Health and Reproduction in Organic and Conventional Swedish Dairy Cows

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Abstract

This thesis compares indicators of animal health and reproduction in organically and conventionally managed dairy cows in Sweden. The first part of the thesis is based on data from a twelve-year longitudinal study of a research farm with parallel but separate organic and conventional management. The second part of the thesis is based on data from a field investigation performed by the author. The field investigation included 20 organically and 20 conventionally managed dairy herds in south-east Sweden. Udder health and reproductive performance were studied in both the research farm and in the field study, general health and length of productive life in the research farm only and early-lactation metabolic profiles in the field study only.

Udder health was assessed by comparing somatic cell counts during first 150 days in milk, number of test-milking occasions with >200,000 cells/ml during first 150 days in milk and number of veterinary treated cases of mastitis. Reproductive performance was assessed by comparing calving interval, calving-to-first insemination and pregnancy success at first insemination. Body condition score and blood metabolites indicating negative energy balance such as non-esterified fatty acids, beta-hydroxybutyrate, glucose and insulin were measured.

Multivariable, multilevel statistical models were consistently employed. Management type, breed, housing, parity, and milk yield were frequently used predictor variables in the different statistical models. The predictor variable of main interest, organic or conventional management, was forced to stay in all models.

The conclusion is that under Swedish conditions, cows in organic and conventional dairy management differ only marginally considering mastitis, reproductive performance and metabolic profiles, implying that animal health in organic management is equally good as in conventional management in these specific fields.

Keywords: organic, dairy cow, udder health, milk yield, length of productive life, reproductive performance, metabolic profile

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To my beloved family

"The whole problem with the world is that fools and fanatics are always so certain of themselves, but wiser people so full of doubts."

"Everything is vague to a degree you do not realize till you have tried to make it precise."

Bertrand Russel

Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Fall, N., Emanuelson, U., Martinsson, K., Jonsson, S. (2008). Udder health at a Swedish research farm with both organic and conventional dairy cow management. Preventive Veterinary Medicine 83(2):186-195.

II Fall, N., Forslund, K., Emanuelson, U. (2008). Reproductive performance, general health, and longevity of dairy cows at a Swedish research farm with both organic and conventional management. Livestock Science 118(1-2):11-19.

III Fall, N., Gröhn, Y., Forslund, K., Essen-Gustavsson, B., Niskanen, R., and Emanuelson, U. (2008). An observational study on early lactation metabolic profiles in Swedish organically and conventionally managed dairy cows. Journal of Dairy Science 91:3983-3992.

IV Fall, N. and Emanuelson, U. (2009). Milk yield, udder health and reproductive performance in Swedish organic and conventional dairy herds. Journal of Dairy Research (in press).

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Abbreviations

BCS	Body condition score
BHBA	Beta-hydroxybutyrate
CFI	Calving-to-first insemination
CI	Calving interval
CMC	Conventionally managed cows
IFOAM	International Federation of Organic Agriculture Movements
LPL	Length of productive life
NEFA	Non-esterified fatty acids
OMC	Organically managed cows
SCC	Somatic cell count

1 Background

1.1 Organic farming

1.1.1 The rise of the organic movement

To illustrate the circumstances under which organic agriculture has progressed it can be categorized in three phases: the formulation of ideas in the 1930's and 40's, the breakthrough of organic thinking in the 1960's and 70's, and finally during the 1980's and 90's the institutionalization (Lund, 2002).

The rapid chemical and technical development of agriculture in the early 20th century resulted in decreased soil fertility with dramatic drops in harvest yields and declining food quality between the world wars. In consequence of this development several movements were initiated and led to what we today know as organic farming (Vogt, 2007). Science-based reform movements, in both the German- and English-speaking worlds, were important elements in the history of organic farming and promoted the concept of "natural agriculture". They called for natural ways of living and advocated vegetarianism, the use of natural medicine, rural living and for people to work as farmers. The reform movements opposed to modern technology, industrialization and urbanization and regarded artificial fertilizers responsible for the decrease in soil fertility and food quality (Vogt, 2007). Simultaneously, in the German speaking countries, the concepts of biodynamic agriculture were developed from the esoteric anthroposophic ideas of Rudolf Steiner (1861-1925). Anthroposophists regards the farm as an organism with a variety of organs such as crop production, animal husbandry, and gardening, where the organism should be able to reproduce itself without supplies from outside (Conford, 2001; Vogt, 2007). In addition to "natural agriculture", biodynamic agriculture has also been influential on the road to modern organic farming. Albert Howard (1873-1947), a British agricultural scientist in New Delhi, India, studied several agricultural areas and concluded that the health of soil, plants, animals and humans was interrelated, and that livestock manure and composting was a key feature for a healthy soil (Vogt, 2007). The latter view was shared by many of the critics of conventional farming (Conford, 2001). Howard was a prominent figure and inspirer in the development of organic farming in the English speaking world. The term *organic farming* was, however, introduced to the world by the British agronomist, Lord Northbourne, who presented the concept of "organic farming" in opposition to what he called "chemical farming" in his book "Look to the land" (1940). The first organic farms established in the Nordic countries started in the 1930's and practiced biodynamic methods (Lund, 2002).

The incipient environmental concern in the 1960's and 70's put agriculture in a new perspective and the ideas of organic agriculture were highlighted (Vogt, 2007). A driving force and symbol of the growing environmental awareness was the book "Silent Spring" (1962) by Rachel Carson, who described the spread of pesticides through the food-chain to animals and humans. In the debate following the book conventional farmers were described as scapegoats, which was in favor of the growing organic movement. New energy was added to the movement by novel environmentalists who engaged in the development and eventually, in 1972 IFOAM was founded by five national organizations (Geier, 2007). Among those organizations was the Swedish Biodynamic Association. Although IFOAM was run by volunteers initially, it came to grow considerably during the 1970's and in 1978 it consisted of 80 member organizations from 30 nations (Bourgeois, 1997). The work to present the first IFOAM Basic Standards was undertaken and in 1980 the first international standards for organic farming were presented.

The third phase in the history of organic agriculture was the institutionalization that mainly took place during the 1980's and 90's. The organic movement started to receive political support and became more integrated in the agricultural sector. In the Nordic countries laws promoting organic farming including public subsidies were introduced in the late 1980's (Lund, 2002) and the first EU-regulations on organic farming were presented in 1991 (The Council Of The European Communities, 1991). The first EU-regulations on organic agriculture were, however, aimed at plant production and a common EU framework for organic livestock production could not be agreed upon until 1999 (The Council Of The European Communities, 1999).

1.1.2 The organization of organic farming today

The International Federation of Organic Movements (IFOAM) is the worldwide umbrella organization coordinating the international network of organic agricultural organizations, today uniting 750 member organizations from 108 countries. The International Federation of Organic Movements has official committees and groups with specific purposes, from the development of standards to the facilitation of organic agriculture in developing countries. The General Assembly serves as the foundation of IFOAM and elects the World Board for a three year term. The World Board appoints members to official committees, working groups and task forces (IFOAM, 2009A).

In Sweden today, the main organic certification body is called KRAV. The KRAV standards are concordant with the IFOAM basic standards and the EU standards, but stricter in some specific areas. KRAV is an association of 28 national organizations that was founded in 1985. The objective was to make a trustworthy and clear tagging of organic feedstuffs in Sweden. Member organisations are for instance food retailers, the Swedish animal rights movement, the Swedish Dairy Association and the association for organic farmers in Sweden (KRAV, 2009).

1.1.3 Animal husbandry in organic farming

In the early history of the organic movement, animal production was not a prioritized concern and the animals were mostly seen as manure producers, important to improve soil fertility and crop production. Rudolf Steiner, the father of biodynamic agriculture did, however, point out livestock as an important ingredient in the farm as "an organism". Along with the development of organic agriculture the role of production animals has been altered (Vogt, 2007). During the 1960's and 70's, when the ideas of organic agriculture were highlighted and further developed, there was an opposition not only towards the industrialized and polluting agriculture, but also against intensive livestock production based on purchased feeds. The organic movement provided ideas of more natural and animal friendly ways of livestock production (Padel *et al.*, 2004). In conclusion, organic animal husbandry in general has developed more slowly than organic plant production, including development of standards and research. The explanation for this is probably that the organic movement developed primarily from environmental rather than animal welfare concerns (Stinner, 2007).

In organic animal production the principle of prevention rather than treatment should be emphasized (The Council Of The European Communities, 1999). To fulfill this idea there are two major approaches. The first one is to improve immunity and resistance to disease through appropriate nutrition and breeding and reduction of stress by allowing the animals to express a natural behavior. The second approach is reducing disease challenge by limiting mixing of animals from different herds, reduced stocking density, employing good hygiene and grazing management to prevent parasitic infections (Padel *et al.*, 2004).

