Organic Dairy Production

Herd Characteristics and Genotype by Environment Interactions

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Abstract

The aim of this thesis was to gain further knowledge about the performance of cows in organic dairy production and their ability to adapt to the organic production environment. Milk production traits, fertility traits, somatic cell count (SCC) and longevity traits were analysed in organic and conventional herds and the reasons for culling in the two systems were investigated. Furthermore, the genetic correlation between traits expressed in organic and conventional production was estimated to assess the occurrence of genotype by environment interaction (GxE). The data contained records from almost all organic and conventional herds in Sweden.

This thesis shows that performance of organically managed dairy cows differs from conventionally managed cows. Cows in organic herds had lower production, better fertility and higher SCC than cows in conventional herds. However, the performance of cows in organic production depended to a large extent on the lower milk production level. At a given production level, organically managed cows had slightly worse fertility but equal SCC as cows in conventional herds.

Cows stayed longer in organic herds than in conventional herds and the main reason for culling differed between the production systems. The main reason for culling in organic production was poor udder health followed by low fertility. In conventional production the main reason for culling was low fertility followed by poor udder health. The results indicate that organic farmers are more concerned about udder health than conventional farmers are.

Genetic correlations for production, fertility, SCC and longevity, estimated in organic and conventional dairy production were in general close to unity. The results indicate that current breeding values for Swedish Red bulls, estimated in conventional production, are adequate for organic production. Weak GxE was found for fertility traits in Swedish Holstein cows, indicating that some cows of this breed are better suited for organic production than others. However, the magnitude of GxE does not justify development of a separate breeding programme for the organic population today.

Keywords: organic production, milk production, fertility, reproduction, somatic cell count, longevity, culling, cow, cattle

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Ju mer man tanker, ju mer inser man att det inte finns något enkelt svar.
Nalle Puh – A.A. Milne

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 Sundberg, T., Berglund, B., Rydhmer, L., Strandberg, E. (2009). Fertility, somatic cell count and milk production in Swedish organic and conventional dairy herds. *Livestock Science* 129, 176-182.

II Sundberg, T., Rydhmer, L., Fikse, W.F., Berglund, B., Strandberg, E. (2010). Genotype by environment interaction of Swedish dairy cows in organic and conventional production systems. *Acta Agriculturae Scandinavica, Section A, Animal Science* 60, 65-73.

III Ahlman, T., Berglund, B., Rydhmer, L., Strandberg, E. (2010). Culling reasons in organic and conventional dairy herds and genotype by environment interactions for longevity. (Submitted to *Journal of Dairy Science*).

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Abbreviations

AI	Artificial Insemination
CFI	Interval between calving and first insemination
CI	Calving Interval
CLI	Interval between calving and last insemination
ECO-AB	European Consortium for Organic Animal Breeding
ET	Embryo Transfer
FLI	Interval between first and last insemination
FS	Fertility determined survival
GxE	Genotype by Environment interaction
IFOAM	International Federation of Organic Agriculture Movements
INCkg	Increase in milk production from first to second lactation, expressed in kg milk
INC%	Increase in milk production from first to second lactation, expressed as a percentage
KRAV	A Swedish certification organization for organic production
NINS	Number of inseminations per service period
PFI	Proportion pregnant at first insemination
PL	Length of productive life
SCC	Somatic Cell Count
S1	Survival through first lactation
S2	Survival through second lactation
S3	Survival through third lactation
UHS	Udder health determined survival

Introduction

Increased awareness about climate change and environmental issues has been followed by a worldwide debate about development of sustainable food production systems, adapted to different farming conditions. The need for sustainable farming systems has, however, been realized by some farmers since the beginning of the 20^{th} century (Lund, 2002). Alternative production systems based on holistic views developed and became with time an integrated part of the agricultural sector, today known as organic farming.

Organic agriculture considers ecological, social and ethical impacts of farming and developed as a reaction to the industrialization of agriculture and the growing reliance on synthetic fertilizers and pesticides (Lund, 2002). The main focus in the development of organic agriculture has been soil fertility and crop production. The animals' role in the agro-ecosystem has been considered important but scientific studies on animal husbandry in organic production have been scarce.

The performance of cows in organic production has been studied in different countries during the last decades. The main focus has been on production traits and animal health, whereas studies of cow fertility and longevity are still scarce. The results available indicate that cow performance differs between organic and conventional herds and the cows' ability to adapt to the organic production environment has therefore been questioned (Pryce et al., 2004). Most organic farmers use the same breeds as conventional farmers and are dependent on the conventional breeding programmes. These animals are mainly selected for high production in an environment that differs from that of organic production, mainly regarding feeding regimes and medical treatments.

Dairy cows' ability to adapt to organic production environments have, according to my knowledge, only been published by Nauta et al. (2006a).

They found that the genes important for milk production differed to some extent between organic and conventional herds in the Netherlands. This means that the bulls with the highest breeding values, estimated in conventional production, may not be the best bulls in organic production.

The main objective of this thesis was to gain knowledge about the performance of organically managed cows in Sweden and their ability to adapt to the organic production environment. Apart from milk production, several functional traits related to fertility, udder health and longevity were investigated. The results of this thesis will indicate whether the current breeding values are adequate for organic production.

General background

Organic dairy production

Development of organic farming

Organic agriculture has grown rapidly the last decades and has gained a significant market share. However, organic farming is not a recent invention. It has its roots in different alternative production methods that were developed in English- and German-speaking parts of the world at the beginning of the 20th century. These methods, e.g. "natural" and "biodynamic" agriculture, were developed as a reaction to the industrialization of agriculture and the growing reliance on synthetic fertilizers and pesticides (Lund, 2002). They were based on holistic views and strived for sustainability, and gained increased attention in the 1960's because of the increased environmental awareness. In 1972, the International Federation of Organic Agriculture Movements (IFOAM) was founded and the concept of "organic farming" was established.

Organic farming was developed and driven by people searching for a sustainable way to farm where land, animals and humans are in harmony. For many years, organic farming was a rare alternative to conventional production, but in the 1980's organic farmers in Europe got better organized and national standards for organic production were developed (Lund, 2002). At the same time, the organic agriculture received attention from politicians, who realized that the lower intensity of organic production could have a positive effect on current agricultural problems, such as overproduction of food in developed countries and pollution of the water. The organic movement received political support, and subsidies for conversion to organic production were introduced in the late 1980's (Lund, 2002).

Today, organic production is an integrated part of the agricultural sector and in 2008, 3.4% of the food products sold in Sweden was organically produced (Statistics Sweden, 2009). Small scale production and local markets have to a great extent been changed to large production facilities and supermarket chains. Supermarket chains in Sweden have introduced their own organic trademarks, for example 'Änglamark' by Coop and 'I love eco' by ICA.

Animals in organic production

Livestock is important for the flow of nutrients at organic farms, because they provide manure and contribute to soil fertility by consuming legumes and grasses. Nevertheless, development of organic animal husbandry was neglected in the early history of organic agriculture, while soil fertility and crop production were emphasized. In the 1960's there was an opposition against intensive livestock production based on purchased feed and in this context, the organic movement provided a more natural way of production (Padel et al., 2004). The development of the organic animal husbandry was, however, slow until the end of the 20th century. Interest in organic animal production is now growing and an increasing number of scientific studies, mainly regarding animal health and welfare in organic systems, have been published. Nevertheless, studies regarding the genetic aspects of organic animal production are scarce.

Principles and certification

Basic standards for organic production were first published in 1980 by IFOAM. These standards are today accepted and implemented by 750 national or regional certification and inspection organizations worldwide. A common European legal framework for organic plant production was introduced in 1991 and was extended with a framework for livestock production in 1999 (The Council of the EU, 1991; The Council of the EU, 1999). The aim of the EU regulation is to look after the interests of the consumers and harmonize trade within EU. Member states cannot set higher organic standards than those in force for the EU as a whole; however, organic control bodies can. Consequently, there is some variation in the organic standards between regions and countries.

Apart from the EU regulation, the producers of organic products in Sweden can have their production certified according to the higher standards of the Swedish organic certification organisations KRAV and Demeterförbundet, established in 1985 and 1957 respectively. All dairy farms that deliver organic milk to the dairies associated with the Swedish

Dairy Association are certified by KRAV. Three independent organizations are responsible for the inspections of organic farms in Sweden: SMAK, Aranea Certifiering and HS Certifiering.

