associated markers was chosen as a region to search for candidate genes. This window around marker ARS-BFGL-NGS-101491 contained eight candidate genes, of which six, *SLC7A5*, *CA5A*, *RNF166*, *MVD*, *CTU2* and *SNAI3*, had no apparent function in mastitis resistance. The *SMAR1* gene product, however, plays an important role in cell cycle, death and signalling through its interaction with proteins such as NFκB, p53 and TGF-β (Malonia *et al.*, 2010). Further, the window contained the *p22-PHOX* gene, whose protein product functions in phagocytosis (Sumimoto *et al.*, 1996). The window around marker BTB-01841922 contained four candidate genes, *TFPI2*, *GNGT1*, *GNG11* and *BET1*, of which only *BET1* is not involved in functions relating to mastitis resistance. The *TFPI2* gene product acts in proliferation and death of smooth muscle cells (Ekstrand *et al.*, 2010). Smooth muscle-like myoepithelial cells that have a protein expression similar to that of smooth muscle cells are present in the mammary gland

(Deugnier *et al.*, 1995). Therefore, the *TFPI2* gene product may also affect mammary tissue. The *GNGT1* and *GNG11* genes code for G proteins that work as signal transductors (Downes and Gautam, 1999) engaged in control of cell migration and adhesion (Ahmed *et al.*, 2010). No genes were present within the 200,000 base pair window around marker BTB-02087354.

In agreement with previous work (e.g. Klungland *et al.*, 2001), the present study detected few associations with LASCS or SDS-SD. This implies that a large number of regions spread across the genome, each with a relatively small effect, contribute to variation in LASCS and SCS-SD. Most of these effects are most likely not large enough to be detected with the traits defined in the present dataset.

At present, relatively few GWAS for LASCS have been published. A GWAS for LASCS and clinical mastitis in Nordic Red cattle by Sodeland *et al.* (in press) showed associations on BTA12, 19 and 20, none of which were detected in the present study. From linkage studies, a precursor of GWAS, it seems that results are specific to studied traits and populations. Environmental factors and the genetic background specific to studied populations and breeds may greatly act upon the magnitude of associations between phenotypes and genetic markers (Rupp and Boichard, 2003). The same limitations may apply to GWAS. Further research, however, is needed to get this insight into the correspondence between GWAS results.

## Conclusion

The present study is one of the first to combine detailed cow phenotypic and genotypic data from research herd located in different countries. The GWAS identified two markers that detected variation in LASCS and two markers that detected variation in SCS-SD, where one marker detected variation in both LASCS and SCS-SD. More knowledge on genetic regulation of LASCS and SCS-SD not only enables more accurate breeding value estimation, but it also helps to identify genes involved in mastitis resistance. This allows understanding the genetic mechanisms resulting in mastitis and the discovery of targets for mastitis therapeutics.

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Wijga, S., Bastiaansen, J.W.M., Berry, D.P., Wall, E., Strandberg, E., de Haas, Y. and Bovenhuis, H., 2010. A whole genome association study to detect loci associated with somatic cell score in dairy cattle. Pdf 0362 in Proceedings 9th World Conference on Genetics Applied to Livestock Production, Leipzig, Germany.

# Efficacy of a *Staphylococcus aureus* biofilm-embedded bacterin against coagulase-negative staphylococci intramammary infections in dairy cows

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The aim of this study was to characterize the CNS species isolated from cows included in a field trial to check the efficacy of Startvac© vaccine in a commercial dairy herd with subclinical CNS mastitis problems. The vaccine contains a bacterin from a strong biofilm producing *Staphylococcus aureus* strain expressing SAAC (Slime Associated Antigenic Complex). A total of 331 healthy lactating cows and heifers with somatic cell counts lower than 150,000 cells/ml were randomized to receive either vaccine or placebo. The animals were milk sampled on a monthly basis during 5 months, for enumeration of somatic cell count (SCC). In those animals showing SCC>150,000 cells/ml, California Mastitis Test (CMT) was performed by quarter. CMT positive quarters were sampled for microbiological analysis, and followed up until they had two consecutive negative isolations. A total of 93 CNS were isolated: 64 in the placebo group and 29 in the vaccinated group. All the 93 CNS isolates were examined for the *in vitro* slime production ability by the Congo red agar (CRA) plate test: slime production was detected in the 37% of the control group isolates and in the 31% of the vaccinated isolates. CNS were also identified to the species level by means of tDNA-PCR.

# Effect of introducing OrbeSeal into a dry cow management programme and the impact on farm economics

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Optimal dry cow management is required to reduce the incidence of mastitis in the first 100 days of lactation. OrbeSeal is the only licensed teat sealer in the major EU markets, being used widely for the prevention of new intramammary infections throughout the dry period. The objective of this study was to determine the economic benefits of using OrbeSeal at drying off. Data were collected from 28 farms which routinely used OrbeSeal in France, Germany, Italy, The Netherlands, Spain and UK, covering two 12-month time periods. The first survey period of 12 months was prior to the introduction of OrbeSeal and the second was after, with 12 months in between. A questionnaire was used to obtain information on management factors and farm records were examined including annual milk yield, average days in milk, number of mastitis cases, veterinary call outs, doses of antimicrobials administered to mastitis cases, cull cows numbers and milk quality. On 23 of the 28 farms all cows were routinely administered dry cow antibiotics in combination with OrbeSeal and on the other 5 farms 31 to 95% of cows received antibiotics plus OrbeSeal, with the remaining animals receiving OrbeSeal alone, at dry off. The mean percentage of cows with clinical mastitis during the first six weeks of lactation decreased from 15.7% to 9.9% following the introduction of OrbeSeal and the mean percentage of cows culled for chronic mastitis fell from 6.6% to 5.6%. The survey demonstrated that OrbeSeal is predominantly used in combination with DCT and this use pattern helps to reduce clinical mastitis immediately post-calving, which is often caused by new intramammary infections during the dry period. The authors would like to thank the participating farms and veterinarians for their support. This work was funded by Pfizer Animal Health.

# Part 12
# Milking machine and milking technique

# Udder health in herds with automatic milking

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## Abstract

Many Swedish farms with an automatic milking system (AMS) have experienced a rise in somatic cell counts (SCC) after the robot introduction. The calculated herd SCC, based on monthly milk recording samples, is the most objective marker for udder health at herd level. A multivariable regression analysis of the association between herd level SCC and herd factors showed that there was a significant statistical association ($P<0.001$) between robot milking and elevated herd level SCC. The statistical model predicted the SCC to be 8% higher than in corresponding production with conventional milking. *Streptococcus agalactiae* has been suspected as a main cause but this is unlikely since a national bulk tank PCR-screening in 2010 estimated the prevalence of *S. agalactiae* in Swedish AMS to 4.9%. A large number of herd investigations have pointed out the same four most common reasons: (1) Poor cow traffic, leading to long and uneven milking intervals; (2) Incomplete milkings were not followed up on a daily regular basis; (3) Ineffective and sparse systemic wash; and, (4) No possibility to segregate healthy cows from those with chronic contagious mastitis. Practical experiences from Swedish AMS have shown certain management procedures to be of great importance to reduce SCC: (a) access to feed and water at least 23 hours a day and no overstocking in any part of the barn; (b) correct settings for every cow in relation to days in milk) and milk yield; (c) routine for monitoring causes of all incomplete milkings twice daily; (d) milk all cows at least two times a day; and, (e) protect the fresh cows during transition and introduction in the barn.

**Keywords:** automatic milking, milk quality, mastitis, analysis, prevention

## Introduction

Swedish farms with an automatic milking system (AMS) have higher bulk tank somatic cell counts (BTSCC) than conventional farms in similar size. The calculated BTSCC based on monthly dairy herd improvement (DHI) samples is the most objective marker for udder health at herd level, and it is of multi factorial genesis. Incidence of veterinary treated mastitis will be less accurate than SCC in monitoring udder health since it in varying extent involves on-farm decisions and management routines. Since more than 85% of newly build or rebuild farms in Sweden is AMS the SCC in these herds is of great interest and importance for the udder health in Sweden as a whole.

## Cell counts – an important issue

The main reason why both farmer and advisor should pay attention to elevated SCC is the loss of milk and thus money. A recent study has demonstrated a production loss corresponding to 0.9 EUR per 1000 increase in SCC per cow-year (Hagnestam-Nielsen, 2009). It is important to point out that the effect on milk production on cow level starts already when the cell count rises above 50,000. This means that the Swedish AMS farms, besides the quality payment, lost around 12 million EUR only the last year due to udder health reasons, of which the major part would be production loss. Some studies also calculate long term effects on reproduction and increased risk for future disease. Such a study would end up in a higher total cost for SCC and mastitis (Heikkilä, personal communication 2011).