1.1.4 Organic dairy farming

The aims of organic dairy farming are to produce milk and meat in a sustainable system based on good animal health and welfare. Compared to conventional production, organic dairy production is characterized by a higher roughage/concentrate ratio, a fertilizer- and pesticide-free production of crops and grass, a prolonged grazing season, an anti-parasite strategy without drugs and emphasis on regular exercise. According to European Union legislation (The Council Of The European Communities, 1999) organically managed cows must be fed organically produced feed, no genetically modified products may be used, and the total daily dry matter proportion of concentrate should not exceed 50% during the first three months of lactation and thereafter not more than 40%. At the time when the studies in this thesis were carried out organically managed herds were, however, allowed to use five percent conventionally produced feed per cow on a yearly basis. Antibiotics and other chemotherapeutic drugs are either forbidden or used less frequently than in conventional farms. For instance, in Sweden the organic regulations prescribe double withdrawal time for delivery of milk compared to the one laid out by the Swedish National Food Administration after treatment with registered pharmaceuticals. Furthermore, cows treated with registered pharmaceuticals more than twice during one year must have their milk withdrawn for six months. In 2007, 7.5 % of the Swedish dairy cows were managed according to organic standards and the number is constantly growing (Ekologiska Lantbrukarna, 2008).

1.2 The concepts of animal health and welfare

Health, as stated by the IFOAM principles of organic agriculture, is the wholeness and integrity of living systems. It is not simply the absence of illness, but the maintenance of physical, mental, social and ecological well-being. Immunity, resilience and regeneration are key characteristics of health (IFOAM, 2009B). In a similar way, the World Health Organization defined health, in 1946, as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO, 1946). Critics may well oppose to the nuisance of such broad and lofty definitions and argue for a more measurable and down-to-earth definition. To many veterinarians, with focus on animals' physical health and the role in helping farmers to provide affordable food, the term "animal health" appears to be, predominantly, a question of absence or presence of disease. Some controversialists even argue that production figures can serve as a direct measure of animal health. Hence, if an animal is producing well, it is thereby also healthy and faring well.

Obviously, there is a close link between animal health and animal welfare. Depending on viewpoints and beliefs, however, the differences in interpretation of the terms are diverging. Corresponding conflicting views as described above are also seen in the perception of animal welfare. Historically, three major positions have emerged in the views of animal welfare (Lund, 2002; Hewson, 2003). One approach is solely considering the animals' subjective feelings in the evaluation of welfare. A second approach is putting weight to the animals' biological functioning as the question of vital importance and the third idea is proposing that it depends on natural behavior.

In the organic context natural behavior is a central feature of animal welfare, whereas biologic functioning probably is more influential in the perspective of natural science, concerning both health and welfare. In the organic philosophy high animal welfare standards are considered important for ethical reasons, and in order to promote health and longevity. Furthermore, animal welfare is probably an important incitement for many organic customers. There is obviously no correct way of combining the different dimensions of animal welfare and there will always be a subjective element in weighing their perceived importance (Knierim *et al.*, 2004). The discrepancy of the stakeholders' different views and definitions of the terms animal health and welfare is essential to be aware of, in order to understand and communicate properly.

1.3 Indicators of animal health in dairy cows

Concerns that animal health in organic management is not satisfactory has been discussed (Jensen, 1999; Hardarson, 2001; Roesch *et al.*, 2005) and consequently there is a need of continuous evaluation of the animal health (Valle *et al.*, 2007). This was behold in a review paper where Lund and Algers (2003) called attention to the lack of peer reviewed papers in this specific area. Animal health assessment can, however, be tackled in several ways. Studies of disease occurrence are possible ways of assessing animal health and can be done by direct cow-side methods as well as by indirect methods. Studies of official health records and performing questionnaires reflecting what farmers can recall or percept are examples of indirect methods. Questionnaire studies tend to be of more subjective nature than the more objective registry and cow-side methods. Health can also be assessed by use of reproductive performance and animal behaviour. Reproductive performance is easiest studied by indirect methods, whereas animal behaviour is most suited for direct assessment methods. Stereotypic behaviour, in contrast to natural behaviour is a sign of ill-heath. However, the indistinct definition of natural behaviour can put a great deal of subjectivity into that kind of assessment.

The following key indicators, representing both direct and indirect study methods, were chosen to illustrate animal health in this doctoral thesis:

Udder health

Poor udder health is often referred to as the most important economically detrimental and most frequent production problem in dairy production in developed countries (Beaudeau *et al.*, 1995). There are direct and indirect ways to measure udder health. Indirectly it can be assessed by indicators related to clinical and subclinical mastitis measuring e.g. inflammatory components or pathogens in the milk. Two common ways of analysing subclinical mastitis are either by somatic cell count-derived measures or California mastitis test reactions. Udder health can be evaluated directly as cases of clinical mastitis. Under Swedish conditions veterinary treated cases of mastitis are expected to be well correlated with all actual cases of clinical mastitis as the animal welfare legislation prescribes veterinary consultation in case of clinical mastitis.

Mastitis is, by far, the most common disease reported in the national animal disease recording system in Sweden. The importance of the disease and large number of registrations makes clinical mastitis a suitable and relevant disease for comparison between organically managed cows (OMC) and conventionally managed cows (CMC). Furthermore, the Swedish official milk recording scheme, which comprise information on e.g. milk yield and somatic cell count (SCC) for a large part of the Swedish cow population, facilitate assessment of subclinical mastitis. Earlier studies of udder health in OMC have not revealed any clear trends. Some indicate better udder health in OMC (Hamilton *et al.*, 2002; Bennedsgaard *et al.*, 2003; Hamilton *et al.*, 2006; Valle *et al.*, 2007), some indicate worse (Hovi & Roderick, 2000; Zwald *et al.*, 2004; Nauta *et al.*, 2006; O'Mahony *et al.*, 2006; Roesch *et al.*, 2006; Thatcher *et al.*, 2008) and some are contradictious or do not indicate any noteworthy differences (Busato *et al.*, 2000; Weller & Bowling, 2000; Hardeng & Edge, 2001; Langford *et al.*, 2008).

General Health

To get an overview of the total disease burden in a herd with a single parameter is not easy. A feasible way to do this at either cow or herd level is, however, calculating the aggregated number of all veterinary treatments. This way of tackling the problem obviously disregard the underlying reasons for the veterinary treatments such as metabolic disease, parasites or infectious disease, but will indicate the general health status. To the author's knowledge, this method has not been widely used. However, Hamilton *et al.* (2002) found a lower mean incidence for all veterinary treated cases in Swedish organically managed cows compared to conventionally managed cows.

Reproductive performance and length of productive life

There is a large variety of reproductive measures used in the dairy sector. The aims of the different measures are different ranging from financial evaluations at herd level, over individual cow management plans to assessment of animal health. Hence, the choice of a reproductive measure is made depending on the purpose of the investigation. To indicate animal health the measure should preferably point to biological functioning rather than management decisions. Measures of reproductive performance have been reported to be influenced by both stress and malnutrition (Sasser *et al.*, 1988; Butler & Smith, 1989; Dobson & Smith, 2000; von Borell *et al.*, 2007). Reproductive performance is also elaborately registered in the Swedish milk recording scheme and indicators based on these are, consequently, suitable for health assessment.

However, the impact of organic farming on reproductive performance has previously not been comprehensively examined and there are only a handful of studies (Hardeng & Edge, 2001; 2005; Roesch *et al.*, 2006).

Yet another factor that is discussed in the comparison of OMC and CMC is longevity, which is a measure of how long time a cow stays alive in the herd. A lower intensity of production is believed to put less stress on OMC's and thus improve the possibilities to survive longer and be more cost-effective due to lower recruitment rates. Two Norwegian studies have indicated better longevity in OMC based on mean lactation numbers (Reksen *et al.*, 1999; Hardeng & Edge, 2001). A frequently used and more refined measure of longevity than mean lactation number is length of productive life (LPL). The most common areas where LPL has been studied previously are in genetic evaluation for breeding selection and in the search to understand how disease and poor reproductive performance influence the culling process (VanRaden & Klaaskate, 1993; Caraviello *et al.*, 2004; Schneider *et al.*, 2007).