The overall aims of the standards are to maintain and enhance the quality of organic production and provide guarantees for the consumers (Padel et al., 2004). The standards represent a compromise between what is desirable from an idealistic point of view and what is currently technically and economically feasible at farm level. The standards are revised at regular intervals but detailed standards are still missing within some areas, such as breeding strategies and the use of modern reproduction techniques. The main differences between organic and conventional production are related to feeding regimes and medical treatments. The differences between KRAV standards and the Swedish animal welfare law, which probably had largest impact on the production environment for dairy cows during the time period of this project, are given in Table 1.

Organic dairy production in Sweden

Organically produced milk was delivered to a Swedish dairy (Värmlandsmejerier, i.e. Milko at present) for the first time in 1989, by nine organic farms with 250 dairy cows in all (Ekologiska Lantbrukarna, 2008). The number of organic dairy farms increased slowly until 1995, when subsidies for organic farming were introduced. Thereafter, many farmers choose to convert to organic production. The rapid increase of organic farms slowed down in the mid 2000's when the market share of organic milk was about 5%. However, the consumer demand for organic dairy products continued to grow, resulting in a scarcity of organic milk. To meet the consumer demand, the dairies increased the payment to organic producers, to entice more conventional farmers to convert to organic production.

In 2009 the number of organic dairy herds in Sweden was 512 and almost 8% of the milk delivered to Swedish dairies was organically produced. This represents an increase of about 12% compared with the year before (Swedish Dairy Association, 2010a). The increase in consumed organic milk between 1990 and 2008 is shown in Figure 1. The proportion of organically managed dairy cows in Sweden is the fourth largest in Europe, after Austria (16%), Switzerland (10%) and Denmark (10%) (Rosati and Aumaitre, 2004; Commission Européenne, 2005).

Table 1. *Comparison of some standards affecting the production environment for dairy cows during the time period of this project, set by KRAV (KRAV, 2006), and the Swedish animal welfare law (Swedish Animal Welfare Agency, 2007)*

Organic regulations	Swedish animal welfare law
Feed management	
• Roughage shall be provided ad libitum. • Concentrate may not exceed 40% of the feed, except for the first three months after calving when 50% is allowed. • ≥ 50 % of the feed shall be produced at the farm. • ≤ 5 % of the yearly feed intake can be conventionally produced. • Genetically modified organisms, synthetic amino acids, urea and chemical solvents are not allowed in feed or in feed production.	• Cattle shall be provided feed of appropriate structure and the ration shall guarantee adequate, comprehensive and well balanced supply of nutrients.
Grazing	
• All animals should spend most of the time at pasture during the grazing season. Animals should also have the possibility to be outside during spring and autumn, except dairy cows kept in barns with similar conditions as outside.	• Cattle older than 6 months should be at pasture at least 6 hours a day during the grazing season.
Housing	
• It is only allowed to tie up cattle older than 20 months.	• Cattle may not be tied-up in a way that cause pain or prevent necessary body movements and rest.
Calving	
• Cows should give birth in a separate pen and may only be tied-up in exceptional cases. • Calves should stay with the dam during the colostrum period	• Special calving pens should exist in loose-housing systems.
Chemical treatments	
• No preventive use of anthelmintics and medicines is allowed, except for vaccines, but clinically affected animals should always be given necessary care. • Withdrawal periods for chemical substances should be twice as long as the periods established by the Swedish National Food Administration.	• It is not allowed to treat cows with hormones and other chemical substances for other purposes than to prevent or cure diseases.

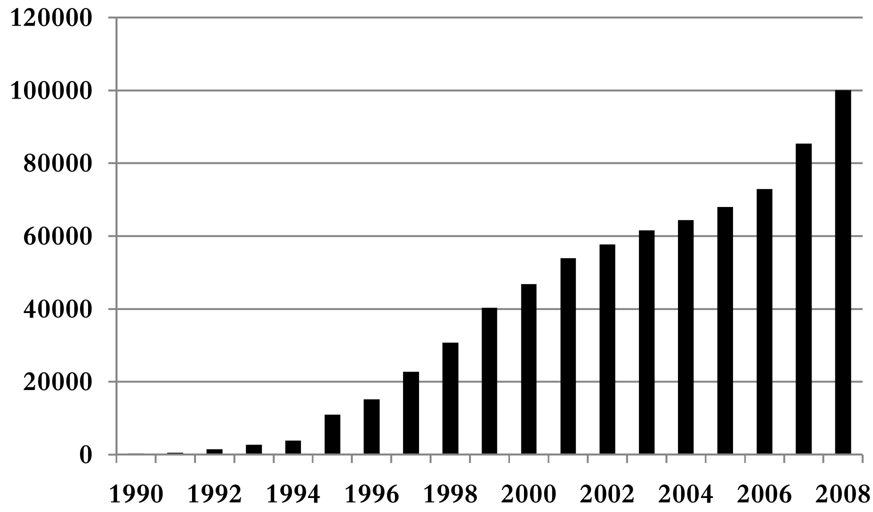

Figure 1. Consumed organic milk (in tonnes) in Sweden between 1990 and 2008 (Swedish Dairy Association (2010b).

Dairy cattle breeding

Aims for dairy cattle breeding

Dairy cattle breeding has become highly internationalized since artificial insemination (AI) was introduced in practical cattle breeding in the 1940's. World trade with frozen semen increased considerably in the 1960's and the convenient distribution of genetic material has resulted in global breeds. For example have North American Holstein genes been incorporated into several Friesian populations and largely replaced the Friesian breed (Philipsson, 1987). The breeding has been characterized by high selection intensities and narrow breeding objectives. The goal has been to increase the outputs of products and the possibilities to increase efficiency by including traits that reduce input costs have been overlooked for decades. Such traits, e.g. animal health, longevity and reproduction traits, are often referred to as "functional traits" and have been shown to be unfavourably correlated with milk production. Genetic correlations between production and functional traits are generally 0.2-0.5 in absolute figures (e.g. Roxström et al., 2001; Wall et al., 2003), and have resulted in reduced disease resistance and fertility within the global dairy cattle population (Rauw et al., 1998; Jorjani et al., 2009).

Breeding for functional traits is complicated due to difficulties in defining the traits precisely and collecting records routinely. Furthermore, these traits have low heritabilities (Roxström, 2001; Fikse and Philipsson, 2007; Berglund, 2008). However, genetic variation exists for functional traits, which justifies inclusion of these in breeding programmes (Philipsson and Lindhé, 2003). These breeding programmes should be based on large daughter groups; to get high accuracy despite the low heritability. The Scandinavian countries have considered functional traits in their breeding objectives since the 1960's, while the interest in other countries has risen during the last decades. Today, many countries have genetic evaluations in place for important functional traits (Mark, 2004; Miglior et al., 2005).

A challenge in dairy cattle breeding is to establish sustainable breeding programmes, which contribute to the maintenance and good care of animal genetic resources for future generations (Gamborg and Sandøe, 2005). The most pressing concerns about today's farm animal breeding are animal health, welfare and integrity, biodiversity, resource use and environmental effects, food quality and safety, and competitiveness (Gamborg et al., 2005). Most of the traits connected to these concerns do not have immediate market economic values. The relative weights given to these traits in the breeding goals are generally low which limits the genetic progress in these traits. Therefore, it has been argued that non-market values should be added to traits with unacceptable selection responses to achieve sustainability (Nielsen et al., 2005).

Genotype by environment interaction

The possibility for convenient exchange of genetic material, mostly semen, has led to globalization of breeds. However, the performance of breeds differs between different climates and production systems. This is due to genotype by environment interaction (GxE) that occurs when animals' ability to change their phenotype in response to changes in the environment differs (Falconer and Mackay, 1996). Thus, partly different genes are important in different environments and, implicitly, each animal would have different breeding values in different environments.

Common ways to investigate GxE are random regression models or multiple-trait models. A random regression model is useful when there is a continuous change in environment, e.g. feed ratio. The model identifies GxE as differences in reaction norms between animals, which describe the phenotype as a function of the environment. When the environment is divided into distinct classes, such as organic and conventional production, the multiple-trait model is preferably used. Traits expressed in the different environmental classes are then analysed as different traits and GxE is identified as a genetic correlation, significantly different from unity, between traits expressed in the different environments (Falconer and Mackay, 1996).