## Herd factors correlation to SCC

A multivariable regression analysis of the association between herd level SCC and herd factors showed that there was a significant statistical association ($P<0.001$) with elevated herd level SCC in both AMS and large herds in Sweden (Table 1; Mörk, 2010). Other herd factors significantly associated to an increased SCC were Holstein as the predominant breed and low milk yield. Although the raw SCC was higher in organically managed herds (Swedish Dairy statistics 2009) there were no significant association between SCC and management type. This is in line with previous studies in Sweden (Fall, 2009; Hamilton *et al.*, 2006) and the high SCC in some organic farms is probably due to other herd factors, such as the four significant ones mentioned above. The statistical model predicted the SCC to be 8% higher in AMS than in corresponding production with conventional milking (Mörk and Sandgren, 2010). The SCC was nearly twice as high for farms with more than 100 cows and three times as high in farms with mainly Holstein breed. The interesting association between high SCC and low yield does probably not mean that low production leads to worse udder health, it is likely the opposite; low SCC will give more milk.

*Table 1. Different herd factors effect on SCC, Swedish recorded cows 2009 (Mörk, 2010).*

| Herd factor | SCC effect |
|---|---|
| Holstein breed vs. Swedish Red | + 50,000 |
| <8,500 kg ECM vs. 9,400 kg ECM | + 50,000 |
| >100 cows vs. 50 cows | + 30,000 |
| AMS vs. tie stall | + 16,000 |
| Organic farm vs. nonorganic | n.s. |

## Reasons for the high SCC in AMS

The hypothesis is that automatic milking in itself is not the problem. The milking process is physically quite similar except for at least four important advantages in AMS. One is the teat preparation which is performed slowly enough and in a very consistent manner. Another advantage is the absence of a teat cup cluster, a situation that eliminates teat wash and much of the spreading of contagious mastitis during milking. The individual take off is also good since it will prevent over milking and back flush of milk into the early emptied quarters. Finally the teat cups will be flushed, sometimes even steamed, between every cow. Despite all this, robot farms in Sweden have significantly higher SCC. This it is not only a problem directly after installation of the new milking system, many farms remain at a higher SCC level even after the first six months with an AMS.

*Streptococcus agalactiae* has been suspected as an important cause but this is unlikely since a national bulk tank PCR-screening in 2010 estimated the prevalence of *S. agalactiae* in Swedish AMS to 4.9% (Figure 1; Landin, 2010a). The prevalence is close though slightly lower to the one experienced in repeated Danish national surveys during the last years (Katholm, 2010). Further, if *S. agalactiae* or *Staphylococcus aureus* is an identified problem in the herd a steam sterilization will not be enough, indicating that the bacteria is transmitted elsewhere than in the robot. It is therefore most likely that contagious mastitis in AMS often is transmitted to healthy cows in the cubicles and the calving pen (Pettersson, personal message 2009).

## Both hard and soft risk factors decides SCC in AMS

Several studies during the last decade indicate that classical udder health risk factors mean a lot also in AMS. Low SCC thus associates with good milking hygiene, correct take-off levels, effective teat dipping and good technical function of the milking machine. Sand bedding,

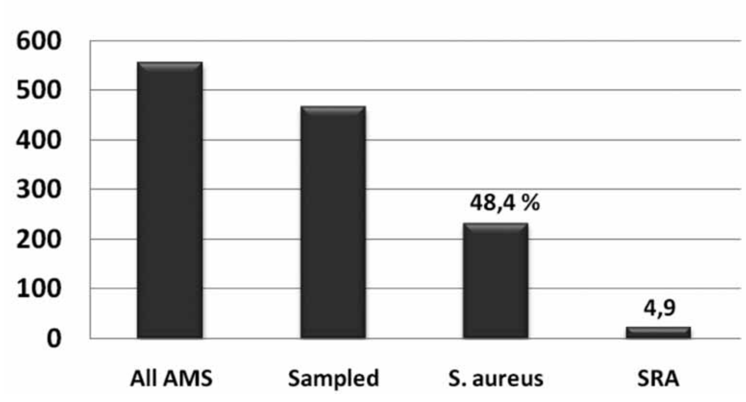


*Figure 1. Prevalence of* Streptococcus agalactiae *(SRA) and* Staphylococcus aureus *in Swedish AMS; National survey on 465 bulk tanks with Pathoproof® PCR (Landin, 2010a).*

cleanliness of the calving pen, udder health monitoring and keeping cows standing after milking are other issues of significant importance (Dufour *et al.*, 2010). Despite the fast technical improvement udder health is not yet better in the numerous new-build farms with AMS than in conventional farms (Everitt *et al.*, 2007; Hovinen *et al.*, 2009; Hovinen and Pyörälä, 2010). Another annoying problem is that the systems for identifying as well clinical as subclinical mastitis is inaccurate and/or difficult to interpret (Hovinen *et al.*, 2006). The software is further equipped with a schedule for drying off the cow that stands in conflict with recent Swedish scientific results (Odensten, 2006).

## Education and methodology

The Swedish Dairy Association has since October 2007 educated well over a 100 veterinarians in an AMS herd health methodology within the strategic herd health program *Health Package Milk* (HPM). A part of the education is an on-farm exam with mentor support from a senior veterinary advisor. HPM when used in AMS includes five analytical steps:

- stall resources and design;
- feeding management and hygiene;
- cow welfare assessment;
- technical function of AMS;
- cow traffic function.

The cow welfare assessment is based on a scheme for cow-examination, originally designed for state of the art determination of current animal welfare in the Swedish System for Animal Welfare (Sandgren *et al.*, 2009). All five steps use critical markers with identified normative goals and alarm levels. The check-list is an Excel-file with separate sheets for the different steps. The markers for cow traffic and technical function have been chosen on basis of results in several Swedish scientific studies (Forsberg *et al.*, 2002; Hamilton, 2007; Melin, 2005; Svennersten and Pettersson, 2007; Wiktorsson *et al.*, 2000).

## Identified reasons for high SCC in AMS

The empirical data from the farm investigations within the HPM education together with studies mentioned above as well as unpublished data points out the same four most common reasons (Landin, 2010b; Pettersson, personal message, 2008; Gustafsson, M. personal message, 2009):

- poor cow traffic, leading to long and uneven milking intervals;
- incomplete milkings were not followed up on a daily regular basis;
- ineffective and/or sparse systemic wash;
- no possibility to segregate healthy cows from those with chronic contagious mastitis.

Additional causes in some AMS were:

- poor function and hygiene in teat preparation system;
- unhygienic conditions in and around the milking station;

- too dirty teats due to poor bedding hygiene in the cubicles;
- poor monitoring of acute mastitis in the herd.

## Actions that have lead to better udder health in AMS

Eight important issues in stall design enhancing cow traffic:
1. no overstocking in any part of the barn;
2. cubicles measurements optimized to cow size in herd;
3. feeding stalls;
4. at least 10 cm water tub per cow or maximum 6 cows per water cup in the stall;
5. 400 cm minimum width in feeding alley;
6. 320 cm minimum with in alley or cross over with water tub;
7. no close placing of entrance and exit to/from robot;
8. no blind alleys.

Twelve management procedures that will reduce SCC in AMS:
1. Access to feed and water at least 23 hours a day;
2. correct settings for every cow in relation to DIM and yield;
3. even distribution of calving all the year around;
4. 55-65 milking cows per robot in the barn;
5. routine for monitoring causes of all incomplete milkings twice daily;
6. milk all cows at least two times a day;
7. cut hair on udders when needed and at least twice a year;
8. protect the healthy fresh cows during transition and introduction into the barn;
9. dry off cows in separate barn, with extended milking interval >36 hours;
10. keep dry off cows in separate barn with high hygienic standard;
11. identify the quality of the cow at introduction into the barn;
12. introduce heifers in the barn during 10-14 days six weeks before calving.

## Conclusions

The calculated SCC from DHI samples in Swedish AMS is higher than in corresponding conventional farms. This objective marker thus points out that udder health is worse on these farms. SCC should be regarded as a signal that there is more milk and money to collect in the herd. Herds that accept higher SCC will earn less money and experience less satisfaction. There is no mysterious or unknown risk factor involved in the undesired Swedish situation. The challenge is simply to optimize the AMS to biological and behavioral facts. The higher SCC in AMS is simply the result of inadequate stall design and management routines. The milking robot is very good when it comes to milking but still very poor when it comes to hygienic activities and still inadequate in monitoring cows. Supervision of animal health and implementation of good management in AMS still demands a keen farmer and a conscious veterinarian. We likely have the knowledge, guts and methods – we just have to deliver it all the way to the farmer and the cow!