Metabolic profiles

In the early lactation of a dairy cow energy intake is usually smaller than energy requirements, which results in negative energy balance and hence mobilization of body reserves. There are different ways of assessing negative energy balance in the clinical setting. Body condition scoring is a fast and easily performed test but somewhat blunt for evaluating individuals. The concentrations of serum non-esterified fatty acids (NEFA), β-hydroxybutyrate (BHBA), glucose and insulin are indirect measures of the magnitude and adaptation to negative energy balance and are commonly used as indicators of negative energy balance (Busato *et al.*, 2002; Andersen *et al.*, 2004; Nielsen *et al.*, 2007).

Concerns have been raised that OMC are at greater risk of negative energy balance than CMC because of the restrained use of concentrates (Hardeng & Edge, 2001; Roesch *et al.*, 2005). Two reasons for this concern are that the cows share the genetic potential for milk production and that restricted feeding may lead to larger negative energy balance and possibly metabolic stress. Conversely, lower milk yields have been shown in organic dairy farming (Roesch *et al.*, 2005) and this could possibly reduce the risk of negative energy balance in OMC. Ketosis is a clinical manifestation of negative energy balance and the prevalence has been studied previously in OMC. Hamilton *et al.* (2002) found no signs of widespread clinical or subclinical ketosis, whereas Hardeng and Edge (2001) found markedly lesser occurrence of clinical ketosis in organic than conventional cows.

1.4 Brief summary of further comparative research in organically and conventionally managed livestock

There are obviously many ways to assess and examine animal health in OMC in addition to the ways described above. There are for example studies on parasitology, where most studies indicate a worse situation concerning parasitic disease in OMC (Höglund *et al.*, 2001; Höglund *et al.*, 2004; Maggs *et al.*, 2008). Investigations on the status of antibiotic resistance have been done showing less abundance in OMC in the USA (Ray *et al.*, 2006; Pol & Ruegg, 2007; Rutherford *et al.*, 2009) where the use of antibiotics is strictly prohibited in OMC. Under European circumstances, where the use of antibiotics is restricted but not prohibited, Bennedsgaard *et al.* (2006) were not able to demonstrate any difference in antibiotic resistance between OMC and CMC. Two recent studies (Rutherford *et al.*, 2008, 2009) scrutinized lameness and hock lesions with lower levels indicated in OMC. Bidokhti *et al.* (2009) analyzed the risk of bovine corona virus infection and bovine respiratory syncytial virus infection clearly demonstrating a better situation in organic herds.

2 Aims

The overall aim was to gain further knowledge about the animal health and reproductive status in organically compared to conventionally managed dairy cows in Sweden.

The more specific aims were:

- To study metabolic parameters around parturition and in early lactation of an organically adjusted feeding plan compared to a conventional ditto.

- To study udder health parameters in organically and conventionally managed dairy cows.

- To study parameters representing reproductive performance in organically and conventionally managed dairy cows.

- To study the length of productive life in organically and conventionally managed dairy cows.

3 Summary of the investigations

3.1 Material and methods

The research was based on two different studies and presented in four publications. The first two publications were based on data from a research farm, Öjebyn, with parallel organic and conventional management. The last two publications were based on data from a field study.

3.1.1 Study design

Study design for the Öjebyn study (study I and II)

The first two publications were based on recordings from a Swedish research farm, Öjebyn, with parallel organic and conventional management for twelve consecutive years (1990-2001). The Öjebyn research farm is situated in the north of Sweden (Long. 218E and Lat. 658N) and was owned by the Swedish University of Agricultural Sciences (SLU). The objectives of the project at the research farm were to develop organic dairy farming and to compare organic and conventional farming systems. The 170-ha farm was divided into two separate systems: one organic and one conventional. The organic system was managed according to the standards of the Swedish organic certification association KRAV (http://www.krav.se), whereas the conventional system was managed according to the standard feeding plan with respect to the area. The same personnel cared for both the OMC and CMC, the stables were equivalent and the same classification of diseased animals was used. When the project was initiated in 1990, all dairy cows were randomly allocated to either the organic or the conventional group. On average, each management group contained about 50 cows throughout the study period and all cows were kept in tie stalls. At initiation of the project, most cows were of pure Swedish Polled breed. During the study artificial insemination with predominantly Swedish Holstein breed was used, which led, at the end of the study period, to a herd mainly consisting of Swedish Holstein cows. Only cows that were born during the study period were included in the study to assure that there was no confounding from individuals that had transferred from conventional to organic at initiation of the study.

Study design for the field study (study III and IV)

The field study was carried out in 20 organically and 20 conventionally managed dairy herds. All herds were located in the provinces of Småland (n=3), Sörmland (n=8), Uppland (n=15) and Östergötland (n=14). The selection was done among herds with >40 cows and herds participating in the Swedish Official Milk Recording Scheme. Furthermore, only herds that were not planning to cease milk production before the beginning of 2007 were included. In the organic cohort, only herds that had been certified organic dairy producers for at least two years, to avoid confounding from herds in transition to organic standards, were chosen. Only organic herds that were feeding 95% organic and 5% conventional feed were chosen. In the predetermined area of study, 52 organic and 283 conventional herds were eligible for inclusion according to the criteria above. All 52 eligible organic herds were asked to participate whereas 156 randomly selected conventional herds out of the 283 eligible herds were asked to participate.

The herds were all visited three times, with the first visit in the spring of 2005, the second in the fall of 2005 and the third and last visit in the spring of 2006. All herd visits were performed by the author himself. At each farm visit, cows and heifers that were within the period from seven days before their predicted calving to 42 days after calving were eligible for inclusion in the study of metabolic profiles. If the number of animals in a herd, meeting the inclusion criteria, was <12, all of them were sampled. If there were >12 eligible cows in a herd, 12 of them were randomly selected using a random number table and included in the study.

3.1.2 Questionnaires

An essential part the field study was to accomplish a questionnaire together with the person responsible for the dairy cows at each farm. The main questionnaire was filled in at the first visit to the herd and during the following visits additional, clarifying questions were presented. The questionnaires were especially focused on management and feeding routines.

Based on questionnaire data, for instance, the roughage/concentrate ratio (Table 1) and the length of the grazing period were estimated. To identify feeding plans that were comparable among the study herds, attempts were done to establish the dry matter amounts of roughage and concentrate at three stages of lactation: zero and 14 days after calving and at maximum production. To standardize, the feeding plan for a hypothetical cow yielding a maximum of 35 kg of milk per day at maximum production was asked for.

Table 1. *Dry matter roughage/concentrate ratio at three stages in lactation in 20 organic and 20 conventional Swedish dairy farms*

	Organic			Conventional		
Time	Q1[1]	Median	Q3[1]	Q1	Median	Q3
Calving	2.3	3.2	4.0	1.8	2.0	2.4
14 d in milk	1.1	1.3	1.5	0.7	0.9	1.1
Maximum production	1.0	1.1	1.3	0.6	0.6	0.7

[1]Q1 represents the 25th percentile and Q3 represents the 75th percentile (study III)

3.1.3 Clinical examination

Clinical examinations of the selected cows were performed and included rating of the general condition by both the farmer and the principal investigator. Furthermore cleanliness, body condition score, a visual fecal classification, examination of regional lymph nodes, respiratory frequency, claw status and direct questions about ongoing or previous treatments. The body condition score (BCS) was assessed according to a scale of one to five, in which one indicates severe undercondition and five indicates severe overcondition (Wildman *et al.*, 1982). The cleanliness was assessed using a hygiene scoring system, developed at the University of Wisconsin, Madison, USA, according to a scale from one to four, in which one indicates a clean body area and four indicates a dirty body area. "Udders", "legs" and "legs and upper legs" were the body areas studied according to the hygiene scoring system.

3.1.4 Blood sampling and analysis

A blood sample was drawn from the tail vein of all selected cows using ten ml evacuated tubes without anticoagulant. Blood glucose concentration and serum concentrations of NEFA, BHBA and insulin were analyzed. Blood glucose was analyzed "cow-side" using a glucometer (Precision Xceed, Abbott Diabetes Care). Tubes were transported at room temperature to a laboratory within four hours after sampling. Sera was then separated by centrifugation (2,000 × g for 10 min) of clotted blood and stored at • 20°C.

Serum samples were analyzed at the Department of Clinical Pathology, Swedish University of Agricultural Sciences, Uppsala, Sweden, using commercial kits according to the manufacturer's instructions. Severely hemolyzed samples were excluded. Serum BHBA was measured by enzymatic quantification (β-Hydroxybutyrate Liqui-Color Procedure No. 2440, Stanbio Laboratory, Boerne, TX). Serum NEFA were measured by a kininimine-red addition (NEFA C, ACS-ACOD method, Wako Chemicals GmbH, Neuss, Germany). Serum insulin was analyzed with a porcine insulin radioimmunoassay by the double antibody/PEG technique (Porcine Insulin RIA Kit, Linco Research, St. Charles, MO).