The environment can be described by one of the many factors that influence an individual, e.g. ambient temperature, availability of nutrients or parasite pressure, or by an indicator of a complex of environmental factors influencing a population. Examples of such indicators are herd characteristics, such as production level or management system, or country (Kolmodin, 2003). GxE in dairy cattle has been investigated for various environmental factors and re-ranking of animals has been found when the difference between the environments is large, e.g. between different climates or production intensities (Carabaño et al. 1989; Cienfuegos-Rivas et al. 1999; Fikse and Philipsson, 2007). However, also smaller differences between environments generate scaling effects, i.e. the difference between animals varies between environments but does not cause re-ranking. Scaling effects may influence the selection response in the environment where no genetic evaluation is performed (Hammami et al., 2009). The economic outputs of the breeding programmes may therefore be over-predicted if existing GxE is not accounted for (Dominik and Kinghorn, 2008). It is therefore important that the choice of bulls is based on evaluations performed in an environment as similar as possible to the environment the progeny will live in.

Breeding in organic dairy production

The organic principles emphasize that animals' capacity to adapt to local conditions should be considered when breeds are chosen and that the animals used in organic production should be selected for improved disease resistance (IFOAM, 2005; The Council of the EU, 1999). However, most farmers converting to organic production keep their former livestock, and therefore, most dairy cows in organic production are of high producing breeds, bred within the conventional production system (Nauta, 2001).

Today, there is an increasing debate about the use of conventional breeding animals in organic farming (Nauta, 2009). Many concerns are related to the ability of high producing breeds to adapt to organic environments, which often involve lower energy and protein intake and limited use of antibiotics. How well animals that are bred in one environment, can adapt to another environment is expressed by the occurrence of GxE. GxE has been found for production traits between organic and conventional dairy production in the Netherlands (Nauta et al., 2006a), which indicates that conventional breeding values are not optimal for organic farmers. Furthermore, different traits may be of different importance in organic herds compared to conventional herds and also the economic weights of traits may differ (Verhoog et al., 2004).

Some concerns are related to the use of modern reproduction techniques, which are inconsistent with the principle of naturalness that is an important part in organic agriculture. Such techniques are for example AI, embryo transplantation (ET), sexed semen and cloning techniques. Moreover, the use of genomic selection, where genetic markers are used to estimate genetic breeding values from blood samples, has been questioned (Spengler and Augsten, 2009).

Biological, ethical and economic considerations must be considered when discussing future options for breeding in organic production. Furthermore, farms in different regions or countries have different basic conditions and it is not likely to find one solution that is appropriate for all organic populations. Alternative breeding scenarios for organic dairy production have been presented by Nauta (2009):

1. Use adapted conventional breeding, i.e. take account of the effect of GxE between organic and conventional breeding and the weighing of different traits. The reproduction techniques used should also be addressed, e.g. by excluding direct use of ET bulls.
2. Use a separate breeding programmes within the organic production system, where the bulls are evaluated based on their daughters' performance in organic farms. All modern reproduction techniques except AI should be excluded.
3. Use local breeding programmes based on natural mating within the farm or region.

Aims of the thesis

The overall objective of this thesis was to gain further knowledge about the performance of cows in organic dairy production and their ability to adapt to the organic production environment, knowledge which may contribute to development of sustainable production systems.

The specific aims were to:

- Compare herd characteristics between organic and conventional production.
- Compare cow performance, i.e., production, fertility, SCC and longevity between organic and conventional herds.
- Analyse reasons for culling in organic and conventional herds.
- Investigate the occurrence of GxE for production, fertility, somatic cell count and longevity in the Swedish Holstein and the Swedish Red breeds.

Summary of the investigations

Materials and methods

Data records and pedigree information were obtained from the Swedish Dairy Association which is responsible for the milk recording system in Sweden. Information from KRAV was used to identify dairy farms with organic crop production. A questionnaire was sent to these farmers to examine which farms also had certified dairy production and if so, during which years. The year of conversion to organic management and the following year were considered as a transitional period. Records from these two years were excluded. Approximately 80% of the Swedish dairy farms with certified organic production were included in the study. The remaining herds were either not identified by the questionnaire or had no records in the data obtained.

Data description

The initial data set contained records collected between January 1998 and September 2005. All Swedish dairy breeds were represented and information from all lactations (1-12) was included. The herds with less than five calvings per year were excluded, resulting in a data set containing information about 99,681 calvings in 471 organic farms and 2,759,393 calvings in 13,976 conventional farms. This data set was used for descriptive statistics of the two production systems (Paper I). All following analyses were restricted to the two main dairy breeds in Sweden, the Swedish Holstein and the Swedish Red, and the conventional material was restricted for computational reasons. Statistical analyses of production, fertility and somatic cell count (SCC) in first, second and third lactation (Paper I) were, therefore, based on 1,251,957 calvings in 6567 randomly selected herds (the last number in the herd identity had to be even). Thus, the organic share of the records analysed was approximately 8%. Heritabilities and genetic correlations between production, fertility and SCC expressed in organic and conventional production (Paper II) were only estimated in first and second lactation. The data set used for these genetic studies contained information from 367,295 Swedish Holstein and 380,252 Swedish Red cows.

The data set used to analyse culling reasons and for genetic analyses of longevity traits (Paper III) contained cows with their first calving between January 1998 and September 2003. Cows that were still alive in September 2009 were given a fictitious date of culling: September 30, 2009. The opportunity period for culling was thus at least six years. Reasons for culling were registered for 139,669 Swedish Holstein and 146,865 Swedish Red cows. For the genetic analysis, the herd-year-season classes were required to have at least 4 observations, which reduced the available data to 124,471 Swedish Holstein and 127,604 Swedish Red cows.

Trait definitions

Seven milk production measures were analysed (Paper I and Paper II). Milk, fat and protein yield, and the percentage of fat and protein (only in Paper I) were based on 305-day production records. Two additional production traits were defined: the increase in milk production from first to second lactation, expressed in kg milk (INCkg) and as a percentage (INC%).

Six fertility traits were defined, using the dates for calvings and inseminations (Paper I and Paper II): the interval between calving and first insemination (CFI), the interval between calving and last insemination (CLI), the interval between first and last insemination (FLI), the number of inseminations per service period (NINS), the calving interval (CI) and the proportion pregnant at first insemination (PFI).

SCC was recorded monthly in the milk recording system, transformed to a logarithmic value and averaged during the period from calving to 150 days after calving (Paper I and Paper II).

Six longevity traits were defined from calving and culling information (Paper III). Productive life (PL) was calculated as number of days from first calving to day of culling. Three survival traits were defined: survival through first lactation (S1), survival through second lactation (S2) and survival through third lactation (S3). Survival was coded as 1 if the cow survived that lactation, indicated by a next calving; as 0 if the cow was culled during that lactation and as missing if the cow had died before that lactation started. Furthermore, two traits describing whether the cow was culled due to low fertility or poor udder health were defined: fertility determined survival (FS) and udder health determined survival (UHS). The code 1 was used if the cow was not culled because of fertility or udder health, respectively, and the code 0 was used if the cow was culled due to these problems. For example, a cow that was culled due to mastitis in her second lactation would have the following records: S1=1, S2=0, S3=missing, FS=1, UHS=0, and a record for PL depending on when she was culled.

Culling reasons

Culling reasons recorded by the farmers in the milk recording system were analysed (Paper III). Twenty different codes were used by the farmers to describe the primary cause of culling. Secondary causes were only registered for 9% of the cows and were not further analysed. The 20 codes were sorted into 8 groups: udder health (mastitis or high SCC), low fertility (poor fertility or not pregnant), low production, leg problems (claw disease or leg disorders), metabolic diseases (ketosis or parturient paresis), other diseases (bovine viral diarrhoea or unspecified disease), other specified causes (teat injury, dystocia, bad milkability, abortion, high age, bad temperament, injury, deformed teat or udder) and unspecified cause.

Statistical analysis

SAS software (SAS Institute Inc., Cary, NC, USA; Version 9.2) was used for data editing. Procedure MEANS and procedure FREQ were used for descriptive statistics (Paper I) and to describe reasons for culling (Paper III). Chi-square test was used to investigate the level of significance between the proportion culled due to different reasons in organic and conventional herds. Procedure MIXED was used for statistical analyses of production, fertility and SCC in organic and conventional production (Paper I). This procedure assumes normal distribution and handles both fixed and random effects.