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# Alert preferences of dairy farmers working with automatic milking systems

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## Abstract

Although a lot of work is done raising the performance of mastitis detection systems detection systems for automatic milking systems, these systems are not perfect. Therefore, performance of a system is a trade-of between several characteristics. The following characteristics of a detection system can be distinguished: the number of alerts given before the occurrence of clinical mastitis, the number of alerts can be given after the occurrence of clinical mastitis, the number of false alerts, the number of missed cows, the health-state of a missed cow and the costs of the detection system. Farmers may have preferences for certain characteristics which are useful to define in order to raise the performance of detection systems. The aim of this study was to explore farmers' preferences for detection-systems, and to try to find a relation between these preferences and certain farm/farmer characteristics. In total 139 farmers were questioned about their preferences using adaptive conjoint analysis. Overall preferences indicated that the number of false alerts and the health-state of a missed cow were most important, while the number of missed cows and whether an alert is given before clinical mastitis were found less important. However, differences between farmers were large. The results of this study give directions for future research on improving detection systems. Besides that the results can be used to adapt detection systems to farmers' preferences or even make the performance of detection systems flexible between farmers.

**Keywords:** mastitis detection, conjoint analysis, mastitis management

## Introduction

The demand for sensor detection of clinical mastitis (CM) has increased since the introduction of the automatic milking system (AMS). This has multiple reasons. The most important reason is that mastitis, in general, is a serious problem in dairy cattle with high negative economic consequences (Halasa *et al.*, 2007), which also negatively affects milk quality. In addition, it is mandatory that abnormal milk or milk from cows with clinical mastitis should be separated from the bulk tank (EC, 2004). Furthermore, one of the best methods to detect CM, stripping before milking, is not possible when using an AMS. In general, it can be stated that individual cow care becomes less intensive when using an AMS (compared with conventional milking), and automatic detection systems (in this case for CM) are needed to compensate for this lower individual care level.

Current mastitis detection systems are not perfect and do not function sufficiently from a farmer's point of view; a lot of false attentions is a major heard complaint. Until now research was mainly focused on improving mastitis detection systems by developing new detection algorithms (e.g. Kamphuis, 2010), by combining information sources to support the farmer in making his decision (e.g. Steeneveld, 2010) or by introducing new sensors (e.g. Kamphuis *et al.*, 2008). In these studies, concerning the performance of mastitis detection, the test results were compared with a gold standard defined by researchers. However there is no agreement among researchers what the real gold standard is (Mein and Rasmussen, 2009).Furthermore, until now no research was done that determined farmers' preferences, whereas they are the end-users that need to work with the detection systems in practice. Therefore, in this research we want to determine what farmers' preferences for a mastitis detection system are and if we are able to find descriptive variables that have a connection with specific preferences. The results from this research can help building a real gold standard for evaluation of detection results. Evaluating mastitis detection-system results on what farmers desire from the system is the best way of giving a practical value to a detection system. Moreover the results can also be used to develop alert lists, by setting adjustment values that better correspond with the farmers' preferences (Hovinen and Pyörälä, 2011) and consequently become more flexible between farms (Kamphuis *et al.*, 2008).

## Materials and methods

### *Data collection*

From a Dutch customer (farmer) database of Lely industries N.V. (including 1274 farmers) 481 farmers were randomly selected to be invited for completing a questionnaire. These 481 farmers were selected by taking a random stratified sample. Stratification was done on years of experience (longer than 5 years, between 1 and 5 years, and shorter than 1 year) and region (North-, East, Southeast- and West-Netherlands) will lead to a more complete range (compared to total farm population) of farms included in the sample. The farmers were invited by a letter to participate in the web-based questionnaire.

### *Survey design*

The survey consisted of two parts: a set of general questions (background information) and the an Adaptive Conjoint Analysis (ACA) (Sawtooth software, 2007).The general questions aimed to elucidate information about the *farm* and the *farmer* (describing variables). In order to do so, questions asked concerning *farm* characteristics were: size (milk quota, nr. of dairy cows, nr. of AMS); geographical region; labour used on the farm (especially labour use for dairy cows); bulk tank somatic cell count (BTSCC); actual situation concerning mastitis at the farm; actual used information sources for detecting CM; grazing management (grazing yes/no, how long). Information about the *farmer* was determined by questions concerning: education level; age; experience; availability of a potential successor; function on the farm (practical and/or more management level) and farmer attitude (precise or not). This information was used to formulate describing variables.

The second part was an ACA, which is a method designed to determine desirable features of a new product. A product is assumed to consist of characteristics (attributes) each with their own level (e.g. for a car the '*color*' is an attribute with *black, white* or *red* as levels). ACA computes utility values for each level within an attribute. The utility value of a complete product is then assumed to be the sum of the utilities for each level of each attribute the product consists of.

For this study, actual attributes, with their levels, were chosen by a combination of literature research, feedback from farmers, and knowledge of experts. The most important characteristics for evaluation of detection system performance are sensitivity, specificity and time-window (Hogeveen *et al.*, 2010). Attributes included were the practical consequences for farmers based on variation in sensitivity, specificity or time-window. Sensitivity, the number of positive cases detected as percentage of total number of positive cases, and specificity, the number of negative cases detected as percentage of total number of negative cases are interdependent. There is a trade-off between both within a certain detection system, which makes determining farmers' preference even more interesting. Sensitivity led to the inclusion of the attributes *number of missed cases* and *status missed* (Table 1). Specificity led to the inclusion of the attribute *false alerts*.

*Table 1. Overview of attributes and levels included in the ACA.*

| Attribute | Description | Levels | | | |
|---|---|---|---|---|---|
| Alert after | First alert is given at highest this amount of time *after* cow actually has CM (hours) | 0 | 24 | 48 | |
| Alert before | First alert is given at highest this amount *before* cow actually has CM (hours) | 0 | 24 | 48 | |
| False alerts | Number of false alerts per day | 1 [a] | 3 [a] | 5 [a] | 10 [a] |
| Nr. of missed cases | Number of missed cows per year | 2 [a] | 4 [a] | 6 [a] | |
| Status missed | Health status of a missed cow | not ill | ill | severely ill | |
| Costs | Variable costs of detection per year (€) | 1200 [a] | 600 [a] | 300 [a] | |

[a] Based on an average farm size of 65 cows, in the ACA these levels were adapted to the actual number of cows.

A time window is a predetermined period, by researchers, around an actual case of CM in which an alert is valued as a true positive detection. The time-window has practical consequences on when the farmer receives the first alert. This alert can appear before or after the first occurrence of CM. The time-window led to the inclusion of the attributes *alert before* and *alert after*. CM detection raises variable costs which can vary among detection systems. This led to the inclusion of the attribute *costs*.

### *Data analysis*

Before performing statistical analysis, data were tested for potential outliers and for incorrect data. To find out the preference of certain attributes, the relative importance of each attribute was determined. The utility values are indicators for the value farmers give to each level within a certain attribute. The difference in utility of the least preferred level and most the most preferred level within an attribute (the range), is an indicator of the relative importance for that attribute. The relative importance of an attribute is expressed as the range of this attribute as percentage of the sum of the total range of all attributes (Sawtooth Software, 2007). In this way relative importance's for all six attributes for each farmer were determined and used for further analysis.

In order to assess relationships between the relative importance of each attribute and the describing variables (farm/farmer characteristics), data were also analysed with general linear models. The general form of the model was:

$$\hat{Y} = \beta_0 + \beta_1 X1 + \varepsilon$$

Where $\hat{Y}$ represents the relative importance of the attribute, the β's represent coefficients for the model, $X_1$ represents the tested describing variables (only one at a time) and ε is the unexplained error by the model. Independent variables with $P<0.05$ were considered significant.

## Results

Of the 481 farmers that were invited, 139 completed the questionnaire. No data was excluded from further analysis. From this data the relative importance for each attribute was calculated. The difference between farmers was large, especially for the attribute costs (Figure 1). When farmers were completely indifferent, all average importances should be 16.7%, since the total of 100% then would be equally divided over the six attributes. Farmers were not at all indifferent as is shown in Table 2 and Figure 1. The attributes *alert after, false alerts* and *status missed* had average importances above 16.7% while the attributes *alert before, number missed* and *costs* had average importances below 16.7%. Table 2 also shows the utility values for all the levels within each attribute. These utility values for each level are scaled to sum up to zero. Utility values indicate the preference for each level compared to the other levels only within that

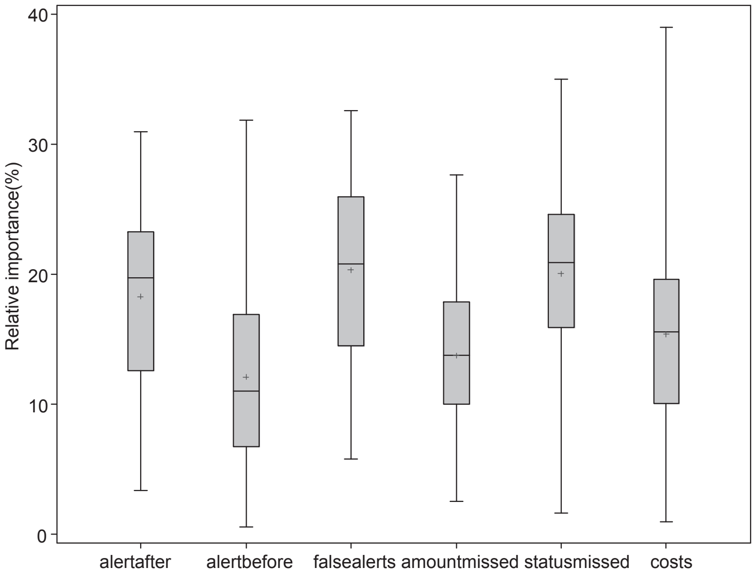


*Figure 1. Graphical representation of relative importance for all attributes. The box represents the first quartile, median and third quartile, the symbol marker is the mean. The endpoint of the lower and the upper whisker are minimum and maximum values respectively.*

specific attribute. For example the fact that the utility for one false alert was higher than the utility for ten false alerts only indicates that one false alert was preferred over ten. Most utility values were as expected, since farmers are assumed to have alerts in time, with a minimum of false alerts, a cow that is not ill, a minimum of missed cows at the lowest costs. One exception was the utility values for the attribute attentions before CM. These utility values indicated that farmers preferred alerts to appear before CM, however, at highest 24 hours before was preferred over at highest 48 hours before CM.