3.1.5 Collection of registry data

Recordings of individual cow data from monthly test-milking occasions and summary data of the first 150 days of lactation such as milk yield, milk composition (fat, protein, urea, SCC) in addition to birth, calving, and culling dates, breed and parity data, used for all the studies, were retrieved from the Swedish Official Milk Recording Scheme. Recordings on veterinary treated cases of disease used for studies I, II and IV, were retrieved from the national disease recording system. For studies I and II data was accessed for the years 1990 to 2001 and for studies III and IV for 2005 and 2006.

3.1.6 Model outcome variables

In studies III and IV the outcome variable milk yield was calculated as kg of energy corrected milk per day.

In the Öjebyn-study the geometric mean from all recorded monthly SCC tests and the number of SCC tests >200,000 cells/ml during the first 150 days of lactation were studied as indicators of subclinical mastitis. Correspondingly, the lactation SCC profiles were investigated in the field study. As an indicator of clinical mastitis the presence of veterinary treated cases of mastitis in the lactation was studied in both the Öjebyn and the field study.

The aggregated number of all veterinary treatments in the lactation was used as a measure of general health. A re-treatment within a certain qualification period was not counted as a new case. The qualification periods were disease specific and ranging from seven to 21 days.

Associations between herd management and reproductive performance were examined by comparing calving interval in days in both the Öjebyn and the field study. In addition, the number of days from calving-to-first insemination was examined in the Öjebyn study and the pregnancy success at first insemination was examined in the field study.

The length of productive life, calculated as the number of days from 1[st] calving to removal, was used as a measure of longevity.

To indicate the level of negative energy balance around parturition and six weeks post partum the following blood parameters were compared: NEFA, BHBA, glucose and insulin. In addition to the blood parameters, the body condition score was evaluated.

3.1.7 Statistical methods

To assess potential differences between CMC and OMC multivariable, multilevel statistical models were consistently employed. The variable of main interest, management type, was forced to stay in all models. Some different model types were used in the assessments. Linear mixed regression models were used to evaluate milk yield, SCC, metabolic parameters, BCS and calving interval (CI) (study II). Logistic regression models were used to assess presence or absence of veterinary treated cases of mastitis and pregnancy success at first insemination. A Poisson regression model was used to assess the total number of cases of veterinary treatments per lactation and furthermore, Cox's proportional hazards regression models were used to evaluate CI (study IV), time to veterinary-treated cases of mastitis, Calving-to-first insemination (CFI) and LPL.

Throughout the studies, model building was done by backward stepwise elimination of main effects with $p<0.2$ (F-test) as the exclusion and re-entering criterion. All possible first-order interactions were subsequently added to the model, and the backward stepwise-elimination process was continued until all remaining effects had $p<0.05$. Evaluations of colinearity among predictor variables were performed for all different models using Spearman or Pearson correlation coefficients. Potential confounders were consistently evaluated, and a variable was considered confounding if the point estimates of the coefficients in a model changed > 20% when the potential confounder was added to the model.

Depending on model type, the fit of the models were evaluated using different approaches.

All statistical analyses were performed using SAS® (SAS Institute Inc., Cary, NC, USA), except for the Cox's proportional hazards models with frailties that were performed using Stata Software (StataCorp LP, College Station, TX, USA).

3.2 Main results

3.2.1 Descriptive statistics

Öjebyn

The Öjebyn research was based on observations from 310 individual cows (OMC n=154 and CMC n=156), contributing 752 lactations (OMC n=380 and CMC n=372). Swedish Holstein was the predominant breed (OMC n=105 and CMC n=108) and the other cows were of Swedish polled and cross breed (OMC n=49 and CMC n=48). Furthermore there was a similar distribution of season of calving and age at first calving among the management groups.

Field study

The herds in the study ranged from 40 to 122 cows, with a median of 60 and 58 cows in organic and conventional herds respectively. Of the 2,482 cows studied 1,540 were of Swedish Red breed, 651 were of Swedish Holstein and 291 were of other or cross breeds. Housing was a skewed variable where loose stall was more frequent in organic (14 out of 20) than in conventional farms (seven out of 20). The length of the grazing periods differed significantly between management types. At herd level, the mean number of weeks on pasture for the OMC was 19.8 weeks (SD=4.9) and 16.2 weeks (SD=5.2) for the CMC.

3.2.2 Milk Yield

Among the cows studied at the research farm (study I) the median peak milk yield in first lactation was 26.3 and 26.9 kg/d, in 2nd lactation 33.0 and 35.4 kg/d and in third lactation or older 34.4 and 37.5 kg/d for OMC and CMC, respectively. The official milk production figures (2003) in the field study at herd level differed between the management types (t-test, $p<0.01$) with an average yearly milk yield of 8,222 kg and 9,171 kg per cow in organic and conventional production respectively (study III). The organically managed herds ranged from an average yearly milk production of 5,350 to 11,200 kg while the conventional farms ranged from 7,850 to 10,700 kg. Linear mixed models of daily milk yield were developed for 1st parity and older cows (study IV). The observations were classified in groups based on weeks after calving with two week intervals. For 1st parity cows the milk yield curves were a bit inconsistent due to differences between breeds that entailed a low number of observations per breed. For older cows the results clearly demonstrated that CMC consistently yielded more milk than OMC throughout the whole lactation (p<0.05 for all intervals) and that the shapes of the curves were similar (Figure 1).

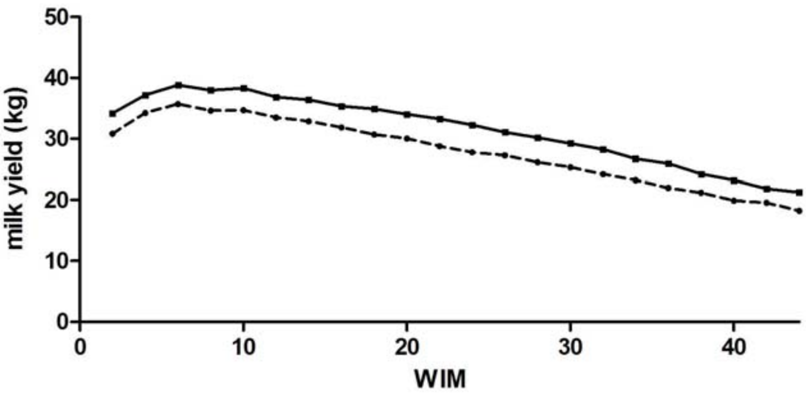


Figure 1. Least-square means estimated from a linear mixed model of milk yield (kg ECM day^{-1}) in second parity and older cows. The observations were classified in groups based on weeks after calving with two week intervals. Significant ($p<0.05$) differences between management type was observed for all time intervals. Organically managed cows are represented by dotted lines lines (----) and conventionally managed cows by solid lines (—). (study IV)

3.2.3 Udder and general health

The SCC-derived indicators of udder health problems applied in the Öjebyn study were average log transformed SCC during the first 150 days after calving and the number of monthly SCC tests exceeding 200,000 cells/ml during the first 150 days after calving. Both indicators were borderline significant (p=0.084 and p=0.060, respectively) in favor of organic management (study I). However, with the present study size, a post hoc power calculation showed that, with a power of 0.8 and a two-sided alpha of 0.05, a difference of 33,000 cells/ml for the average log SCC model or an incidence rate ratio of 0.65 for the high-SCC model would be needed to detect a significant difference.

A 305 days lactation SCC-profile was evaluated from the cows in the field-study herds and did not reveal any relevant trends or differences between management types (study IV). Furthermore, evaluations of clinical mastitis were performed for both the Öjebyn (study I) and the field study (study IV). Presence or absence of veterinary treated cases of mastitis in the studied lactations was evaluated for the Öjebyn study and time to veterinary treatment of mastitis was evaluated for the field study. None of the studies demonstrated any differences between the management styles (OR=1.0 and HR=1.0, respectively).

In the Öjebyn study the total number of cases of veterinary treatments per lactation was also studied as an indicator of general health (study II). The results did not imply any differences between the management types.

3.2.4 Reproductive performance

The indicators of reproductive performance in the Öjebyn study were time from calving-to-first insemination and calving interval (study II). The interval from calving to first insemination was similar between the management types for cows 1[st] and 2[nd] lactation, but for cows in 3[rd] lactation and older the CMC had a significantly lower Hazard-rate ratio than OMC in the corresponding age group (HR=0.62). To indicate reproductive performance in the herds of the field study pregnancy success of first insemination and calving interval were analyzed (study IV). No difference was found in pregnancy success of first insemination, but there was a lower Hazard-rate ratio (HR=0.72) for calving interval in OMC (p=0.02). A graph of the Kaplan-Meier survivor hazard functions for OMC and CMC shows that the curves are adjacent, but differentiate markedly when 50% of the cows have had a calving interval (figure 2).