The following statistical model was used for all traits in Paper I:

y = production system + herd (nested within system) + breed + interaction between system and breed + age at calving + calving year + calving season + interaction between year and season + residual

A complementary model that included a regression on milk yield, nested within production system and breed, was used to analyse the fertility traits and SCC. This model was used to test whether differences found between the systems when the original model was used were due to differences in production level.

Pedigrees for Swedish Holstein and Swedish Red cows used in the genetic analyses of production, fertility, SCC and longevity (Paper II and Paper III) were traced as far back as possible. Heritabilities and genetic correlations between the traits, expressed in organic and conventional production, were estimated from bivariate analysis using the DMU package (Madsen and Jensen, 2008). If the bivariate analysis did not converge due to genetic correlations close to unity, the heritabilities in organic and conventional production were estimated with univariate analysis. If the analysis using the animal model did not converge due to other reasons, a sire model was used instead. A one-sided 5% test (1.645 x SE) was used to determine whether the genetic correlations were significantly different from 1.

The following bivariate animal model was used to analyse production, fertility and SCC in Paper II:

y = herd + age at calving + calving year + calving season + animal + residual

Longevity was analysed using the following bivariate animal model in Paper III:

y = herd-year-season + age at first calving + animal + residual

Main results

This project generated more results than have been published in Paper I, II and III. Some of these non-published results that are descriptive statistics of Swedish interest have been included in this thesis.

Location of organic dairy herds in Sweden

The proportion of cows in organic production increased gradually, from 2.0% in 1998 to 4.8% in 2005 (not published). Most of the organic dairy farms were located in the middle of Sweden, in the area between Gothenburg and Stockholm. More than 25% of the organic farms were located in the area around Stockholm and almost 28% were located in the area around Gothenburg. The organic dairy farms were rare in both the northern and the most southern part of Sweden, only 9.5% of the farms were found in these regions (not published).

The number of organic farms in percentage of all dairy farms in the different regions also showed a high proportion of organic farms in the area around the two largest cities, Stockholm and Gothenburg (Figure 2). However, around Malmö (Sweden's third city in population size) in the south, the proportion of organic farms was low (not published).

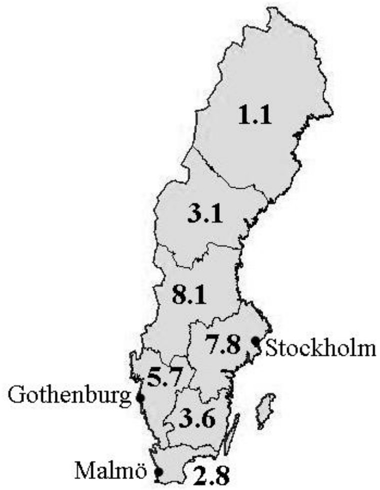

Figure 2. The location of the organic dairy farms in proportion of all dairy farms in different regions of Sweden.

Herd characteristics

Herd size

The mean herd size, measured as the number of calvings per herd and year, was larger in organic production than in conventional production (Paper I). The organic herds increased more in size during the period studied, from 27.5 cows in 1998 to 51.1 cows in 2004. Corresponding figures for conventional herds were 29.9 and 39.9 cows, respectively.

Breed distribution

The breed distribution in organic and conventional production differed considerably (Paper I). In conventional production, 95% of the cows were of the Swedish Holstein and the Swedish Red breeds, and the breeds were approximately equal in numbers. In organic production a majority of the cows were of the Swedish Red breed (Table 2). The proportion of Swedish

Holstein cows was lower than in conventional production, in favour of more rare breeds such as Jersey and the Swedish Polled breed and different crosses. However, the proportion Swedish Holstein increased slightly during the time period of this project.

Just above 4% of the Swedish Red cows (4.1%) were in organic production and the corresponding figure for Swedish Holstein was 2.7% and for Jersey and Swedish Polled 9.2% and 8.5% respectively (not published).

Most herds contained cows of both the Swedish Holstein and the Swedish Red breed. However, the proportion of herds with both breeds was larger in organic production (71%) than in conventional (65%). In organic herds it was much more common to only have cows of the Swedish Red breed (21%) than to only have Swedish Holstein cows (7%). In conventional herds, it was equally common to house only Swedish Red cows (17%) as Swedish Holstein cows (18%) (not published).

Table 2. *Breed distribution in organic and conventional production, in percent*

Breed	Organic	Conventional
Swedish Holstein (SH)	35.5	46.9
Swedish Red (SR)	54.3	45.8
Jersey	1.5	0.5
Swedish Polled	1.2	0.5
SH x SR[1]	2.9	2.4
SR x SH[1]	2.0	1.1
Other breeds/crosses	2.8	2.9

[1] Father breed x mother breed

Milk production

Milk, fat and protein yield were lower in organic production compared with conventional production, and the percentage of fat and protein was slightly lower in organic herds (Paper I, Table 2). In organic production the least square means for milk yield were 6725 kg, 7702 kg and 8083 kg for lactation 1-3, respectively. Corresponding least square means in conventional production were approximately 700 kg higher; however, the difference between the systems decreased slightly with increased lactation number. The increase in milk production from the first to the second lactation was higher in organic herds when expressed in kg milk, whereas no significant difference was found when expressed as a percentage, calculated at individual cow basis.

Fertility

Cows in organic herds showed a slightly better fertility compared to cows in conventional herds, irrespective of lactation number (Paper I, Table 3). The interval measures (CFI, CLI, FLI and CI) were all shorter in organic herds, the total number of inseminations was lower and the proportion that got pregnant at first insemination was higher. The differences between systems were small but significant, and could be explained by the difference in milk production. At a given production level, an organically managed cow tended to have worse fertility compared to a conventionally managed cow (Paper I, Table 4).

SCC

The SCC was higher in organic herds compared to conventional herds, irrespective of lactation number (Paper I, Table 3). The difference in SCC found between the systems could be explained by a dilution effect and was no longer significant after adjustment for milk yield (Paper I, Table 4).

Longevity

The age distribution was different in organic and conventional herds. The replacement rate was lower in the organic farms resulting in a lower proportion of cows in first and second lactation and a higher proportion of cows with lactation number three and higher, compared with conventional farms (Paper I, Figure 2). The mean productive life in Swedish Holstein was 1154 days in organic production and 1087 days in conventional production. Corresponding means in the Swedish Red breed were 1159 and 1045 days (Paper III, Table 1).

Culling reasons

The overall most common reason for culling in Swedish organic herds was poor udder health followed by low fertility (Table 3). The order of these two main reasons was the opposite in conventional herds. Low production was the third most common cause of culling in both production system and there was no significant difference between the systems. The fourth most common reason for culling was leg problems, which was slightly, but significantly, higher in conventional herds, whereas culling for other diseases did not differ.

The culling pattern was the same for both Swedish Holstein and the Swedish Red; however, there were differences in magnitude (Paper III, Table 2). Culling due to poor udder health was particularly common for Swedish Holstein in organic production. Furthermore, the shift from low fertility being the main reason for culling in first lactation for both breeds and production systems, to poor udder health occurred at a lower age in organically managed cows (Paper III, Table 3).

Table 3. *Reasons for culling in organic and conventional production; records from both Swedish Holstein and Swedish Red cows*

Cause of culling	Organic	Conventional	p-value
Mastitis or high SCC	26.7	20.6	<0.0001
Low fertility	23.0	25.9	<0.0001
Low production	8.3	8.8	0.0540
Claw or leg problems	5.0	5.9	<0.0001
Metabolic diseases	1.8	2.0	0.0637
Other diseases	2.5	2.7	0.1105
Other specified causes	15.3	16.2	0.6735
Unspecified causes	16.8	17.9	0.0003

GxE in organic and conventional dairy production

Significant interactions between production system and breed were found for 14 of the 35 production and functional traits analysed (Paper I, Table 2 and Table 3). However, no re-ranking between the breeds was observed and the relationship between the breed performances showed no clear pattern. After adjustment for milk yield, the interaction between system and breed was only significant for four traits (Paper I, Table 4).