Significant statistical relationships were found between certain attributes and describing variables (Tables 3 and 4). The importance of the number of false alerts was negatively related to the milk production per cow as well as to the amount of available labour per cow (Table 3). This suggests that farmers with high producing cows and a higher labour availability adhered less value to the number of false alerts. Besides this, the importance of the number of missed cows was negatively related to the number of cows per AMS as well as to the mastitis incidence. The importance of the health state of a missed cow was negatively related to the percentage of severe cases of CM.

In Table 4, significant relationships between class variables and the attributes are shown. Farmers being more precise (attitude) adhered more value to having an alert before CM and less value to the number of false alerts. Besides this, farmers using an AMS-parameter for

*Table 2. Relative importance and utilities per level for each attribute.*

| Attribute | Average relative importance(%) | Level | Zero-centered utilities | | |
|---|---|---|---|---|---|
| | | | Mean | 5%-95% percentile | |
| Alert given before CM in time | 12.1 | not before | -0.27 | -0.77 | 0.37 |
| | | until 24 h before | 0.21 | -0.1 | 0.57 |
| | | until 48 h before | 0.05 | -0.36 | 0.5 |
| Alert given after CM in time | 18.3 | not after | 0.57 | 0.1 | 0.98 |
| | | until 24 h after | -0.12 | -0.51 | 0.26 |
| | | until 48 h after | -0.45 | -0.77 | -0.1 |
| Number of false alerts | 20.4 | 10 false alerts | -0.59 | -0.96 | -0.18 |
| | | 5 false alerts | -0.17 | -0.58 | 0.13 |
| | | 3 false alerts | 0.16 | -0.19 | 0.45 |
| | | 1 false alerts | 0.58 | 0.13 | 0.93 |
| Number of missed cows | 13.8 | 6 missed cows | -0.4 | -0.7 | -0.1 |
| | | 4 missed cows | 0.01 | -0.24 | 0.32 |
| | | 2 missed cows | 0.38 | 0.04 | 0.7 |
| Health status when cow is missed | 20.1 | not ill | 0.59 | 0.15 | 0.92 |
| | | ill | -0.01 | -0.34 | 0.33 |
| | | severely ill | -0.58 | -0.91 | -0.17 |
| Costs | 15.4 | € 1,200 | -0.47 | -0.8 | -0.12 |
| | | € 600 | 0.06 | -0.29 | 0.39 |
| | | € 300 | 0.4 | 0.06 | 0.83 |

*Table 3. All significant relationships between continuous descriptive variables and attributes.*

| Variable | False alerts | | Number of missed cows | | Status missed | |
|---|---|---|---|---|---|---|
| | Estimate (β) | *P*-value | Estimate (β) | *P*-value | Estimate (β) | *P*-value |
| Milkproduction/cow (x 1000 kg) | -1.15 | 0.05 | NS | NS | NS | NS |
| Labour per cow (minutes/cow/day) | -0.73 | 0.03 | NS | NS | NS | NS |
| Severe cases CM (severe/total cases) | NS | NS | NS | NS | -0.08 | 0.05 |
| Cows per AMS (nr. cows/AMS) | NS | NS | -0.1 | 0.03 | NS | NS |
| Mastitis incidence (% of herd/year) | NS | NS | -0.09 | 0.02 | NS | NS |

NS= not significant.

*Table 4. All significant relationships (P-values) between class descriptive variables and attributes.*

| Variable (nr. of classes) | Alert before CM | False alerts | Number of missedcows | Costs |
|---|---|---|---|---|
| Farmer attitude (4) | 0.02 | 0.01 | NS | NS |
| Detectionparameters (2) | 0.04 | NS | NS | 0.03 |
| Mastitissituation (3) | NS | NS | 0.01 | NS |

NS= not significant.

CM detection adhered more value to having an alert before and less value to the costs than farmers using non-AMS-parameters. Also, when the actual situation of the farm (good, normal or problematic) as perceived by the farmers was bad, farmers adhered less value to the number of missed cows.

## Discussion

The results of this experiment show that farmers indeed have preferences concerning the performance of CM detection systems. Though there are large differences between farmers in preferences, the average importances give a good indication for farmers' preferences. Farmers gave the status of a missed cow and the number of false alerts a relatively high importance. The latter is in line with Kamphuis (2010) who stated that the number of false alerts is a serious problem in CM detection-systems. The fact that farmers think cow health status is important can be seen as an indication that farmers have a higher preference for detecting the worse cases (very ill) instead of the mild cases of CM.

The number of missed cows is of relative low importance which was unexpected. The reason behind this can be that farmers want a detection system only to give an alert when necessary (low number of false alerts) and consequently accept an increase in missed cows, because they feel they are able to detect these missed cases themselves. They perceive a detection system more as a supportive system than as a complete replacement of the farmer.

Lately there has been some discussion on whether alerts should be given prior to CM, and if so how long prior to CM should the farmer receive this alert (Hogeveen *et al.*, 2010). This study indicates, through the utility values of alert before (Table 2) that farmers indeed think it is beneficial receiving an alert prior to CM. However, receiving an alert 24 hours before is preferred over 48 hours before. Alerts being given too early in time will decrease the practical use of it (Hogeveen *et al.*, 2010).

Farmers using primarily AMS-parameters for CM detection, adhered more value to having an alert before and less to costs. These farmers probably have a higher trust in their AMS and, therefore, think receiving alerts prior to CM is worthwhile and accept higher detection costs.

This is the first time an experiment, with this aim, was done. The results give insight in what (Dutch) farmers think is important in CM detection. Researchers can use these results when formulating the gold standard, since now it is more clear what farmers expect from a detection system. A more practical application of these results is by implementing this knowledge in setting adjustment values that better correspond with farmers' preferences as well as make systems that are more flexible in their settings (Hovinen and Pyörälä, 2011; Kamphuis *et al.*, 2008), since we also showed that there is considerable variation in preferences. Besides that, this work gives directions for future research. The focus should be on lowering the number of false alerts and increasing the link between CM detection and cow health. Also research aimed at giving alerts prior to CM can be done more precise, because adaptation to farmers' preference is possible.

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# The role of sensor measurements in treating mastitis on farms with an automatic milking system

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## Abstract

Mastitis detection is aimed at finding cows with clinical mastitis (CM) so they can be treated. Farmers with an automatic milking system (AMS) rely on mastitis alert lists, generated by the AMS, to detect cows with CM. These lists are based on sensor measurements collected during milking. Mastitis detection models with sufficiently high sensitivity and specificity will help to select the CM cases that need treatment. The current CM detection performance can be summarized with a sensitivity of 36.8% and a specificity of 97.9%. These values don't meet the suggested requirements on CM detection performance (sensitivity >70%, specificity >99%). Recent research was able to improve detection performance by using better detection algorithms, adding non-sensor information, and using new or improved sensors. The achieved sensitivity and specificity, however, were still not perfect. This imperfection may be explained by the fact that the majority of the alerts are from cows with intramammary infections. Some of these cows will develop CM, but the majority will not become clinically infected. Therefore, reaching a very high specificity (e.g. 100%) for CM detection is very difficult, and it is expected that future CM detection models on an AMS will not be perfect. As a consequence, farmers with AMS have to accept that not all CM cases will be detected, that some cases will be detected late, and that there will be false-positive alerts. With this inevitable imperfect detection in mind, it is essential to start thinking about detection and treatment protocols for farmers with AMS. These protocols may include specific actions for new alerts and for alerts which are on the list for weeks. This paper can be seen as a starting point for a further debate on providing treatment protocols for farmers with AMS.