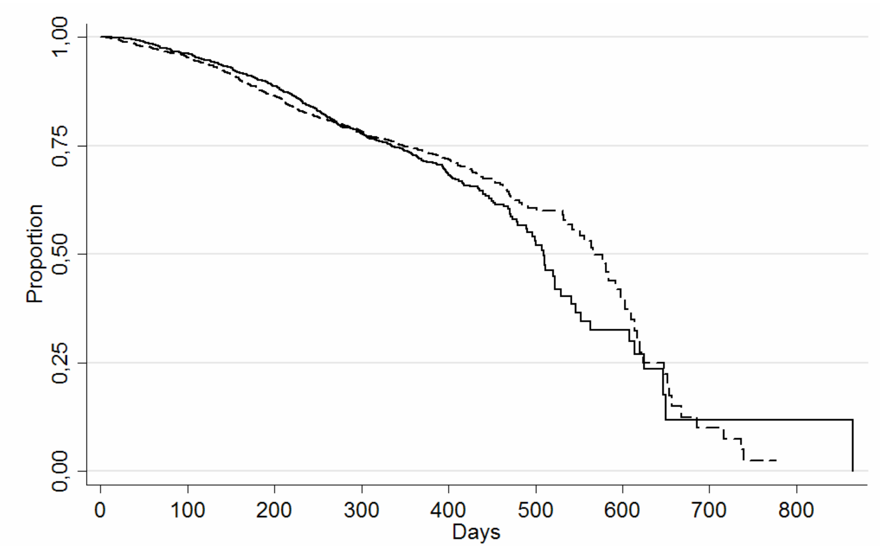
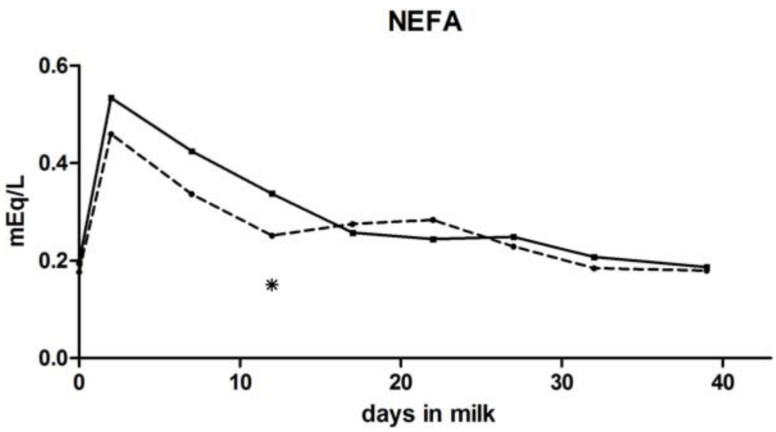


Figure 2. Kaplan-Meier survivor hazard functions of the calving interval from the field study. Organically managed cows are represented by dotted lines lines (----) and conventionally managed cows by solid lines(—).

3.2.5 Metabolic profiles

The analyses of blood metabolites and BCS did not show any essential differences between management types (study III). However, the least-square means for serum NEFA and BHBA concentrations showed tendencies of lower concentrations at some points in time in OMC and are presented in Figure 3.



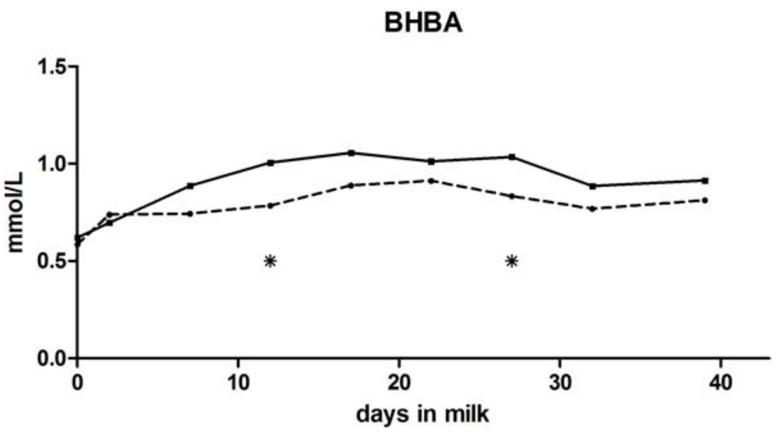


Figure 3. Least-square means from linear mixed models of the serum non-esterified fatty acids (NEFA) and β-hydroxybutyrate (BHBA) in Swedish lactating dairy cows from 20 organically and 20 conventionally managed farms studied to determine metabolic profiles. Organically managed cows are represented by dotted lines lines (----) and conventionally managed cows by solid lines (—).Time points with a significant difference ($p < 0.05$) are denoted with ★. (Study III)

There was no clear difference in serum insulin concentration observed in February through March, except for the time periods from zero to four and from 30 to 34 days in milk. No difference in serum insulin concentration was observed from October to December. No significant differences in serum glucose or body condition scores were found.

3.2.6 Length of productive life

The survival analysis of LPL in the data from the Öjebyn study did not reveal any significant differences between management types (study II).

4 General discussion

The underlying reason for conducting this project was the possibility of differences in animal health between organic and conventional management. Mental and social aspects were, in addition to the absence of disease, essential parts of the previously mentioned IFOAM and WHO definitions of the health concept. This thesis is, however, written with the starting point in veterinary science, and the assessment of animal health is focused on biologic functioning and built on such value assessments. Hence, this thesis aims to investigate possible differences in disease patterns that may relate to differences in housing conditions, treatment thresholds and restrictions on medicine use, farmer attitudes, cost-benefit relations and feeding strategies. Detailed discussion of each specific analysis is found in the respective paper and the ambition of the general discussion below is to summarize the principal features of the investigations.

4.1 Milk yield

Milk yield is not included in the thesis as an indicator of animal health, but as an important piece of background information. Virtually all studies comparing OMC and CMC, our as well as others, come to the unanimous conclusion that CMC yield more milk than OMC (Hardeng & Edge, 2001; Roesch *et al.*, 2005; Sato *et al.*, 2005; Ellis *et al.*, 2007; Pol & Ruegg, 2007; Roesch *et al.*, 2007; Rozzi *et al.*, 2007). The nutritional management associated with production system is the most likely explanation for this, where the organically managed farms rely on less concentrates and more roughage-based rations. A study by Andersen *et al.* (2003) comparing milk yield in cows given high or low amounts of concentrates gives support to this explanation. As a consequence of the difference, production level is a potential confounder why it should be taken under consideration while assessing animal health, if possible. It is noteworthy, however, that the variation in the organic cohort in the field study was larger than in the conventional one (study III and IV), indicating a more heterogeneous array of herds. This also implies that OMC may be at least as productive as CMC, given the right conditions, and then also possibly affected by the same negative consequences of high production as CMC.

4.2 Udder and general health

In addition to study I and IV only a handful of earlier studies have compared udder health parameters in OMC and CMC. Most of the studies origin from Europe but there are also studies from the USA.

4.2.1 Somatic cell counts

No differences in SCC between the management types were found in either of studies I or IV. Previously published studies provide rather divergent results when comparing SCC-derived measures in OMC and CMC. Consistent with studies I and IV bulk-tank somatic cell-count was compared without detecting any differences in a British study (Ellis *et al.*, 2007). In other studies (Hovi & Roderick, 2000; Hardeng & Edge, 2001; Nauta *et al.*, 2006; Roesch *et al.*, 2007) higher overall geometric means of SCC were demonstrated in OMC. In the study by Roesch *et al.* (2007), the difference was significant in early lactation (median 31 days), but not in later lactation (median 102 days). In that study the higher mean SCC in OMC was due to a higher number of cows having high SCC and not a generally increased SCC. When Hardeng *et al.* (2001) stratified the analysis on lactation number they found a significantly lower geometric mean in OMC in second lactation and a higher geometric mean in OMC in 6th lactation or higher, but no significant differences were found in the remaining lactations. Furthermore, Hardeng *et al.* (2001) studied the proportion of SCC recordings >200,000 cells/ml but no difference between the groups was identified. On the contrary, Hovi and Roderick (2000) reported higher proportion of SCC recordings >200,000 cells/ml in British OMC. In another British study by Weller and Bowling (2000) the bulk-tank SCC was significantly higher in OMC. The results from a Swiss study of 152 organic herds showed that the geometric mean SCC in organic bulk-tank milk was 15% lower than the Swiss average of 100,000 cells/ml and attributed that to the relatively low milk production in organic herds (Busato *et al.*, 2000). In line with the findings of Busato *et al.* (2000), a Swedish study of “udder health scores” in 26 organically compared to 102 conventionally managed herds indicated better udder health in OMC (Hamilton *et al.*, 2006). The selection bias introduced in the study by

Hamilton *et al.* (2006), where volunteer organic herds were compared to all conventional herds of comparable size in the same region, may possibly explain the difference in results compared to studies I and IV. In the two previously mentioned British studies (Hovi & Roderick, 2000; Weller & Bowling, 2000) the lack of dry period treatment was discussed as a possible explanation of the worse SCC status in OMC. Both studies were, however, carried out when organic dairy farming was a novel phenomenon in Britain with only a small number of organic herds. Hence, the studies are probably not particularly representative of current British organic herds. In general, European studies executed before the implementation of the EU-legislation on organic livestock production (The Council Of The European Communities, 1999) in respective country must be regarded as less indicative of the current status of organic dairy production.