The genetic correlations estimated for milk production traits, fertility traits and SCC expressed by Swedish Holstein cows in organic and conventional production were above 0.93, except five fertility traits that were below 0.80 (Paper II, Table 4). Three of these (CI, CLI and PFI), all expressed by cows in second lactation, were considered significantly different from unity. Genetic correlations between organic and conventional production for longevity traits in Swedish Holstein were all above 0.88 (Paper III, Table 4). In the Swedish Red breed all genetic correlations estimated were above 0.88, except for one longevity trait (FS), for which the genetic correlation was 0.80 and considered significantly different from unity (Paper II, Table 4 and Paper III, Table 4).

Genetic correlations between fertility traits expressed in two groups of conventional farms that differed in mean production level by 1000 kg were all above 0.91 (Paper II). The difference in production level corresponds to the difference in uncorrected mean values between organic and conventional production (not published). Some of the genetic correlations for fertility traits expressed in organic and conventional production during the summer season were low (0.30), whereas genetic correlations generally were close to unity during winter season (Paper II).

The heritabilities estimated in organic production were 0.001-0.10 for fertility traits and SCC, 0.23-0.35 for yield traits, and 0.03-0.10 for the increase in milk production from first to second lactation. Similar heritabilities were estimated in conventional production (Paper II, Table 3). The heritabilities estimated for longevity were 0.09-0.18 for length of productive life and 0.01-0.30 for the survival traits, with a clear increase in heritability with higher lactation number (Paper III, Table 5). No clear pattern in heritability values were identified between the production systems.

General discussion

Organic dairy herds

The results of this research project show that most organic herds are located in the middle of Sweden, in the areas around Stockholm and Gothenburg, which are the largest cities in Sweden. This is in agreement with consumer demand for organically produced food that is highest in city areas whereas consumers in the countryside, especially in northern Sweden, have a higher demand for locally produced food in general (personal communication[1]). According to representatives from the Swedish dairy industry there are good conditions for organic farming in northern Sweden and many dairy producers located in this area have been interested in certifying their herds according to the organic standards. However, the northern dairies have not produced organic products due to low demand from the consumers in this area (personal communication[2]). The opposite situation exists in the most southern part of the country, where there has been a great consumer demand but few producers willing to convert to organic production, mostly due to lack of land for the forage production necessary (personal communication[3]).

Organic herds have traditionally been smaller than conventional herds (von Borell and Sørensen, 2004). The mean herd size in Sweden was, however, larger in organic production than in conventional during the period 1998-2005 (Paper I), which is in agreement with Danish results (Bennedsgaard et al., 2003). The increased herd size agrees with the shift in ideological orientation of farmers converting to organic production that has

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been recognised during the last decades. Organic producers appear to be more business-minded than before and economic reasons for conversion to organic production seem to have become more important than ideological motives, such as animal welfare, environmental impact and health concerns (Padel, 2001; Flaten et al., 2006, Koesling et al., 2008). However, after conversion the farmers appear to be influenced by the organic values and change their way of thinking with time (Lund, 2002).

In general, the same breeds have been shown to dominate in organic production as in conventional production. Consequently, Holstein cows dominate in organic herds in many countries, e.g. Germany, the Netherlands and Canada (Rahmann and Nieberg, 2005; Nauta et al., 2006b; Rozzi et al., 2007). In Sweden, the Swedish Holstein is slightly more common in conventional production than the Swedish Red and would therefore be expected to be most common also in organic herds. However, most organically managed cows are of the Swedish Red breed (Paper I). This shift in main breed between the production systems may be due to different preferences between organic and conventional farmers. The Swedish Red has a lover production level than the Swedish Holstein (Paper I), but is still a high producing breed, and milk yield is important regardless of production system. Furthermore, the Swedish Red has generally better fertility and udder health, higher slaughter value and lower feed intake than the Swedish Holstein. These attributes makes the Swedish Red economically similar to the Swedish Holstein despite the lower milk production (Sandgren and Lindberg, 2007), and probably suits the ideology of many organic farmers. Other countries where non-Holstein breeds dominate are Austria and Switzerland where Simmental and Brown Swiss cows are most common in both organic and conventional production (Baumung et al., 2001; Haas and Bapst, 2004).

The proportion of cows of rare breeds, such as Jersey and the Swedish Polled breed, and different crosses are higher in Swedish organic herds than in conventional herds (Paper I). The preference of organic farmers for non-Holstein breeds and for mixed breeds was also found in Wisconsin by Sato et al. (2005). This may indicate that organic farmers are not fully satisfied with the animal material available and are searching for alternatives. However, within the Swedish Holstein and the Swedish Red breed, the top ten lists of AI-bulls used in organic and conventional production were similar (not published). This indicates that within these breeds, organic farmers in general select bulls with the same attributes as the conventional farmers do.

Dairy cows in organic production

The lower production levels found for organically managed cows compared with conventional cows (Paper I) were expected. Previous studies of organic dairy production have shown a uniform picture regarding the milk production level, which tends to be 10-30% lower in organic production compared with in conventional production (e.g. Reksen et al., 1999; Sato et al., 2005; Valle et al., 2007). The lower production levels are probably due to a lower energy intake by cows in organic production, because organically produced feed tend to contain less energy than conventionally produced feed and the proportion of roughages is generally larger in organic feed rations (Kristensen and Kristensen, 1998; Reksen et al., 1999).

The production of organically managed cows was particularly low in first lactation (Paper I) which may be due to deliberate choices by the farmers to limit the pressure on young cows. A lover production in first lactation has been suggested to contribute to a more sustainable cow that stays longer in the herd (Bapst, 2001). If organic farmers try to limit the pressure on young cows, you may also expect slightly higher age at first calving. Age at first calving was, however, similar in organic and conventional production (Paper I), which indicates that the farmers have the same intentions for cow maturity regardless of production system. It is therefore likely, that the low milk yield in first lactation is caused by a lower amount of energy available for production, because energy still has to be allocated for growth during first lactation.

The proportion of cows culled due to metabolic diseases was similar in organic and conventional production (Paper III), indicating that cows in organic production are able to adapt their production level to the energy available. The same conclusion has been drawn from studies of metabolic variables in organically and conventionally managed cows (Roesch et al., 2005; Fall et al., 2008a). Studies of clinical manifestations of metabolic disturbances have seldom been able to show any differences between organic and conventional production, possibly because these studies often have been performed on small data materials (Fall, 2009). Hardeng and Edge (2001) and Bennedsgaard et al. (2003) did, however, show significantly lower incidences of ketosis in organically managed cows.

Cows in organic herds may allocate larger proportion of the energy available for milk production, leaving less to maintain other body functions such as fertility, which tends to be lower in organic production than in conventional production at a given production level (Paper I). Other studies of fertility in organic production have shown impaired fertility compared to conventional production (Reksen et al., 1999), or no differences between the systems (Nauta et al., 2006a; Valle et al., 2007; Fall et al., 2008b). The risk of being culled due to poor fertility was, however, lower for cows in organic herds compared to cows in conventional herds (Paper III). This indicates that organic farmers do not consider fertility to be as problematic as conventional farmers do, in relation to other culling reasons.

The difference found in SCC between organic and conventional production was significant but small (<0.2 SD) and could be explained by a dilution effect because the difference was no longer significant after adjustment for milk yield (Paper I). Other studies of udder health in organic and conventional production in Sweden have shown no difference (Fall et al., 2008c) or better udder health in organic herds (Hamilton et al., 2006). Together, the results indicate small differences in udder health between organic and conventional production in Sweden. The large proportion of cows culled due to poor udder health in Swedish organic herds (Paper III) was therefore not expected. This indicates that organic farmers are more concerned about the udder health than conventional farmers, and organic farmers are also known to consider mastitis to be the dominant disease problem (Vaarst et al., 2003).

One explanation for the high culling frequency due to poor udder health in organic herds, despite the similar level of udder health as in conventional herds, could be that organic farmers also have to consider the organic standards when evaluating cows. The standards prescribe limited use of antibiotics and twice as long withdrawal periods after medical treatment. Under current Swedish milk-pricing system it is generally more profitable for farmers to sell a larger volume of milk with higher SCC than to discard high SCC milk in order to obtain a higher average milk price (Nielsen et al., 2010). It is therefore likely that mastitis has a larger negative impact on farm economy in organic production, due to the prolonged withdrawal periods, than in conventional production where farmers can deliver milk with high SCC to a higher extent. Furthermore, differences in ethical considerations between organic and conventional farmers may be involved in the culling decisions, because animal health status has been suggested to have a higher value in organic production compared to conventional production (Verhoog et al., 2004).