**Keywords:** detection, treatment, automatic milking, mastitis

## Detection and treatment of clinical mastitis with automatic milking – current practice

Treatment of mastitis is traditionally focused on detection and diagnosis of clinical mastitis (CM), which are based on abnormalities of milk and/or the udder observed during milking. Farmers with an automatic milking system (AMS) rely on mastitis alert lists from the AMS for information on the udder health status of their cows (Hogeveen and Ouweltjes, 2003). These alert lists are generated from sensor measurements collected during milking (e.g. electrical conductivity (EC) and colour measurements) and report the cows suspected of having CM. A general complaint of dairy farmers working with an AMS is that these lists present contain a relatively large number of false-positive alerts.

A sensitivity (SE) of 70% and a specificity (SP) of >99% are proposed by Mein and Rasmussen (2008) as test characteristics for CM detection with an AMS, while Hogeveen *et al.* (2010) proposed an SE of 80% and an SP of 99%. Recently, an SE of 36.8% and an SP of 97.9% were reported as test characteristics for detection of CM with current AMS (Mollenhorst and Hogeveen, 2008). Especially the low SP causes the dairy farmers working with AMS to complain about the relatively large number of false-positive alerts on the mastitis alert lists. Several detection models were developed with the aim to reduce the number of false-positive alerts (e.g. De Mol and Ouweltjes, 2001; Cavero *et al.*, 2008). The SE and SP of these models, however, remain too low to substantially reduce the number of false-positive alerts and at the same time retain a sufficient detection of true CM cases.

Improved levels of SE and SP will help to select the CM cases that need treatment. Potentially, the test characteristics can be enhanced by using improved detection algorithms, adding non-sensor information, and using new sensors. This paper describes the methods that can be used to improve mastitis detection performance on farms with an AMS, and discuss the consequences of these detection results for treatment decisions. Finally, some suggestions for treatment protocols for farms with an AMS are given.

## Improving mastitis detection with AMS

### *Improving detection algorithms*

In the past, several methods were used to improve CM detection performance (e.g. Cavero *et al.*, 2006; Friggens *et al.*, 2007). An algorithm that has not been used so far for CM detection is decision tree induction, which is a commonly used technique for classification problems (Quinlan, 1986). It is believed to be able to deal with data that are noisy, imbalanced, and incomplete; three characteristics that apply to problems associated with data from automated CM detection systems.

To improve CM detection performance a Dutch study collected data at nine Dutch dairy farms milking automatically during a 2.5-year period (Kamphuis *et al.*, 2010). Data included sensor data (EC, colour and yield) at the quarter level and visual observations of quarters with CM recorded by the dairy farmers. Sensor data of 3.5 million quarter milkings were collected, of which 348 quarter milkings had CM. Data were divided into a training set, including two-thirds of all data, and a test set. Cows in the training set were not included in the test set and vice versa. A decision tree model was trained using only clear examples of healthy (n=24,717) or diseased (n=243) quarter milkings. The model was tested on 105 quarter milkings with CM and a random sample of 50,000 quarter milkings without CM observation. Different time windows were applied, as it was known that these would influence detection performance (Sherlock *et al.*, 2008).

Table 1 summarizes detection performance of the decision tree model using different time windows when validated on all 50,105 quarter milkings of the test set. The decision tree model with a time window including the 24 hours before the CM observation resulted in a SE of 40% at a SP of 99%. A considerable increase in SE was found when a time window of 24 h before or after a CM observation was applied, the SE increased to 66.7% at an SP of 99%. Results also demonstrate that SE increased as the selected time windows were widened, and that not all CM were detected by the decision tree, even when very wide time windows were applied. Slightly more than 10% of the CM cases were not detected when a time window of 10 days (240 h) before, to 7 days (168 h) after the CM observation was applied at an SP of 97.9%.

The results show that decision tree induction made it possible to maintain SE at about the same level as models currently used by AMS but to decrease the number of false positive alerts by more than 50%. The developed CM detection model did however not reach a SE of 80% and a SP of 99% within a time window of 48 hours or less, which is required (Hogeveen *et al.*, 2010).

*Table 1. Influence of time window length (in hours) on sensitivity (SE) at a fixed specificity (SP) of 99% ($SE^{99}$) and a fixed SP of 97.9% ($SE^{97.9}$) of a decision tree model being validated with 50,105 quarter milkings.*

| **Used time window (h)** | | **$SE^{99}$** | **$SE^{97.9}$** |
|---|---|---|---|
| **Before CM observation** | **After CM observation** | | |
| <24 | 0 | 40.0 | 57.1 |
| <24 | 24 | 66.7 | 79.0 |
| 48 | 24 | 69.5 | 81.0 |
| 120 | 0 | 70.5 | 81.0 |
| 240 | 168 | 84.8 | 89.5 |

### *Adding non-sensor information*

In current CM detection models it is assumed that all cows on a farm have the same probability to have CM. This assumption, however, is incorrect as it is known that, for example, cows in early lactation have a higher probability of CM than cows in late lactation (e.g. Steeneveld *et al.*, 2008). It is therefore expected that updating a probability of having CM based on sensor measurements with a probability of having CM based on non-sensor information will improve the CM detection performance (Steeneveld *et al.*, 2010a).

The probabilities of having CM for each quarter milking obtained with the decision tree induction model (Kamphuis *et al.*, 2010) were updated with a probability of having CM based on non-sensor information. The non-sensor information included parity, day in milk, season, somatic cell count (SCC) history and CM history. The resulting updated probabilities were the basis for the CM detection model, and was evaluated using the same test data set described by Kamphuis *et al.* (2010). The detection model based on sensor measurements (described by Kamphuis *et al.*, 2010) was compared with the detection model based on the updated probabilities by means of an ROC-curve. The area under the ROC-curve (AUC) was used to evaluate the detection performance. The AUC was 83.0 for the CM detection model based on sensor measurements alone, while the AUC based on sensor measurements and non-sensor information was 80.8. Results showed that adding non-sensor information to all milkings did not improve CM detection performance (Steeneveld, 2010). This result was confirmed by another study (Steeneveld *et al.*, 2010b). These unexpected results can be explained by the non-discriminative power of SCC obtained with the four-weekly milk recording to distinguish between CM and non-CM. Also the correlation between somatic cell count and EC, and the cows with subclinical mastitis may explain the unexpected results.

### *Using new sensors*

In general, detection performances of models including more information than just sensor measurements of EC are better. This suggests that adding information from other sensors is valuable in improving the detection of CM. These other sensors may be already existing ones, but they may also include newer and more complex sensors such as sensors determining the SCC.

The potential value of on-line composite somatic cell count (ISCC) sensing as a sole criterion or in combination with quarter-based EC of milk for automatic detection of CM during automatic milking was explored by Kamphuis *et al.* (2008). Data were generated from a New Zealand pasture-based research herd applying AMS, and included EC, ISCC, monthly determined SCC and observed CM cases. Three detection models were compared. The first model used EC as sole criterion for CM, the second one used SCC information only, and the third model applied a fuzzy logic algorithm to combine these two information sources. The SE of all three models was fixed at 80%. The success rate (also known as the positive predictive value) and the false alert rate (number of false positive alerts per 1000 cow milkings) were used to evaluate detection performance.

Table 2 shows the performance measures for the three different detection models. Using EC alone as a detection tool resulted in a success rate of 11.0% and a false alert rate of 4.7. Values for the ISCC model were better than the model using EC alone. Combining sensor information to detect CM resulted in a 2- to 3-fold increase in success rate and a 2- to 3-fold reduction in false alert rate compared with the model using ISCC or EC alone. The results suggest that CM detection performance improved when ISCC information was added to a detection model using EC information alone.

## Consequences for treatment decisions

Approximately 0.32% of all cow milkings in a year at a farm with an AMS will show abnormalities (De Koning, 2010). Together with the current CM detection performance (Mollenhorst and Hogeveen, 2008) this will result in approximately six alerts per day for a herd with 100 milking cows. Generally, all of these alerts will be false-positive alerts for CM. Although the developed algorithms and new sensors improve the CM detection performance, the achieved SE and SP are far from perfect. This imperfection may be explained by the fact that the majority of the alerts are from cows with intramammary infections. Some of these cows will develop CM, but most of them will not become clinically infected. Therefore, reaching a very high SP (e.g. 100%) for CM detection is very difficult, and it is expected that future CM detection models on an AMS will not be perfect. This means that farmers have to deal with this imperfect detection, resulting in missed CM cases and detecting CM (too) late (both due to a SE too low), and false-positive alerts (due to a SP too low).

