Selective Breeding in Organic Dairy Production

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Abstract

Organic dairy farming started to take off in the early 1990s, when the European Union laid down organic standards for animal production. Until now, however, only incidental steps have been taken towards organic breeding and organic farmers mainly use breeding stock from conventional breeding programmes. This thesis focuses on the possibilities for breeding in organic dairy farming.

This thesis starts with describing the basic backgrounds of organic dairy farming and the results of a study that was carried out in 1999-2000 on the vision on cattle breeding. The main conclusions are that breeding in organic dairy farming should be in line with the intensions of organic farming and that farmers need animals that fit to their extensive farming system.

This study is followed by describing the differences and the magnitude of genotype by environment interaction (G x E) between conventional and organic dairy production. There proved to be significant differences in levels of milk production, percentage of protein in the milk, milk cell count and fertility between Holstein heifers on organic or conventional farms. A fairly large impact of G x E was found indicating that organic dairy farmers might have difficulty with selecting the right animals from the conventional supply of breeding bulls. This effect may be caused by the lower uptake of energy by cows in organic agriculture.

After this a study into organic dairy farmers' breeding aims in relation to their farm management was carried out in 2005. This study shows that, despite differences in farm management, organic farmers had more or less the same breeding aim and many farmers were already experimenting with breeds and crosses in a quest for the most suitable type of cow for their farm. There was, however, no relationship between the farm management system and the breed or cross used, which indicates that although farmers demand suitable animals, they do not know what type of cow this would be.

Based on the results of the different studies, three distinct options are formulated for breeding in organic dairy farming: (1) use of adapted conventional breeding, (2) a separate breeding programme and (3) a breeding system based on natural mating. The advantages and disadvantages of each of the three breeding options are described in relation to naturalness, technical breeding issues, societal concerns and costs and benefits. These illustrate the complexity of the breeding issue in both breeding-technology and social terms. Restricting the use of conventional breeding would effectively mean the rejection of a system with a long and successful history, and throw organic dairy breeding back on its own resources. It is concluded that 'system innovations' at multiple levels are needed to create new, sustainable breeding systems, stakeholders must join forces to stimulate the development towards appropriate breeding.

J.W. Nauta met dochter Sjoukje en de fokstier, anno 1971.

"Foar de fokkers dy't der wienen, der binne en wer komme"

(For the breeders that were, that are and will come again)

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Chapter 1

General Introduction

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1.1 Organic farming

Organic farming has a long history in Europe. Until the late1980s, organic farming in the Netherlands was largely equivalent to bio-dynamic farming. Organic farming started to take off in the early 1990s. The European Union laid down organic standards, first for crop production and later for animal production (EU, 1992 and 1999), in order to give consumers assurance of the integrity of organic products. Since then, organic agricultural production has continued to grow steadily (Willer and Yussefi, 2007). The total area under organic agriculture in Europe in 2006 was about 7.4 million hectares, or 1.63% of the total agricultural area (Eurostat. 2008) In the Netherlands, organic farming currently accounts for about 2,5% of the total agricultural area and there are about 1465 organic farms (Bio-monitor, 2008). The sector's growth can be attributed to the broad appeal of organic farming principles (De Wit & Van Amersfoort, 2001) and to government support schemes (MinLNV, 2000 and 2001).

Organic farming systems differ from conventional systems in many aspects. In general, the functional integrity of production prevails over resource sufficiency in organic farming, while it is the other way around on conventional farms. A cow's function in the ecosystem is to convert roughage into milk and meat, and functional integrity implies that the animal should primarily be used in that way instead of feeding rations aimed solely at maximising returns. Such rations may include ingredients that can be used directly for human consumption (Haiger *et al*, 1988). Organic production is more strongly tied to local resources, either farm-based or area-based (COBL, 1977; Baars, 1990a; Nauta *et al*., 1999; Van Veluw, 2004), while conventional farming focuses on high production levels achieved through high quantities of inputs purchased on the world market.

While the principles of organic farming are clear (EU, 1999; IFOAM, 2002), this does not mean that organic production has completed its development and achieved all its goals. Work is still being done, or should be done, at many different levels and on many aspects in order to realise an organic production chain without external inputs lacking organic certification. One aspect requiring more organic development is selective breeding. As regards plant breeding, the first steps have been made towards breeding practices that are more in keeping with organic standards (Lammerts Van Bueren *et al*., 2002; Baker *et al*., 2002). In animal breeding, however, only the odd step has been taken in this direction (Baars, 1990b; Postler, 1998; Bapst, 2001;).

1.2 Animal breeding in organic farming

Animal breeding in organic dairy farming is a complex issue. When organic dairy production first took off, little attention was paid to breeding livestock that specifically met the requirements of organic farming (Baars and Nauta, 2001). Legislation concerning animal breeding in organic farming is limited and vague. For example, animals used in organic farming "should be able to adapt to the local environment" and "local breeds are preferred" (EU, 1999). Yet organic farmers mainly use mainstream conventional breeding animals, which is allowed under current organic regulations.