The prolonged withdrawal periods in organic production has sometimes been suggested to decrease the tendency to call for veterinary assistance and thereby have a negative effect on animal health (Lund and Algers, 2003). Our results do not support this suggestion. The proportion of cows culled due to other diseases than mastitis in Swedish organic and conventional herds was similar (Paper III). This is in agreement with other studies of cow health in organic production, which generally have shown similar health status in organic and conventional herds (Bennedsgaard et al., 2003; Valle et al., 2007; Fall et al., 2008b).

Breeding in organic dairy production

Breeds suitable for organic production

Most farmers converting from conventional to organic dairy production keep their livestock. Consequently, a large proportion of the organically managed cows are of high yielding breeds. These animals have been selected in conventional environments that often involve high input of external recourses in comparison to organic production, and the capacity of the animals to adapt to the organic environment may therefore be limited.

Local breeds have been suggested to suit the organic production system and to be important to retain genetic diversity. For example, organic farmers should raise traditional, local or rare breeds according to the standards of the Soil Association in Great Britain (Soil Association, 2010). However, in general these breeds have too low production levels to make the production economically sustainable, unless it is a production aimed for niche markets where it is possible to get a higher price (Pryce et al., 2004). Cross-breeding with high production breeds and local breeds may be an alternative for organic producers but needs to be further investigated before used in large scale. A study of the effects of crossbreeding in Dutch organic dairy farms has shown that breed effects differ across farming systems, even within the organic production (de Haas et al., 2010). On the basis of current knowledge on dairy cow adaptation to different environments it is suggested that organic farmers should use robust breeds with broad breeding goals, including both production and functional traits (Pryce et al., 2004). Swedish breeding programmes have included functional traits since 1960's, which is probably one explanation for the high performance of Swedish cows in organic production (Paper I). Furthermore, no interactions of importance have been found between breed and production system in Sweden (Paper I). The interactions found showed no re-ranking, only differences in scaling that to a large extent were explained by the differences in milk yield between organically and conventionally managed cows. This means that the difference we observe between the breeds in conventional production, regarding e.g. breed mean values for health and fertility, largely remain in organic production. These results, in combination with the fact that both breeds are almost equally common in conventional production, indicate that the Swedish Holstein and the Swedish Red breed suit the organic production conditions in Sweden equally well.

Genotype by environment interaction

The results of this thesis show that the same genes are important for Swedish Holstein and Swedish Red cows in organic and conventional herds, in general. However, GxE of a magnitude that may cause re-ranking of animals between organic and conventional production environments has been found in the Holstein breed for fertility traits in Sweden (Paper II) and for production traits in the Netherlands (Nauta et al., 2006a). This indicates that some Holstein cows are better suited for organic production than others with regard to these traits. No other studies of GxE in organic and conventional dairy production systems have been published, according to my knowledge, and the studies in Sweden and the Netherlands show contradictory results for some traits. It is therefore difficult to draw general conclusions regarding GxE in organic and conventional dairy production. Different results may be due to differences in the definition of the traits investigated, differences between the breeds or lines studied and differences in the statistical models used. Furthermore, the organic standards differ to some extent between countries, such as the use of homeopathy and proportion home grown feed, as do the conditions for conventional production. In Sweden for example, all cows should be at pasture at least 6 hours per day during summer according to the animal welfare law, which decreases the difference between the two production systems compared to other countries.

The GxE found for fertility in the Swedish Holstein could not be explained by the difference in production level between organic and conventional production (Paper II), which indicates that other unknown environmental factors are involved. It is likely, however, that the genes of interest are related to energy intake and allocation. Energy density tends to be lower in organic feed rations (Kristensen and Kristensen, 1998; Reksen et al., 1999), and low energy intake is known to influence the fertility in Holstein cows (Pryce et al., 1999; Pollott and Coffey, 2008; Rodriguez-Martinez et al., 2008).

One explanation for the weak GxE in organic and conventional production in Sweden is that the difference between the systems is small, owing to the Swedish animal welfare law. Furthermore, the possibility of including up to 5% conventionally grown feed in organic feed rations during the period when the data were collected may have reduced the nutritional differences. The standards were changed in 2008 and today

100% of the feed has to be organically grown, making the difference between the production systems larger. Another explanation could be that the cows are able to adapt to the differences that exist, owing to the broad breeding goals that have been used in Sweden for decades. However, even if the trait-by-trait approach used in the performed studies showed no or weak GxE, it is possible that an economic index combining all traits would have shown a stronger interaction due to changes in the relative importance of the traits between the systems (Namkoong, 1985).

Traits important in organic production

The ideology of organic farming is based on ethical considerations regarding the environment and the health and welfare of humans and animals. This ethical framework is reflected in the organic standards and should affect the management strategies in organic farms. It is therefore likely that the traits important for animals in organic herds differ to some extent from those important in conventional herds. The pressure to breed for functional traits is considered to be higher in organic production than in conventional production for both economic and ethical reasons (Pryce et al., 2004). Some traits, such as mastitis resistance, may have a higher economic value in organic herds than in conventional herds, due to the extra costs of prolonged withdrawal periods after medical treatment. Increased mastitis resistance would also increase animal welfare, which should have a high value in organic production. Other traits that have been suggested to be highly important for dairy cows in organic production are: parasite resistance, strong legs and claws, persistency of lactation and increased milk yield from first to third lactation (Bapst, 2001; Pryce et al., 2004). Several additional traits are considered highly important for all livestock species in organic production: disease resistance, fertility, longevity, high feed efficiency, foraging ability and temperament (Pryce et al., 2004; Hörning, 2006).

The possibility to mitigate climate change by cattle breeding has been emphasized since the report "Livestock's long shadow" was published by FAO in 2006. According this report, the livestock sector is responsible for 18% of the total greenhouse gas emissions measured as CO_2 equivalents. The largest share of this derives from deforestation to expand pastures and arable land (Steinfeld et al., 2006). Other factors that contribute are for example processes on the farms, such as cultivation, harvest, transport, and of course the animals and the manure they produce. Especially ruminant animals produce methane as part of their normal digestive process. The amount of methane emitted from a cow is known to be influenced by the diet and the management of the cow (Place and Mitloehner, 2010), but a genetic component may also be involved (Robinson et al., 2010; Hegarty and McEwan, 2010). Cassandro et al. (2010) estimated the heritability of predicted methane production in Holstein Friesian cows to be 0.12. Reduction of methane emissions by genetic selection demands individual measurements from a large number of cows. Methods to analyse the methane concentration in cow's breath, which contains 90% of the methane emitted by cows, are under development (Lassen et al., 2010). Genetic selection to reduce emissions is already performed indirectly through traits such as milk production and feed efficiency, but it could be further improved by inclusion in a selection index. This should be considered in development of organic breeding programmes.

Economic weights of traits

In traditional breeding programmes the relative importance of traits is determined solely by the economic return associated with the genetic gain for each trait (Hazel, 1943). Inclusion of functional traits in breeding goals for dairy cattle demands new strategies for genetic evaluation. The economic value of functional traits is often difficult to estimate, and some functional traits, e.g. traits connected to animal welfare or environmental impact, cannot solely be evaluated in terms of short term profit. They have an additional value, related to ecological, social and ethical aspects of farming which is difficult to express in monetary units (Groen et al., 1997; Olesen et al., 2000). One way to include such non-market value traits in the breeding goal, without estimating their specific value, is to use desired gain index (Olesen et al., 1999; Nielsen et al., 2005). The desired genetic gain in the traits included in the breeding goal is then predefined and the economic weights necessary to achieve this genetic gain are calculated.