Obviously, to treat as many CM cases as possible, all mastitis alerts have to be checked visually. This is, however, not performed in practice (Claycomb *et al.*, 2009; Neijenhuis *et al.*, 2009). This is most probably due to the difficulty to fetch the cows and the perceived unnecessary visual checks. Moreover, the vast majority of farmers (65%) do not use any explicit rules for deciding upon which cows to check visually for CM (Neijenhuis *et al.*, 2009). These farmers thus take their inspection decisions based on intuition and do not have a fixed working routine. The combination of an imperfect SE, no visually checking of all alerts and no fixed routine will

*Table 2. Performance statistics using electrical conductivity (EC) and on-line somatic cell count (ISCC) information as detection tool for clinical mastitis.*

| | **Alerts based on EC** | **Alerts based on ISCC** | **Alerts based on EC and ISCC** |
|---|---|---|---|
| Success rate | 11.0 | 15.6 | 32.0 |
| False alert rate | 4.7 | 2.9 | 1.2 |

result in missed CM cases and delayed detection of CM cases. Consequently, cows are not treated optimally according to the traditional view on treatment of CM. As farmers have to deal with the imperfect CM detection performance of an AMS, new approaches for detection and treatment may improve the overall treatment of intramammary infections. Below some approaches are discussed.

New mastitis alerts with extremely high EC-values in combination with a decreased milk production have the highest probability of being from cows with CM (Steeneveld *et al.*, 2010b). Therefore, it is suggested all of these alerts be checked visually. The alerts with less extreme EC-values and less decreased milk production are most likely false-positive alerts or are an indication of a mild CM infection. For these mild CM cases a farmer may consider postponing the treatment because these cases can cure spontaneously. If the mild CM case does not cure spontaneously, treating that case with antibiotics is still sensible as cure rates were not lower for mild CM cases treated 24 h after observation (Keefe *et al.*, 2010). If the milk from a cow with a new alert is visually normal and the alert remains on the lists for the subsequent two or three days it will need to be visually checked again. Cows on lists for weeks are likely to have developed mild CM or to be chronically infected. These chronically and often subclinical infected cows can have clinical flare-ups and they can spread the infection to herd mates. In both situations, these cows cause economic loss. These cows need a visual check again after two to three weeks. At this second check, a CMT test or the SCC information from the milk recording test days are essential additional information sources for judging the cow's udder health. If these cows have positive CMT tests or have high SCC, the next step is to take a milk sample for bacteriological culturing. If the culture results demonstrate that the pathogen involved is a contagious one, it may be economically beneficial to treat this cow with antibiotics (Van den Borne *et al.*, 2010). All of the above mentioned suggestions should be discussed further in a team of multidisciplinary experts, including researchers, veterinarians and AMS engineers.

## Conclusions

The CM detection performance with AMS is not perfect, and probably never will be. The too low SE and SP will result in CM cases that are missed, in delayed detection of CM cases and in the occurrence of false-positive alerts. To deal with this imperfect detection, it will be good to develop novel detection and treatment protocols for farmers with an AMS. This can include, for instance, specific actions for new alerts and alerts which are on the list for weeks. The given suggestions in this paper can be seen as a starting point for further discussion on this topic.

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# Influence of milk yield and take-off settings on milking parlour performance and udder health

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## Abstract

The first aim of this study was to monitor parlour performance in high producing Israeli herds using the parameter proposed by Reid and Stewart (2007) for herds milked three times daily with 55 kg milk/stall/hour. Milk yield, somatic cell count (SCC) and the culling rate were monitored correspondingly. The second aim was to examine if by increasing manufacturers default take-off settings in Israel, there will be no detrimental effect on parlour performance and udder health (SCC). A survey was carried out in 2010 on 32 top producing herds totalling 9347 cows averaging 13,208 kg/cow/year and an SCC of 173,000 cells/ml. 44% of the herds monitored achieved the 55 kg milk/stall/hour recommended by Reid and Stewart. In 2008 a random survey of 32 farms with an average milk yield of 11,885 kg/cow/year, similar to the herd book average, only 16% of the herds surveyed attained the above mentioned target. When checked against a proposal of 50 kg milk/stall/hour by Reid (2008), 59% of the herds in 2010 and 32% of the herds in 2008 reached the recommended target. In the current survey two subgroups with different cluster take of settings were compared. Nineteen farms had takeoff settings of less than 600 gr/min, whereas 13 farms had settings above 600 gr/min, the latter were significantly higher than manufacturers default settings (350 - 480 gr/min). Only 7 of the 19 farms (37%) attained the proposed parlour performance whereas 7 of the 13 farms (54%) attained this goal. There was no significant difference in milk yield, SCC and culling rate between the two subgroups. Although the average SCC in the herds surveyed was lower than the national average, there was no evidence of negative effects on udder health (SCC) by increasing takeoff settings to a level of 600 gr/min or above.

**Keywords:** high yielding cows, computerized management systems, commercial dairy farms

## Introduction

Lactation in the dairy cow is influenced by various management factors as well as the milking equipment. Milking efficiency is a combination of proficiency of the milker, operation of the milking equipment, and cow factors including udder shape, temperament and physiological traits.

Computer monitoring is common in Israeli dairy herds, helping in the assessment of parlour performance on individual farms, to advise on possible shortcomings, and to monitor recommendations and improvements (Ginsberg *et al.*, 2010, 2011).

Parlour throughput can be measured in various ways: cows/hour, milk/hour, milk/stall, milk/shift or milk/stall/hour to name a few. The latter is the best way to measure overall parlour performance thereby neutralizing the size of the milking parlour and number of milkers (Reid and Stewart, 2007). Their proposed goal for herds milked three times daily in parlours was 55 kg/stall/hour.

In 2008 Ginsberg *et al.* (2010) conducted a random survey on 32 farms to monitor parlour performance using a different proposal by Reid (2008) of 50 kg milk/stall/hour. Results of this survey showed that 32% of herds milked three times a day, yielded the recommended goal.

In order to achieve optimum parlour performance, all parameters of the milking equipment must be fine tuned including the automatic cluster removers (ACR).

The use of ACR has led to a significant reduction in over-milking, and a reduction in machine on time (Rasmussen, 1999). The delay for cluster removal is embedded in the milk meter. Long removal delays result in a longer time under a low milk flow rate at the end of the milking. Although milk meter settings are determined by agreement between the herdsman and the equipment installer, most manufacturers allow the milker to manually override the automatic take-off (ATO) settings. In many parlours, the most conscientious workers will disable the automatic take-offs (set take-offs to manual), because of the desire to be absolutely certain that every cow is completely milked out.

Historically, cows were considered milked out when the milk flow rate decreased to 200 gr/min and most ACR's were set to this level. Early studies by Sagi (1978) and Rasmussen (1993) concluded that the cluster can be detached at a flow rate of 400 gr/min. Milking time was significantly shorter, with no negative effect on the milk yield and the incidence or prevalence of clinical and sub clinical mastitis.

Reid and Stewart (1997) studied the effects of parlour performance on two farms by changing detacher settings. The results showed a reduction in unit on time. The managers also reported that cows were calmer in the milking parlour.

Further studies with different management strategies and goals supported the results of all of the previous studies. (Stewart *et al.*, 1999, 2002; Maggliaro and Kensinger, 2005; Billon *et al.*, 2007).

Jago *et al.* (2010) once again studied the effect of raising the take off settings from 200 to 400 gr/min on pasture-based cows in New Zealand, milked twice daily with a minimal pre-milking routine. The results concurred with all previous studies.

By monitoring the milk yield of the highest producing herds in the Israeli Herd book, the aim of this study was to: (a) compare the average somatic cell count (SCC; as an indicator for udder health) of the herds surveyed to the national average and possibly demonstrate that manufacturers default take-off settings in Israel (350 - 480 gr/min) can be increased with no detrimental effect on udder health; (b) monitor the ATO settings and parlour performance in high producing Israeli herds; (c) compare the parlour performance (milk/stall/hour) in this survey to the results of a previous random survey. In the present study we examined to what extent the surveyed farms met the goals of 50 and 55 kg/stall/hour respectively.

## Materials and methods

Forty of the highest producing Israeli herds milked three times daily were screened in order to attain: (a) manufacturer of the milking equipment; (b) ATO settings; (c) number of milking stalls; and (d) milk production at each milking on ten consecutive days. Farms using milking robots or weigh jars were not included in the survey leaving 32 farms to be monitored individually.

Information from the 2010 Israeli dairy herdbook showed that these 32 herds had average annual milk yields between 12,500 and 14,400 kg and ranged in size from 45 to 937 cows. Data monitored from the herd included: (a) yearly milk production; (b) annual SCC averages; and (c) culling rate.

Although there are many types of milk meters used in Israel, all of the farms in the study used only 'Afimilk' (SAE Afikim, Kibbutz Afikim, Israel) and 'SCR' (SCR Engineers Ltd, Netanya, Israel) milk meters. On farms using 'Afimilk' equipment, the parameter milk/stall/hour is part of the parlour performance report needing no further calculation. On farms using SCR equipment, the calculation was made based on milk yield and total milking time at each milking obtained from the herd management program, divided by the number of milking stalls.