This research into animal breeding in the organic sector focuses on dairy cattle, primarily because the organic dairy sector is the largest and oldest organic livestock sector in the Netherlands and a large amount of data is available concerning animal production performance. In addition, organic dairy production is strongly tied to the land, so that the conversion to organic farming poses serious challenges (Kristensen and Kristensen, 1998; Toledo *et al*., 2002; Kristensen and Mogensen 2000; Bennedsgaard *et al*., 2003; Vaarst *et al*., 2003; Hovi *et al*. 2003; Hardarson, 2001). Finally, usage of conventional breeding stock (Veeteelt, 2000) which is based on breeding techniques such as embryo transfer (ET) conflicts with organic farming principles.

Two broad areas raise concern: (1) the adaptation of animals to the organic environment, i.e. the selection of animals that can produce efficiently in the organic environment, and (2) the naturalness of breeding, i.e. the technologies used for the selection and reproduction of such animals.
In general, organic farmers use the same breeding stock as their conventional colleagues (Veeteelt, 1999). These animals are selected for the conventional production system, a high input system based on requirement feeding. There are concerns about the capacity of such animals to adapt to the low-input organic environment (Hardarson, 2001; Nauta *et al*., 2001), characterised by lower energy and protein content in feed, restricted use of antibiotics, farm environments which are more dependent on local resources, and more complex farm management.

Since conventional breeding programmes are heavily based on modern selection and reproduction technologies, the use of the conventional breeding stock (through AI) includes the (indirect) use of mass selection, artificial insemination (AI) and modern reproduction technologies such as multiple ovulation, in vitro embryo production and embryo transfer (ET). Concerns about this use are growing (Baars, 1993; Varekamp, 1997; Spranger, 1999; Nauta *et al*., 2001; Bapst and Zeltner, 2002). Such practices do not sit easily with organic farming ideals: they are perceived as unnatural and lead to genetic erosion (Miglior, 2000;Weigel, 2001). Organic farmers stress the importance of 'natural processes' in their production systems (Padel 2000; Midmore *et al*., 2001; Verhoog *et al*., 2003; Lund , 2006) and one of the sector's aims is to stimulate biodiversity (EU, 1999).

1.3 Adapting animals

Farmers who converted to organic production have to make some major changes in farm management. Most importantly: chemical fertilizers are prohibited, there is a limit on feeding concentrates (cattle diets should contain at least 60% dry matter conserved or fresh roughage) and on antibiotics use (no prophylactic use of antibiotics or certain other drugs on a herd basis) (EU, 1999). Consequently, cows in organic farming have a lower intake of energy and protein, and antibiotics are only administered in case of severe infections. After conversion, the change in feed has the greatest impact on high-producing cows (Padel, 2000), which are usually of the Holstein Friesian breed. In a survey of Dutch organic dairy farms in 2001 (Nauta *et al*., 2001), Holstein was found to be the predominant breed. Many farmers with Holstein cows reported health and fertility problems (Nauta *et al*., 2001). Similar findings have been reported in other countries (Margerison *et al*., 2002; Hardarson, 2001; Vaarst *et al*., 2003; Hovi *et al*. 2003) and are in fact also reported in conventional dairy farming (Rauw *et al*., 1998). There is not a great deal of information, however, about the effect of organic conversion on individual dairy cows' milk production, fertility and health. The information that we do have is based on questionnaires (Nauta *et al*., 2001; De Jong and Van Soest, 2001) and studies of relatively small groups of organic herds, both with and without statistical analyses to account for differences in breeds and relationships between animals (Kristensen and Kristensen, 1998; Toledo *et al*., 2002; Kristensen and Mogensen 2000; Bennedsgaard *et al*., 2003; Vaarst *et al*., 2003; Hovi *et al*. 2003).

Organic dairy farmers still use the same breeding bulls, supplied by AI companies, as their conventional colleagues (Veeteelt, 2000). It is uncertain, however, whether these bulls provide the traits required for organic production or whether organic dairy production requires a selection of bulls specifically for the organic environment. An important parameter in this matter is the magnitude of genotype by environment interaction (G x E). G x E is the phenomenon that different genotypes react differently to different environments (Falconer and Mackay, 1996). At the start of this research, no information was available on the magnitude of a possible G x E between organic and conventional production (Boelling *et al*., 2003). The existence of G x E might lead to a re-ranking of bulls and might have consequences for organic farmers' choice of genetic material. A useful way to quantify the effect of G x E is the genetic correlation between traits as expressed in two environments (Falconer and Mackay, 1996). When the correlation is lower then 0.80, the effect of G x E is important and re-ranking of breeding bulls will be significant (Robertson, 1959). Significant re-ranking of bulls is not observed for production traits in the Dutch conventional dairy farming sector (Ten Napel and Van der Werf, 1992; Mulder *et al*., 2004, Calus *et al*., 2002). Between low input systems and intensive management systems, however, correlations have been found between 0.48 and 0.90 (Weigel *et al*., 2001; Raffrenato *et al*., 2003, Berry *et al*., 2003). Organic farming is an example of a low input environment.