4.2.2 Mastitis

Neither of studies I and IV showed any difference in the occurrence of clinical mastitis. Hence, it is not so bold to conclude that the previously described differences between organic and conventional management are not likely to affect the udder health under Swedish conditions. The results from studies I and IV are in line with the findings of Hovi and Roderick (2000) that in spite of demonstrating higher overall geometric means of SCC did not find any differences in farm incidence rates of mastitis. Some other studies have, however, shown lower incidences of mastitis treatments in OMC under Norwegian, Danish, Swedish, British, U.S. and Norwegian conditions, respectively (Hardeng & Edge, 2001; Bennedsgaard *et al.*, 2003; Hamilton *et al.*, 2006; Ellis *et al.*, 2007; Pol & Ruegg, 2007; Valle *et al.*, 2007). Different explanations for the lower incidence of clinical mastitis have been suggested. Some authors discuss unwillingness to treat diseased OMC with registered pharmaceuticals due to the prolonged withdrawal times of milk as a potential reason for the difference in their studies (Hardeng & Edge, 2001; Ellis *et al.*, 2007). Registry data is generally referring to veterinary treated cases of clinical mastitis and do not include cases of clinical mastitis that are solely handled using udder massage, frequent milking and alternative medicine. A recent study (Langford *et al.*, 2008) based on farmer recall data, in contrast to the earlier mentioned studies based on registry data, found a non-significant tendency ($0.05 \leq p<0.1$) that a lower proportion of cows in organically managed British herds were affected by mastitis per year than in their conventionally managed counterparts. The difference in feeding regimens was discussed as a potential explanatory factor by Hamilton *et al.* (2006), however, they concluded that there was little support in previous literature and advocated more research to elucidate the associations between high levels of concentrates and udder disease.

The results regarding mastitis frequency from a British and an Irish study was contradictory to the studies presented above, pointing to a higher incidence in OMC (Hovi & Roderick, 2000; O'Mahony *et al.*, 2006). Incorrect treatment of intramammary infections in organic management leading to recurring cases of mastitis was hypothesized as an explanation for the findings by O'Mahony *et al.* (2006). A longitudinal research farm study from New Zeeland (Thatcher *et al.*, 2008) also showed significantly higher incidence of clinical mastitis in OMC, but the study herd was pasture-based and therefore the production was rather different from other studies.

Previously published studies have shown that high milk yield is a risk factor for clinical mastitis (Barnouin *et al.*, 2005; O'Reilly *et al.*, 2006). In line with this Busato *et al.* (2000) and Bennedsgaard *et al.* (2003) have considered lower production levels in OMC as a potential explanation for better udder health in OMC.

Accordingly, the organically managed herds in studies I and IV, having significantly lower milk production, could have been expected to have a better udder health, which was not supported by our analyses. On the other hand, as the same udder health status was achieved in both management types, one could argue that the organically managed herds had better udder health management as they achieved it with a more restrictive antibiotic policy.

4.2.3 General health

Analyzing data on specific diseases in the two study designs was, with the exception of mastitis, not suitable due to the small number of disease observations. Nevertheless, a simple comparison of the observed data in study I indicated a lower incidence of paresis puerperalis in OMC compared to CMC (n=12 and n=23 respectively), which is in accordance with other studies (Weller & Bowling, 2000; Hardeng & Edge, 2001; Hamilton *et al.*, 2002). On the other hand ketosis was more common in OMC compared to CMC (n=12 and n=6 respectively) which is opposite to the findings in the studies mentioned above.

To get an aggregated view of disease at the research farm the total number of veterinary treatments per lactation as a measure of general health was examined. No significant differences were, however, found (study II).

Under certain circumstances, when the farmers' thresholds for consulting a veterinarian are similar, assessment of the total quantity of veterinary treatments can be a fair indicator of overall animal health, but in other settings it appears rather blunt. In the standardized setting at the research farm, where the same treatment thresholds were employed, the total number of veterinary treatments was considered informative. The previously mentioned study by Hamilton *et al.* (2002) also studied the total number of veterinary treatments, reporting a significantly lower number in OMC compared to CMC. However the previously mentioned bias in selection of herds in that study may also have influenced the general health results.

4.3 Reproductive performance

The impact of organic farming on reproductive performance has not been comprehensively examined and there are only a handful of studies. Cows with a high genetic potential have been suspected to cope badly with the organic rules because of the feeding restrictions (Hardarson, 2001; Nauta *et al.*, 2006). In line with this the reproductive measures CI and CFI was reported to be longer in the winter season in Norwegian OMC compared to CMC, suggesting deficient energy supply as an explanation (Reksen *et al.*, 1999). This idea was also supported by Sehested (2003) who demonstrated that a lower concentrate supplementation can cause prolongation of CFI and CI in organic cows. Studies II and IV did, however, like most other similar studies not indicate any consistent differences in reproductive performance parameters (Roesch *et al.*, 2005; Nauta *et al.*, 2006; Roesch *et al.*, 2006; Scottish Agricultural College, 2007). In another recent Swedish study of a total of 7,241 herds, representing 86% of all Swedish dairy herds, CFI and CI were reported to be significantly shorter at herd level in OMC compared to CMC (Lof *et al.*, 2007). Furthermore, the study by Löf *et al.* (2007) presented descriptive figures on CFI and CI in Swedish herds highlighting that the herds in study II and IV were among the best 25^{th} percentile of Swedish herds with reference to CFI and CI.

While comparing reproductive performance in OMC and CMC the ideal measure preferably reflects biological processes rather than management decisions. Depending on study design the same measures may be more or less informative in that aspect. In the field study (IV), CI is somewhat questionable as a biological indicator of health because it is affected by differences in voluntary waiting period between herds. In the research farm setting, however, where voluntary waiting period and some other management factors were equivalent, the CI was a better indicator of animal health. Hence, no crucial weight regarding animal health is given the result of the investigation of CI in study IV. The CI was yet included in the study as it is commonly used in other studies of reproductive performance.

When carefully scrutinized there was actually an indication of a longer CFI in older CMC (3rd lactation and older) in study II and furthermore study IV indicated that CMC were less likely to have a CI than OMC (Hazard-rate ratio of 0.72). A potential explanation could be an effect of a more severe metabolic stress in CMC. For the reasons that the significant difference in CFI was only found in older cows and that CI in the field study setting was not an ideal biological indicator, the differences should be interpreted conservatively.

4.4 Metabolism

As mentioned before, the rules of organic dairy farming put restrictions on the use of concentrates. Hence, there has been concerns that the high energy demands of early lactation can not be satisfied in organic management (Hardeng & Edge, 2001; Kristensen & Pedersen, 2001; Roesch *et al.*, 2005). This matter has not been elaborately studied apart from a study by Roesch *et al.* (2005) and study III. Study III showed that the profiles of all tested metabolic variables (NEFA, BHBA, insulin and glucose) and the BCS-profiles were very similar between OMC and CMC. Roesch *et al.* (2005) compared NEFA and BHBA at 30 days post partum and BCS at three different time-points (30 days pre partum, 30 and 100 days post partum) without discovering any differences. Altogether, both studies demonstrate that OMC are not more prone to develop a negative energy balance than CMC. Furthermore it means that OMC adapt their milk production to feeding.