## Results

25 of the farms surveyed (78%) used 'Afimilk' milk meters with a default detachment setting of 480 gr/min, only 7 farms (22%) in the survey used SCR equipment with a default detachment setting of 350 gr/min. (Table 1)

In 2010, parlour performance was determined in a survey of 32 top producing herds with 9,347 cows averaging 13,208 kg milk/cow/year, the production difference was 1,688 kg higher than the herdbook average. In 2008 a random survey of 32 herds with 9,088 cows using

*Table 1. Distribution of milk meters by manufacturer and default detachment settings.*

| Manufacturer | No. of farms | % of farms | Default detachment settings |
|---|---|---|---|
| Afimilk | 25 | 78 | 480 |
| SCR | 22 | 7 | 350 |

'Afimilk' equipment and producing 11,885 kg milk/cow/year with a difference of 424 kg in milk production between the surveyed herds and the average milk production of all Israeli herds in the fore mentioned year. Culling rate on farms surveyed in 2010 was slightly lower than the national average and lower than the previous survey, testifying to less stringent culling criteria (Table 2).

Although there was no difference in annual SCC on farms surveyed in 2008, the average annual SCC on farms surveyed in 2010, was 173,000 cells/ml; 58,000 cells/ml lower than the national average of 231,000 cells/ml. This data was insignificant due to the large distribution and the fact that 12.5% of herds surveyed were above the national average.

Results of individual herds surveyed showing detachment settings (gram/min.) and parlour performance (milk/stall/hour) are presented in Figure 1.

In the random survey of 2008 only 5 of the farms (16%) met Reid and Stewart's (2007) proposed target (55 kg milk/stall/hour). In the survey of high producing herds in 2010, this target was reached by 14 of the farms (44%), a significant improvement when compared to the previous survey. When checked against the proposal of Reid (2008) of 50 kg milk/stall/hour, 59% of the herds in 2010 and 32% of the herds in 2008 reached the recommended target.

Detachment settings were not monitored in 2008 but this was after the introduction of a new management program where default detachment setting were raised from 343 gr/min to 480 gr/min and very few if any farms had settings above this level.

*Table 2. Comparison of survey data to total herdbook data.*

| | Milk (kg) | Average SCC (*1000) | Total cows | Culling rate % |
|---|---|---|---|---|
| Survey farms 2010 | 13,208 | 173 | 9,347 | 23.2 |
| All Israeli herdbook farms 2010 | 11,520 | 231 | 101,393 | 26.0 |
| Survey farms 2008 | 11,885 | 216 | 9,088 | 28.0 |
| All Israeli herdbook farms of 2008 | 11,461 | 215 | 103,895 | 29.8 |

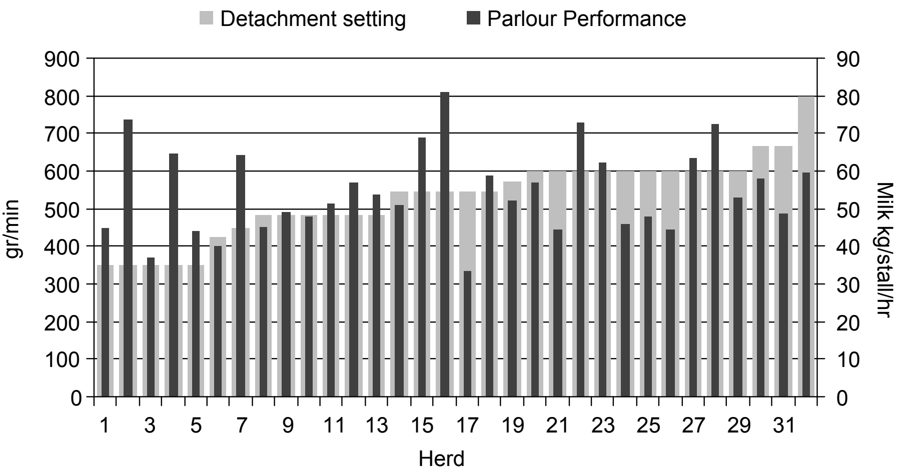


*Figure 1. Comparison of the herds with regard to parlour performance (milk/stall/hour) and ATO seetings (gr/min).*

In 2010, 19 of the farms surveyed using Afimilk equipment had ATO settings above the factory default of 480 gr/min, only 6 farms did not change the default settings. All of the farms using SCR equipment were below 480 gr/min. 65% of the farms surveyed had ATO settings higher than 480 gr/min; the vast majority (13) with 600 gr/min and as high as 800 gr/min. Two subgroups with different ATO settings were compared, 19 farms with ATO settings of less than 600 gr/min and 13 farms with settings of 600 gr/min and above.

Only 7 of the 19 farms (37%) with default settings less than 600 gr/min attained the proposed parlour performance whereas 7 of the 13 farms (54%) with settings above 600 gr/min attained the goal of 55 kg milk/stall/hour. When compared against 50 kg milk/stall/hour, 11 of the 19 farms (58%) with default settings of less than 600 gr/min attained the recommended parlour performance, 8 of the 13 farms (62%) with settings above 600 gr/min attained this goal.

There was no significant difference in SCC and culling rate between the two subgroups (Table 3).

*Table 3. Influence of different detachment settings on parlour performance, SCC and culling rate.*

| Detachment setting | Total farms | Milk/stall/hr >55 farms | Milk/stall/hr <55 farms | Average SCC (*1000) | Average culling rate (%) |
|---|---|---|---|---|---|
| ≥600 gr/min | 13 | 7 (54%) | 6 (46%) | 174.6 | 24.7 |
| <600 gr/min | 19 | 7 (37%) | 12 (63%) | 171.0 | 22.4 |

## Discussion

Parlour performance depends on various factors: milk yield, frequency of milking, number of milkers and their skill, cow movement, cow grouping strategy, milking routine; unit attachment time, how fast peak flow rate is achieved, unit detachment settings and more. The use of computerized dairy management systems have contributed greatly in the evaluation of parlour performance.

Reid and Stewart's (2007) parameter of 55 kg milk/stall/hour and Reid's (2008) proposal of 50 kg milk/stall/hour for parlour performance in herds milked three times daily are one of the tools in evaluating parlour performance. This parameter expresses the combined influence of milkers, cows and milking equipment. Using a computerized dairy management system it is possible to calculate and display this parameter.

In this study on Israeli top producing herds, 44% of the herds monitored yielded the recommended 55 kg milk/stall/hour, whereas in a random survey in 2008 on herds with a milk yield similar to the herd book average, only 16% of the herds attained the above mentioned target. When checked against a proposal of 50 kg milk/stall/hour by Reid (2008), 59% of the herds in 2010 and 32% of the herds in 2008 reached the proposed target. The large discrepancy in parlour performance when reducing the goal by 5 kg milk/stall/hour, suggests that a larger number of farms needs to be surveyed in order to determine a goal for optimal parlour performance.

Although it is a known fact that the milk curve and flow rate influence parlour performance (Reneau and Chastain, 1995, Reid and Stewart, 2007, Reid, 2008), there was no way to monitor these parameters in 22% of the farms using SCR equipment. Therefore this parameter that possibly influenced the performance of some of the herds surveyed was not checked in this study. We must therefore hypothesize that the improvement in the number of herds reaching the recommended goal is due to the fact that in this study cows yielded 1688 kg/milk higher than the average in the herdbook.

The second aim of the study was to examine if by increasing the manufacturers default ATO settings, there will be any detrimental effect on parlour performance and average SCC as an indicator for udder health. In the current survey two subgroups with different ATO settings were compared, 19 farms with takeoff settings lower than 600 gr/min against 13 farms with settings above 600 gr/min, the latter were significantly higher than manufacturers default settings (480 gr/min).

Fewer farms (37%) with detachment settings below 600 gr/min attained the parlour performance goal of 55 kg milk/stall/hour than then farms obtaining the goal of 50 kg milk/stall/hour (54%). Farms with settings above 600 gr/min were not affected. The correlation between take of setting levels and the parlour performance goals is obvious. As there was no significant difference in milk yield, SCC and culling rate between the two subgroups, this finding suggests that take of settings can be raised with no detrimental effect on udder health (SCC), as well as having no effect on herd health and fertility (culling rate).

Average SCC in all of the herds surveyed, although 58,000 cell/ml lower than the national average, were not statistically significant. Nevertheless, there was no evidence of negative effects on udder health. Further study has to be done in order to explore possible positive effects on udder health.

The findings of this study support the results of previous studies indicating that default ACR settings can be set at 600 gr/min with no detrimental effects on milk yield, udder health and milk quality.

Computerized dairy management systems are helpful in monitoring different management related factors on a large number of cows in commercial dairy farms and to advise the farmer how to improve parlour performance.