Breeding in organic production – today and tomorrow

Based on the magnitude of GxE found in organic and conventional production in Sweden (Paper II and Paper III), breeding values estimated for Swedish Red bulls in conventional production can be used by organic farmers. Conventional breeding values for Swedish Holstein bulls, on the other hand, may be misleading for fertility traits. Farmers that strive for better fertility in their herds by choosing bulls with high breeding values for fertility may therefore not achieve the genetic progress they expect. However, the magnitude of GxE and the small proportion of organically managed Swedish Holstein cows (2.7% of the population) affect the options for organic breeding. Mulder et al. (2006) showed that two separate breeding programmes were optimal when the genetic correlations between two equally common environments were below 0.6, and that this threshold value increased to 0.7-0.8 with very high selection intensity. However, two separate breeding programmes are less appropriate in situations when one of the environments is less common than the other (Mulder et al., 2006), as the situation is for organic production in Sweden today.

Different production conditions and ethical considerations between organic and conventional production may influence the breeding goals. The differences in choice of breeds and culling criteria found in this thesis indicate that organic and conventional farmers may have different perspectives. The relative importance of traits may therefore differ between the systems and it is also possible that additional traits should be considered for cows in organic herds, as already mentioned. Total merit indexes, adjusted for organic production, have been developed in Switzerland, Germany and Canada (Bapst, 2001; Krogmeier, 2003; Rozzi et al., 2007). Such indexes make it possible for organic farmers to identify the conventional bulls best suited for organic production. The indexes have been implemented by breeding organizations in both Switzerland and Germany but only a few of the organic farmers seem to use them. The bulls used in organic and conventional production are practically the same in Switzerland and Germany, respectively (personal communication[4,5]). The traits included in these organic total merit indexes are with few exceptions similar to those included in the conventional breeding programmes in the Nordic countries. Even so, many of the traits that have been suggested to be important in organic production are not considered in the current Nordic breeding programmes.

Farmers today, that have other preferences than those reflected in the conventional breeding programme should select bulls based on their breeding values for specific traits that are important in their particular herd. Thereby, an adaptation of the herd to the current farm environment will be achieved. However, the improvement possible in one specific trait depends on the genetic level and variation among the conventional bulls available.

The use of modern reproduction techniques in organic production is debated within the international organic movement. This does not seem to be an issue among organic dairy producers in Sweden, but many of the techniques currently used in cattle breeding, e.g. AI, sexed semen and genomic selection, are considered to be unnatural among organic producers

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in other countries. Furthermore, some techniques involve hormone treatments, e.g. ET, which does not agree with the organic ideology (Spengler and Austen, 2009). In a meeting held in connection to the 1st International IFOAM Conference on Animal and Plant Breeding in Santa Fe, USA, in 2009, development of an IFOAM position paper for animal breeding in organic production was discussed. A proposal for such guidelines for breeding is now developed within the European Consortium for Organic Animal Breeding (ECO-AB, 2010). AI may be allowed to enable accurate estimation of breeding values for low heritability traits, avoid spreading mounting diseases and decrease the risks for the herdsmen connected with handling bulls etc. However, other reproduction techniques may be banned. This would have a large effect on the organic dairy production in Sweden which is dependent on bulls from the conventional breeding programme where techniques, such as ET and genomic selection are used. If the possibility to use conventional bulls in organic dairy production disappears in the future, Swedish organic farmers will have to convert back to conventional production; alternatively, an organic breeding programme without the banned techniques has to be developed.

Options for organic breeding in Sweden

The structure of a future Swedish breeding programme for organic dairy production depends on the reproduction techniques allowed. Many farmers would probably have difficulties in adjusting to natural mating, but if AI is allowed the possibility to develop an organic breeding programme increases. Development of such a breeding programme involves several important decisions. First, with the small proportion of cows in organic herds, it would be favourable to choose one breed, possibly the Swedish Red because it dominates in organic production today. Secondly, the breeding goal needs to be defined. An index based on desired gain in the traits important in organic production would probably be preferable for organic breeding to be able to take economic, ecological, societal and ethical aspects in consideration. Inclusion of additional traits, e.g. related to animal welfare or environmental impact, may also increase the price the consumers are willing to pay for organic products and thereby partly finance the breeding programme. Nevertheless, a breeding strategy that requires less investment and that is appropriate for a small population has to be identified. Nauta (2009) suggested that such breeding programmes may be based on young bulls or storage of frozen semen from culled bulls (the cold system). In the young sire scheme most cows are inseminated with semen from the latest batch of yearling bulls, except potential bull dams for which a small group of older bulls may be used (Bichard, 2002). A smaller quantity of semen has to be stored and most bulls are culled before 2 years of age which decreases the costs of the programme. Alternatively, the bulls can be sent back to the farms and used for natural service. The breeding values of individual bulls have low reliability, but when a group of young bulls are used they are expected to in average perform close to the mean value of the batch and their genetic superiority is introduced quickly in the population (Bichard, 2002). This strategy is used for the Guernsey breed today, and the so called cold system is used for the Dutch Meuse Rhine Issel breed. This system is based on storage of semen from bulls that are culled after a certain quantity of semen has been collected (Nauta, 2009). A breeding programme based on young bulls that can be used for natural service after the semen has been collected, may however, be more easily accepted by the organic movement, and by the consumers, than a breeding program based on culling young bulls.

The small organic population size will affect the size of the daughter groups and thereby decrease the accuracy of the breeding values estimated, especially for low heritability traits such as fertility and disease resistance. One way to increase the organic population would be to collaborate with other European countries. This requires evaluation of the occurrence of GxE between the organic environments in different countries, which need to be accounted for in a joint breeding programme. Collaboration would also decrease the cost for a separate breeding programme, buy on the other hand, this strategy may not be in agreement with the organic ideology which promotes the use of local breeds and resources.

Conclusions

- The location and characteristics of organic dairy herds in Sweden differs from those of conventional herds. Organic herds are most common in areas around big cities. They have in general a larger number of cows, and increase more rapidly in herd size, compared to conventional herds. Organic herds have a larger proportion of cows of the Swedish Red breed, rare breeds and crosses, and a lower number of Swedish Holstein cows.
- The performance of organically managed dairy cows differs from conventionally managed cows. Cows stay longer in organic herds and have lower production, better fertility and higher SCC than cows in conventional herds. The performance of cows in organic production depends on the lower milk production level to a large extent. At a given production level, organically managed cows have slightly worse fertility but equal SCC as cows in conventional herds.
- The main reason for culling in organic herds is poor udder health followed by low fertility. In conventional production the main reason for culling is low fertility followed by poor udder health. Low production is the third most common cause of culling in both systems.
- No important interactions between breed and production system was identified, indicating the differences we observe between the Swedish Holstein and the Swedish Red breed in conventional production remain in organic production.
- Genetic correlations for production traits, fertility traits, SCC and longevity traits, estimated in organic and conventional production in Sweden are in general close to unity, indicating no GxE. The current breeding values estimated for Swedish Red bulls seem to be adequate for organic production. Weak GxE was found for fertility traits in second lactation Swedish Holstein cows, indicating that some cows within this

breed are better suited for organic production than others. However, the magnitude of GxE does not justify development of a separate breeding programme for the organic Swedish Holstein population today.

- Differences in breed distribution and culling criteria between organic and conventional production indicate that the preferences of organic and conventional farmers differs to some extent.
- Organic farmers that have other preferences than those reflected in the conventional breeding programme should select bulls based on their breeding values for specific traits that are important in their particular herd, instead of using the bulls' total merit indexes.

Future Research

As shown in this thesis, there are differences between Swedish organic and conventional dairy production both on farm and cow level. Nevertheless, the magnitude of GxE in organic and conventional production does not justify development of organic breeding programmes. There are, however, still issues that need to be addressed and evaluated before the need for organic breeding programmes, and the possibility to develop such programmes, can be fully assessed:

- Traits that are especially important for organic dairy production have to be identified.
- The relative importance of traits may differ between organic and conventional dairy production due to different economic conditions and ethical considerations. Market and non-market weights of the traits important for organic production should therefore be investigated.
- If the traits of importance and the relative importance of traits are shown to differ between organic and conventional production, alternative breeding programmes need to be developed for the organic production.
- Development of breeding programmes within the organic system depends on the organic population size and the reproduction techniques allowed. It would therefore be interesting to investigate how large the proportion of organically managed cows has to be to make different types of organic breeding programmes efficient.
- Collaboration between different countries would increase the organic population size dramatically. GxE may occur between organic production systems in different countries. This needs to be investigated and existing GxE needs to be accounted for in joint breeding programmes.