Studies II and IV did not offer any god possibilities to examine clinical manifestations of metabolic disturbances because veterinary treated cases of metabolic disease were rare. Hence, the size of our studies did not encourage any further epidemiological analyses. Other researchers have presented figures of the ketosis incidence, but most have not reported any major differences (Weller & Bowling, 2000; Hamilton *et al.*, 2002; O'Mahony *et al.*, 2006). Those studies are based on rather small numbers of observations implying low statistical power and thus difficulties in obtaining significant differences even if such existed. Hardeng and Edge (2001) and Bennedsgaard *et al.* (2003) have, however, demonstrated significantly lower ketosis incidence in OMC compared to CMC in large epidemiologic studies in Norway and Denmark, respectively.

4.5 Length of productive life

Studies by Bennedsgaard *et al.* (2003) and Hardeng and Edge (2001) support the idea in organic philosophy that living conditions make OMC live longer than CMC. The underlying hypothesis is that better longevity is accomplished through reduction of stress and disease challenge, e.g. the lower milk yields in OMC. Study II did, however, not support that idea, but showed equal LPL in OMC and CMC. The conclusions in the previous studies were based on mean lactation number instead of LPL and must be regarded less indicative of longevity than the results presented in study IV.

4.6 Methodological considerations

4.6.1 Study design and study populations

The most commonly used study design to compare OMC and CMC is a cohort study with a number of farms of each management type. The obvious advantage of this design is that ordinary commercial farms can be enrolled in a pure type of observational study. The farms will be fairly easy to identify and a random selection will hopefully result in representative selection of the target populations. However, comparisons of health parameters in OMC and CMC, when the observations originate from different herds, as is most common, may partly reflect other wide-ranging differences in management routines and not solely direct effects of the organic farming. One way of avoiding this sort of bias is to keep OMC and CMC at the same research farm with the same general management except from differences in the rules of organic farming. The target population then gets small, and results may not be suitable to extrapolate outside the research farm. However, the results emanating from such a study design will hopefully reflect the direct effects of organic farming in a very neat and unbiased way. In this thesis both strategies were employed to approach the topical question of animal health in OMC from different angles.

Selection bias

The target population in the field study was OMC at Swedish herds with more than 40 milking cows on average. To draw conclusions about the target population from the findings in the study population, and possibly, also extrapolate the results to other populations the selection of study population was important. So, in order to allow for inferences with high degree of internal validity, the study design was carefully considered in order to avoid systematic bias, as far as possible. Hence, in the designated study area herds were randomly selected for invitation to participate, and furthermore, the study herds were randomly selected from all farms willing to participate. The need for "willingness" in this type of study introduces a risk of selection bias when assigning herds and is able to alter the internal validity. In the field study the risk increased as the willingness to participate was unequal between the cohorts. These selection bias problems may have altered the results, but hopefully there were no systematic effects. Unfortunately this common type of selection bias is hard to control for, and the direction of the effect is unpredictable. Consequently, one must subjectively weigh the study results regarding possible selection bias.

Information bias

A second source of bias is incorrect or misclassified data, often referred to as information or misclassification bias. All studies included in this thesis (I-IV) rely on registry data. A recent Swedish validation study indicated moderate overall correspondence of manual herd registrations and data from the national disease recording system registry (Mörk *et al.*, in press). In addition, the study reported on differential misclassification associated with different diagnoses and state-employed vs. private veterinarians (e.g. incidences for abomasal displacement and mastitis were 0.8 and 0.9, and 28.8 and 19.3 in farmers' data compared to the national disease recording system, respectively). Unfortunately there is no study for the Swedish Official Milk Recording Scheme, but it seems reasonable to assume similar or better reporting of fertility data compared to disease data, due to a shorter reporting chain. In the process of examining disease parameters in the field study (study IV) three herds were excluded due to a yearly mastitis incidence under two percent, indicating incomplete registry data. Hence, while interpreting the studies in the thesis it is important to be aware of the incomplete registry data and the differential data loss. Even though a recent Norwegian study (Valle *et al.*, 2007) actually indicated differential misclassification between organic and conventional management with reference to disease reporting, the differences in the structure of the dairy sectors, the disease reporting systems, animal welfare acts and possibly also attitudes towards alternative treatments between Norway and Sweden calls for careful interpretation under Swedish conditions. In study IV, there were no signs of differential data loss with regard to conventional vs. organic management, which would be the most devastating misclassification bias to alter the results. To avoid the problems associated with inadequate data quality one could perform studies based on farm registrations. However, of practical reasons, the effort would be close to insurmountable in extensive studies, like study III and IV, and the study population would probably have to be smaller leading to loss of statistical power and an increased risk of selection of bias.

Publication bias is another issue, where positive study results are handled differently from negative. In the context of comparing animal health in organic and conventional dairy management, where negative results are implying a lack of difference, there is an abundance of published such results, why such bias has been of lesser concern in studies I–IV.

4.6.2 General difficulties in the subject area

A legitimate and recurring question when reviewing the available literature on animal health in OMC is the difficulty of drawing inferences when comparing different countries (Lund & Algers, 2003; Ruegg, 2008). Even though the EU-countries, where most of the organic research is performed, obey to the same legal framework (The Council Of The European Communities, 1999), there are differences in organic as well as conventional management within those countries. Differences are found in attitudes towards disease treatments and views on animal welfare. As an example, in contrast to most other countries, Swedish organic rules and regulations do not promote alternative medicine over conventional veterinary medicine as a direct consequence of the strict Swedish animal welfare legislation. Despite the mentioned differences comparisons within the EU are valuable as long as one is aware of the dissimilarities and interpret results with wariness. However, drawing inferences about animal health and disease patterns in Sweden in relation to studies originating from outside the EU is too vague in most situations inasmuch as the rules and managements are too discrepant.

As pointed out in studies I–IV and also by others, the most prominent differences between organic and conventional management are found in the feeding regimens. However, to find out and document individual feeding plans in our type of large scale epidemiological studies has proved to be difficult not least in comparison to experimental settings. Despite having three occasions to refine and clarify the feeding information, the questionnaire results were somewhat disappointing as the herdsmen were giving rather vague answers. It was hard to perceive if the herdsmen told the true situation or if it reflected what their advisors had recommended. The most valuable figure emanating from this was, however, the roughage/concentrate ratio that indicated that the EU-legislation (The Council Of The European Communities, 1999) was implemented in the organic herds. To better capture and analyze feeding information in a field study like ours, an evaluation performed at the herd by feeding advisors would probably be advisable.

The previously described differences in the definitions of animal health and welfare between organic philosophy, the general public perception and animal science can constitute trouble in communication between interest groups. For instance, a lightly coughing animal that is allowed to express natural behaviour and is fed primarily roughage would perhaps be judged healthy and faring well by an organic herdsman while a veterinarian would not.

4.6.3 Statistical methods

Choosing appropriate statistical methods is always a question of great matter. In this thesis CI was analysed in two different ways. In study II CI was analysed by linear regression, whereas it was analyzed by survival regression in study IV. Linear regression is commonly used to analyze CI (Hare *et al.*, 2006; Lof *et al.*, 2007) and the interpretation of results is rather straight forward. In this special context the disadvantage of linear regression is that observations without a new calving date must be left out of the analysis. If the distribution of missing observations in the linear regression is skewed the results can get distorted. There is no risk for that in survival regression analysis as all observations are used. The results from survival analyses can, however, be somewhat harder to interpret. One way to simplify the interpretation of the Hazard-rate ratios from the survival analysis the results can be to present a survival curve as in Figure 2.

Another, previously mentioned, issue of methodological interest is the impact of studies with a small number of observations and therefore low statistical power on the number of studies presenting negative findings. In an attempt to address this kind of shortcoming post-hoc estimations of differences that could be ruled out with a statistical power of 0.8 was done in study I. The results of these estimations indicated that relatively large differences were needed to establish significant differences with the given number of observations. In conclusion, it is important to reflect over the number of observations in studies demonstrating negative results.

After the development of a model it is appropriate to evaluate the validity – how well the model works and fit the original data. Unfortunately, as model validation is an area under rapid development, more complex models are left without golden standards for validation and have a tendency to carry some vagueness in the methodology. Some of the models in studies I-V are of complex nature and the validations are done with the best of intentions, but may not necessarily be optimal.

5 Conclusion

Under Swedish conditions cows in organic and conventional dairy management differ only marginally considering udder health, reproductive performance, length of productive life and metabolic profiles around parturition and in early lactation, implying that animal health in organic management is equally good as in conventional management in these specific fields.