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# Bacterial migration through teat canal related to liner action

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Udder health and behaviour of cows being milked are directly related to the performance of milking machines. Observations of milking animals reveal common problems of teat swelling, kicking/stepping, increased heart rates, increased adrenaline, uneven udders and slow milking quarters associated with the milking process. Mastitis is the most costly problem in the dairy industry with cleanliness and procedures identified as a means of achieving quality milk and positive animal health but the mechanisms by which bacteria cross the teat canal are not fully understood. Research (DF) shows skin bacteria, including *S. aureus*, can remain confined in the teat canal for long periods. Milk collected conventionally was contaminated by the bacteria in the teat canal, while milk extracted by syringe directly from the teat sinus was sterile. It is postulated that the liner pinching the teat apex causes an intrusion of the wax-like keratinaceous lining moving bacteria into the teat sinus, introducing an intra-mammary infection. A unique pulsation system (WG) with two valves, one for vacuum, one for air was developed supporting this idea. A combination of a very short C phase with longer D phase and low collapse pressure round liners changes the closing liner action. This simulates full teat length massage similar to suckling action of a calf as opposed to a common pinching action. Liner action and vacuum cause milk flow from the teat creating the milking environment for the cow. The pulsator is the core of a basic milking system with air and vacuum dynamics from the pulsator interacting with the liner playing a key role in final results. Results using this unique pulsation system show longer sustained peak flow, shorter milking time, fewer infections, improved teats, better udder integrity with less kicking. Inspection of worn liners proves unique liner action from a compressive massage. An extended D phase improves teat massage while retaining natural integrity of the teat canal with similar improvements for cows and goats.

# Classification of mouthpiece chamber vacuum records in milking-time tests

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A study on possible measures of vacuum acting on the teats during machine milking was made as a part of international efforts to improve methods for milking time tests, coordinated by a working group under International Dairy Federation. Data from milking-time tests in TINE's advisory service were collected and supplemented with data on production and udder health in the herds. Data were processed to find parameters that could be related to the milking and udder health, and be useful in the assessment of vacuum records from a milking-time test. The analysis showed that a very high or a very low mouthpiece chamber (MPC) vacuum was associated with poor udder health. The best parameter found on herd level was the proportion of cows milked with a medium high MPC vacuum. This parameter, defined in the range 10-30 kPa, showed a very strong association ($P$<0.01) with the mastitis index as defined in the official herd health records. This new knowledge will be integrated in new systems for milking-time tests, and thus be useful in practical dairying for checking the aptness of the cluster (liners) for the teats in the herd. The combination of a new user friendly vacuum logging unit and extended knowledge on the assessment of vacuum records may induce a step forward in the use of milking-time tests in advisory services, and for companies in testing of new liner designs.

# Key messages for an efficient udder preparation routine

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Maintaining healthy udders and producing quality milk should be a passion of all dairy producers. One of the corner stones to reach these goals is an adequate teat preparation before cluster attachment. The pre-milking udder preparation routine should stimulate milk letdown and minimize the risk of contamination of the milk by bacteria and soil. At the same time the udder preparation must be practical and labour efficient. Although the importance of good udder preparation is well established, there is a wide variation in routine, as in mistakes, practiced by farmers at the milking parlour. Farmers are reluctant to change habits. Advice for changing the udder preparation routine is often perceived as more labour and slow-down of the milking process; even though, the proposed routine is more efficient and increases cow throughput with beneficial udder health and milk quality. Communication must be substantiated to bring the message and show the benefits of the right routine that fits the farm, considering that every farm is different and there is not something like a 'one fits all' udder preparation routine. In this paper we present key points that need to be taken into account for advising the right udder preparation routine on the farm. Attention needs to be paid to the environment where cows are housed and milked in, management practices, post dipping routines and the regulatory environment the farm is producing in.

# Effects of material, shape and mouthpiece venting on liner performance

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It is well known that liners have a major influence on milking performance. The majority of research on liners has been done using natural and synthetic rubber liners that are round in cross-section. Silicon has been used as a liner material and triangular, square and 'tri-circular' cross-sections have been for several decades. A more recent addition to the wide variety of liner designs is the addition of vents to the liner mouthpiece. This paper presents the results of a series of experiments designed to develop methods for characterizing liner performance and investigate the effects of material, shape and mouthpiece venting. The two primary measures of the gentleness of milking are the prevalence of teat-end hyperkeratosis and congestion of teat tissues during milking. The primary milking machine influence on teat-end hyperkeratosis is the compression applied to the teat-end during the D-phase of pulsation. A new dynamic method using the start of milk flow was used to rank the compression applied by a range of commercial liners. These differences in overpressure were highly correlated with teat end hyperkeratosis scores in field studies. Tissues can become congested at the end of the teat due to insufficient liner compression and/or in the teat barrel due to high mouthpiece vacuum. We have developed a method of estimating teat-end tissue congestion and made observations of teat barrel congestion for a range of liner types. The completeness of milking is usually measured by the stripping yield, amount of milk left in the udder after the detachment, which can be measured manually or by machine striping. we have developed a method using the change in milk yield as a measure of completeness of milking to avoid the difficulties associated with hand-stripping.

# Wearing gloves for milking in Western New York: To wear or not to wear?

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Quality Milk Production Services (QMPS) offers evaluations of the dairy farm operation with regard to optimal and safe production of high quality raw milk. Federal standard for milk SCC currently is 750,000 cells/ml. QMPS provides herd evaluations to prevent any rise in bulk tank SCC above regulatory level. Risk factors are identified and addressed. Milkers can transfer mastitis-causing pathogens from their hands to uninfected teats, thus a biosecurity recommendation has been that milkers wear gloves for any milking routine. There is no data about wearing gloves for milking in Western New York. The objective of this study was to give preliminary data on this strategy in Western New York. Between April 2010 and March 2011, QMPS regional lab (Geneseo, NY) performed 50 whole herd samplings because these herds violated the federal standard for SCC (i.e. herds were required by law to participate in our program), and 61 herds voluntarily asked for a whole or partial herd sampling (i.e. herds participating in our program as a preventative action). A survey questionnaire included a question about wearing gloves for milking, no questions were made on farmers' opinion about wearing gloves. Descriptive analyses were used to explore the data. The association of violating federal SCC standard and wearing gloves was analyzed by logistic regression. Across all farms, gloves were worn in 48.7% of the herds, while gloves were not worn in 51.3% of them. Stratifying by herds (i.e. required versus voluntary) indicated that gloves were only worn in 16% of the required herds, while milkers wore gloves in 84% of the voluntary herds ($P$<0.001). Herds where milkers have worn gloves had lower odds of violating the federal SCC regulation compared to those herds where milkers did not wear gloves (OR: 0.071, SE: 0.033. $P$<0.001). In conclusion, in about half of the dairy farms, milkers wore gloves for any milking routine in Western New York. Wearing gloves was generally associated with lower bulk milk SCC.

# New technology for vacuum-logging during milking helps advisor

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Udder health problems are often related to the milking equipment, many times in combination with inadequate milking routines. Notorious are teat-end vacuum fluctuations due to poor quality liners, liner slips or insufficient vacuum capacity. Pathogens reaching the teat-end due to 'back-spray' or 'cluster-flooding' is another known cause. This poster is about experiences of milking advisors with a new technology that is now available to log the vacuum at relevant points during milking ('wet test') to better analyze milking equipment and milking routines. The development of this new technology was initiated by the IDF Working Group 'Milking Time Tests methodology and interpretation of results' and deployed by Tine, the Norwegian dairy farmers cooperative. This new technology (VaDia: Vacuum Diagnostics of milking) is a battery operated data logger, small and light enough to be taped to a teatcup during milking. VaDia logs the vacuum data at four points during milking and works completely 'stand-alone'. This enables the advisor to forget about the actual measurement and concentrate on observations of milking routines and collection of other relevant information. After the milking the data can be analyzed in detail, indicating clearly all vacuum irregularities and thus where the milking equipment and milking routines are underperforming. VaDia has been recently introduced to the milking advisors in some Nordic countries. This poster will elaborate on the experiences of Tine's milking advisors with this new technology and how it helps the advisors to do a better job when assisting farmers in controlling their udder health problems.

# The world of post milking teat disinfectants: features, uses and risks

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Post milking teat disinfectants have been widely tested and used to prevent mastitis caused by contagious and environment bacteria. NMC has a documented reference list of products that have proved to be effective and the results have been published in peer-review publications. Appropriate use of teat disinfecting products reduces mastitis rates and consequently would reduce the need for antibiotic use. Post milking teat disinfectants are based on a range of germicides, differing types and levels of emollient, physical forms, and are applied to teats by a range of methods. Historically products were applied by dipping or spraying and in most published studies products were applied by dipping. Today products are marketed in a range of physical forms/applications methods without always a clear understanding of the advantage of the different product types. Product types include: dippable, sprayable, high viscosity, barrier/film forming products, foam products, dry powders, and winter dips. This paper will review the intended benefit of the different types of teat disinfection products and the possible risk factors associated with them. The goal is to create a communication tool on appropriate use of teat disinfectants.

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