- The environmental variation within organic and conventional production systems is large, likely larger than between the systems. The effects of alternative classification strategies based on, e.g., feeding and pasture strategies, housing conditions and management considerations, should therefore be investigated to find the optimal way of classifying Swedish dairy herds. The need for different breeding programmes for different types of herds can then be assessed.

Svensk sammanfattning

Bakgrund

Konsumenternas efterfrågan på ekologiskt producerade mejeriprodukter har ökat betydligt sedan den första ekologiska mjölken levererades till ett svenskt mejeri år 1989. Idag, tjugo år senare är nästan åtta procent av den invägda mjölken ekologiskt producerad och efterfrågan fortsätter att öka. Den ekologiska husdjursproduktionen utvecklas i takt med att allt fler producenter lägger om sin produktion, men avel är ett område som fortfarande är eftersatt. IFOAM, den världsomspännande paraplyorganisationen för ekologisk produktion har satt upp generella riktlinjer för husdjursavel i ekologisk produktion, t.ex. att djuren ska vara anpassade till lokala förhållanden och vara av raser som selekterats för ökad sjukdoms- och parasitresistens. Ett generellt accepterat regelverk för husdjursavel saknas däremot i dagsläget och de flesta ekologiska producenter använder sig av samma raser och linjer som de konventionella producenterna. Dessa djur har selekterats för en hög mjölkproduktion i en konventionell produktionsmiljö, och det är oklart hur väl de kan anpassa sig till den ekologiska produktionsmiljön.

Det övergripande syftet med denna avhandling var att få ökad kunskap om mjölkkornas prestation i ekologisk produktion och deras förmåga att anpassa sig till den ekologiska produktionsmiljön, vilket kan bidra till utveckling av hållbara produktionssystem.

Sammanfattning av studierna

Denna avhandling baseras på studier av data från den svenska kodatabasen som bland annat innehåller information om kornas härstamning, besättning, insemineringar, kalvningar, mjölkproduktion, djursjukdata och information om utslagning. Datamaterialet innehöll information från nästan alla ekologiska och konventionella besättningar vilket gjorde det möjligt att beskriva vad som är karakteristiskt för ekologiska mjölkbesättningar i Sverige.

De flesta ekologiska mjölkkobesättningarna fanns i trakterna kring Stockholm och Göteborg, medan den största andelen ekologiska besättningar återfanns i västra Svealand och Gävleborgs län. De ekologiska besättningarna var i genomsnitt större än de konventionella besättningarna och växte i snabbare takt. Även rasfördelningen skilde sig åt mellan systemen, med en större andel SRB, lantraser och korsningar i ekologisk produktion.

Kor i ekologiska besättningar hade i genomsnitt bättre fertilitet men lägre mjölkproduktion och högre celltal än kor i konventionella besättningar. Den lägre produktionsnivån i ekologiska besättningar visade sig ha en stor inverkan på kornas fertilitet och celltal. Vid en given produktionsnivå, t.ex. 8000 kg mjölk per år, var fertiliteten faktiskt något sämre hos kor i ekologisk produktion jämfört med kor i konventionell produktion, och celltalet var detsamma i båda systemen.

Livslängden var något längre hos kor i ekologisk produktion och även anledningen till att kor slås ut skilde sig mellan systemen. Den främsta utslagningsorsaken i ekologiska besättningar var dålig juverhälsa, följt av låg fertilitet. I konventionella besättningar var ordningen den omvända, låg fertilitet den vanligaste utslagningsorsaken följt av dålig juverhälsa. Låg produktion var den tredje vanligaste utslagningsorsaken i båda systemen och följdes av klöv- och benproblem. Andelen utslagna kor pga. metaboliska sjukdomar skilde sig inte mellan systemen vilket tyder på att korna i ekologisk produktion kan anpassa sin mjölkproduktion till den lägre utfodringsnivån.

Inga viktiga samspel hittades mellan ras och produktionssystem för de egenskaper som vi analyserat. Detta innebär att de skillnader vi ser mellan raserna i konventionell produktion kvarstår i ekologisk produktion. Det finns med andra ord ingenting som tyder på att den ena rasen skulle vara bättre anpassad till ekologisk produktion än den andra.

Inga genotyp-miljösamspel av betydelse hittades hos SRB vilket innebär att de egenskaper som vi studerat till största delen styrs av samma gener i ekologisk och konventionell produktion. Detta innebär att de avelsvärden som skattas för tjurar i konventionell produktion kan användas i ekologisk produktion. Hos svensk holstein hittades däremot svaga genotyp-miljösamspel för vissa fertilitetsegenskaper. Detta tyder på att vissa individer inom rasen är bättre anpassade till den ekologiska produktionsmiljön än andra. Skillnaden i produktionsnivå mellan systemen kunde inte förklara de samspel som hittades vilket innebär att andra okända miljöfaktorer är inblandade. De genotyp-miljösamspel som hittades hos svensk holstein visar att tjurarnas avelsvärden för fertilitet kan vara missvisande för ekologiska producenter. Trots detta är det inte aktuellt att utveckla speciella avelsvärden för ekologisk produktion i dagsläget. Samspelen var för få och för svaga, och dessutom är andelen svensk holstein kor i ekologisk produktion väldigt liten (2.7% av den totala populationen) vilket gör en speciell avelsstrategi ineffektiv och kostsam.

Framtiden för ekologisk mjölkkoavel

Behovet av att utveckla separata avelsprogram för ekologisk produktion styrs inte enbart av förekomsten av genotyp-miljösamspel. Om egenskaper som anses viktiga inom ekologisk produktion saknas i det nuvarande avelsmålet, eller om egenskapernas relativa vikt skiljer sig mellan ekologisk och konventionell produktion bör man också överväga att skapa ett separat avelsmål för ekologisk produktion. Vilka egenskaper som är viktiga för svenska ekologiska producenter är oklart i dagsläget men i andra länder har ett flertal egenskaper diskuterats, t.ex. grovfoderomvandlingsförmåga, parasitresistens och en flackare laktationskurva för att minska risken för negativ energibalans i början av laktationen. De skillnader i rasval och utslagningsorsaker som vi hittade mellan ekologisk och konventionell produktion tyder på att producenterna till viss del har olika preferenser, men detta måste studeras mer innan några säkra slutsatser kan dras.

Förutsättningarna för ekologisk produktion förändras med tiden vilket också påverkar behovet av att utveckla ekologiska avelsvärden eller ekologiska avelsprogram, och möjligheterna att genomföra detta i praktiken. Sedan 2008 ska allt foder till ekologiska mjölkkor vara ekologiskt odlat, vilket innebär att det kan finnas starkare genotyp-miljösamspel idag än vad våra resultat visar. Vidare fortsätter andelen kor i ekologisk produktion att öka vilket ökar möjligheterna för ett ekologiskt avelsarbete. Hur stor den ekologiska populationen behöver bli för att göra ett sådant arbete effektivt är dock oklart i dagsläget.

De ekologiska regelverken revideras regelbundet och nya internationella regler för hur avel ska bedrivas i ekologisk produktion kan få stora konsekvenser för svenska mjölkproducenter. Det har länge saknats ett konkret förhållningssätt till husdjursavel inom den ekologiska produktionen men nu arbetar IFOAM, den världsomspännande paraplyorganisationen för ekologisk produktion, med att ta fram regler för husdjursavel. En av de avgörande frågorna är vilka reproduktionstekniker som ska tillåtas inom ekologisk produktion. Många av de moderna teknikerna anses alltför onaturliga i vissa länder och en del tekniker kräver hormonbehandling vilket inte är förenligt med den ekologiska ideologin. Semin kommer med största sannolikhet att tillåtas för att till exempel möjliggöra avelsframsteg i egenskaper med låg arvbarhet, såsom fertilitet och hälsa, och för att förhindra smittspridning mellan djuren samt minska risken för skador vid hantering av tjurar. Mjöligheten att använda andra tekniker, såsom embryotransfer, könsseparerad sperma och genomisk selektion, i ekologisk produktion kan däremot bli mer begränsat än det är idag. Ett sådant beslut skulle medföra stora begränsningar i användandet av konventionella tjurar i ekologisk produktion. En utveckling av ekologiska avelsprogram kan därför bli oundviklig om vi vill ha kvar ekologisk mjölkproduktion i framtiden.

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