6 Future research

There is currently a very strong trend towards environmental concern and awareness in the western world. Hence, the progression of organic farming is facilitated. Many countries in the EU have national goals for the expansion of organic farming. Furthermore, animal health and welfare issues have come to be decisive factors for consumers, politicians and other stakeholders in modern society. Dairy farming is constantly changing due to structural and possibly also environmental challenges. Thus, a continuous supervision by unprejudiced scientific research about possible effects of organic farming on animal health and welfare is essential. National and international policy makers and also the organic movement itself need scientific support to make rational decisions in the process of developing organic farming. As we know them today, the organic rules are not always based on scientific facts and actual experience, but also philosophy. To further develop the rules of organic farming there is a need of research and scientific influence as there still is a long way to fulfill the long term goals of sustainability in combination with first-class animal health and welfare.

A recent example of a change that alter the conditions for organically managed dairy cows in the EU is the new requirement of 100% organically produced feed instead of the previous 95%. Hence, it would be interesting to follow up on metabolic profiles under the new feeding restrictions because the 5% conventional feed, usually concentrates of high-quality, may have been used during peak milk yield where the needs are greatest.

For the future studies there are several ways of developing the assessment methods. Differences in feeding has shown to be a central and recurring issue To achieve higher quality results studying metabolic parameters and metabolic disturbances it would be necessary to make more detailed records of feeding. The poor results of recording feeding rations by questionnaires at herd level in relation to the ambitious efforts in the field study demonstrated the bluntness of the method. In order to refine information on feeding a possibility would be to engage professional personnel to make on-farm measurements.

An aspect of udder health that would be interesting to focus on is the distribution of mastitis agents. The management differences could possibly benefit different bacteria and the question is not yet studied under Swedish conditions. Furthermore, it would be rewarding to proceed the evaluation of longevity in a large field study.

An alternative way of scrutinizing the field study data would be to compare outlier herds, e.g. the highest and lowest producing quartiles in each management type. The array of organic herds was rather heterogeneous ranging from the lowest to highest observed average yearly milk production, why the average health effects possibly may differ substantially from the lower to the higher producing herds.

Another future challenge is to investigate the quality of the national disease recording system and the Swedish Official Milk Recording Scheme to find out whether there is differential misclassification between the management types. Furthermore, to improve the quality of disease and fertility data used for the health assessment an interesting solution for field studies could be to develop a system for in-herd data recording instead of relying on the official records. Higher quality data in combination with a large study population would offer excellent opportunities to study potential differences in specific diseases with more accuracy than was possible in this project. In-herd data recordings would perhaps also be an opportunity to register other aspects of health that better mirrors health as it is defined by the WHO.

7 Populärvetenskaplig sammanfattning

7.1 Bakgrund

Den ekologiska rörelsen har utvecklats ur flera alternativa jordbruksrörelser. Utvecklingen kan grovt delas in i tre faser: utvecklingen av idéer under trettio- och fyrtiotalet, genombrottet för ekologiskt tänkande under sextio- och sjuttiotalet samt institutionaliseringen under åttio- och nittiotalet. Världens ekologiska rörelser är sedan 1972 sammanslutna i en centralorganisation, IFOAM.

En av grundidéerna för att uppnå god djurhälsa i ekologisk djurproduktion är att förebyggande åtgärder är att föredra före medicinsk behandling av sjukdomar. Genom lämplig utfodring och avel samt att djuren får möjlighet att bete sig naturligt vill man förbättra djurens motståndskraft mot sjukdomar. Vidare är tanken att smittrycket i djurbesättningar minskas genom att begränsa blandning av djur från olika besättningar, minska antalet djur per ytenhet och genom bra beteshygien.

Målet med den ekologiska mjölkproduktionen är att producera mjölk och kött i ett hållbart system baserat på god djurhälsa och djurvälfärd. Jämfört med konventionellt skötta mjölkkor utfodras ekologiskt skötta mjölkkor med en större andel grovfoder i förhållande till kraftfoder, foder som är producerat utan konstgödsel och bekämpningsmedel, djuren får en längre betesperiod och får regelbunden motion. Den tid man måste vänta innan man får leverera mjölk från kor som behandlats med medicin (karenstiden) skiljer sig också mellan driftsformerna. I Sverige är denna tid dubbelt så lång för ekologiskt jämfört med konventionellt producerad mjölk. I motsats till tanken att djurhälsan påverkas positivt av ekologisk djurhållning finns dock även farhågor att djurhälsan istället kan påverkas på ett negativt sätt. Orsakerna till att djurhälsan i ekologisk produktion ibland befaras vara sämre än i konventionell är bland annat ökad stress till följd av underskott på energi i fodret, underlåtenhet att behandla sjuka djur till följd av lång karenstid, skillnader i djurens närmiljö, djurägarnas inställning till djurhållning, skillnader i ekonomiska avvägningar och skillnader i utfodring.

Syftet med avhandlingen var att utvärdera om djurhälsan skiljer sig åt mellan kor i ekologisk och konventionell mjölkproduktion.

7.2 Sammanfattning av studier och resultat

För att uppnå avhandlingens syfte speglades djurhälsoläget hos korna genom studier av tecken på juverinflammation och juverinfektion (juverhälsa), generell sjuklighet, fertilitet, produktiv livslängd samt hur ämnesomsättningen fungerade. Två olika studieupplägg användes för att studera och besvara frågeställningarna. Det första upplägget innebar studier av hälsoparametrar hos de kor som ingått i ett tolv år långt försök med parallell ekologisk och konventionell produktion som genomfördes vid SLUs försöksgård Öjebyn mellan 1990 och 2001. Det andra upplägget innebar genomförandet av en stor fältstudie av kor på 20 ekologiska och 20 konventionella mjölkgårdar. Olika sorters statistiska bearbetningar användes för att utröna om det var någon skillnad mellan produktionsformerna.

Mjölkavkastning och juverhälsa

I enighet med tidigare kunskap visar avhandlingen att mjölkproduktionen generellt sett är lägre i ekologiska besättningar än i konventionella.

Dålig juverhälsa är det vanligaste och mest ekonomiskt betydelsefulla sjukdomsproblemet hos mjölkkor. Juverhälsan studerades genom att jämföra förekomsten av veterinärbehandlade juverinflammationer och genom jämförelser av olika celltalsmått. Celltal är en indikator på inflammation i juvret som bygger på antalet inflammatorisk celler i mjölken. Med hjälp av celltal kan man identifiera även lindriga juverinflammationer som inte ger iakttagbara symptom. Inget av de olika juverhälsomått som användes visade på några relevanta skillnader mellan driftsformerna.

Generell sjuklighet och kornas livslängd

Som ett mått på den generella sjukligheten i Öjebystudien undersöktes det totala antalet registrerade sjukdomstillfällen för varje laktation. I nämnda studie jämfördes också kornas produktiva livslängd. Förespråkare för ekologisk djurhållning menar att lägre mjölkproduktion i kombination med andra levnadsbetingelser ger korna förutsättningar för ett längre produktivt liv. Varken den generella sjukligheten eller kornas produktiva livslängd skilde sig dock åt mellan ekologisk och konventionell drift.

Fertilitet

Utfodringen är en av de faktorer som skiljer mest mellan ekologiskt och konventionellt skötta kor. Tidigare studier har visat att underutfodring och stress är faktorer som kan ge nedsatt fruktsamhet. Genom att studera hur långt kalvningsintervall korna hade, hur lång tid det förflöt från kalvning till den första inseminationen gjordes och hur stor andel av korna som blev dräktiga efter den första inseminationen efter kalvningen bedömdes fruktsamheten. Inga betydande skillnader mellan ekologisk och konventionell drift påvisas med avseende på fertilitet.

Ämnesomsättning

Kor kommer ofta i en negativ energibalans just efter kalvning. Det innebär att produktionen av mjölk förbrukar mer energi än den energi korna kan få i sig genom sin föda. Det finns farhågor om att ekologiska kor, som enligt de ekologiska reglerna skall äta mindre energirikt foder (kraftfoder), skulle drabbas värre av negativ energibalans än konventionella kor. För att undersöka hur kornas ämnesomsättning fungerade i perioden runt kalvningen studerades därför några olika ämnen i blodet. Dessa undersökningar visade inte på några relevanta ämnesomsättningsskillnader mellan ekologiskt och konventionellt skötta kor i den aktuella tidsperioden.

7.3 Slutsats

Under svenska förhållanden skiljer sig ekologiskt och konventionellt skötta kor endast marginellt med avseende på juverhälsa, generell sjuklighet, produktiv livslängd, fertilitet och ämnesomsättning kring kalvning. Detta tyder på att djurhälsan hos ekologiska mjölkkor är lika bra som hos konventionella, i alla fall för de områden som undersöktes i avhandlingen.

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