1.4 Naturalness of breeding

In organic farming, the debate about the use of reproduction technologies is closely connected with views on naturalness. In breeding terms, respecting natural processes would imply natural mating of animals. Mating cattle was the standard procedure until cryo-technology and artificial insemination (AI) of cows were developed around 1950. These techniques enabled the insemination of much greater numbers of female stock per bull, and lifted the limitation of geographical proximity. It also enabled breeders to estimate reliable breeding values of bulls based on the performance of their daughters at several farms (Rendel and Robertson, 1950). This ultimately led to the current situation of a worldwide network of cattle breeding companies and suppliers of semen from breeding bulls of different breeds and origin.

The development of organic farming rules, which pursue production based as much as possible on natural processes, has gradually given rise to a discussion about the use of AI and the conventional breeding programmes based on AI and other modern reproduction technologies (Bartusek, 1991; Varekamp, 1997; Baars and Nauta, 2001; Spranger, 1998; Haiger, 1999; Bapst en Zeltner, 2001, Verhoog *et al*., 2003).

Verhoog *et al*. (2003) found that farmers and other stakeholders had very diverse views on naturalness in organic farming. Some were very pragmatic and considered it sufficient to produce in compliance with organic production regulations. Others were more focused on developing ecological systems for their farms and on assuring the integrity of their animals (Verhoog *et al*., 2003). In line with this, there are different views on animal breeding within the organic sector, too. While pragmatic farmers simply keep using AI bulls from conventional breeding programmes, others want to obtain animals that fit right for their farm and explore breeding systems based on the integrity of animals, often keeping bulls at the farm for natural mating (Baars, 2005).

1.5 Diversity in organic farming

Organic farming is more dependent on local resources, a characteristic that naturally results in diversity. Individual organic farms also differ due to the individual choices farmers make as regards naturalness of the production system, and ecological, economic and social aspects (Østergaard, 1997; Padel, 2000; Verhoog *et al*., 2003; Darnhofer *et al*., 2005). Multifunctional farming systems are also a specific objective of organic farming.

In the 1990s, many specialised dairy farms in the Netherlands converted to organic farming. Some continued to specialise in dairy production, but the majority of farmers (up to 80%) transformed their business into a multifunctional farm (Biologica, 2006), taking up activities such as: cheese making, farm gate shops (i.e. milk and meat products), nature development and conservation, rotating crop production, care farms and recreation.

Farmers' own ideas about best 'organic farm practices', as well as new rules and market prices also result in different farming strategies. There are differences, for example, in the extent that farmers purchase external inputs (high input vs. low input farming) or take natural farm processes as their guiding principle (Van der Ploeg, 2003). Verhoog *et al*. (2003) observed that there are pragmatic organic farmers who formally comply with the rules of organic farming, but continue to have a conventional problem-solving approach, seeking to maximise their level of external inputs. This farming style is characterised as 'non-chemical approach'. There are also farmers who opt for a more systemic approach and closed cycles, which he called the 'agro-ecological approach'. In this style of farming, closed cycles at farm level and systemic solutions are more important rather than end-of-pipe-solutions. The third category of farmers is focused on the intrinsic values of the farm, the animals, their landscape and includes natural service. This is called the 'integrity approach' (Verhoog, ibid.).

Such differences in farming strategies may imply different breeding requirements (Groen *et al*., 1995). On a multifunctional farm, for example, milking cows may need to have other characteristics than milk production alone, such as high protein milk for cheese, good build for meat production (dual purpose breeds) or a friendly nature for farm visitors. If a farm has a surplus of land area in relation to its milk quota, it can produce milk economically on roughage, and should have milking cows with lower yields (Van der Ploeg, 2003). On-farm breeding may require more young stock to select from (Nauta *et al*., 2005), and may therefore require dual-purpose breeds as more animals are culled per year.

1.6 The objectives of this research

The problems with conventional farm stock, the vague legislation and use of undesirable breeding technologies, different views on naturalness in organic farming and the diversity of farms all combine to make animal breeding in organic dairy production a complex issue which is not transparent for either farmers or consumers of organic products. A clear standpoint on breeding in organic dairy farming is needed. It was hypothesised that organic farming would have specific requirements as regards animal breeding and types of cow, and would need a different genetic improvement strategy than conventional farming. The goal of this research was to present possible breeding scenarios for organic dairy farming based on the current situation and possibilities.

The objectives of the study are:

a. to analyse the current situation in breeding for organic farming, including the views of farmers and other stakeholders as regards breeding goals and use of reproduction technologies;
b. to quantify genotype x environment interaction between organic and conventional dairy cattle farming;
c. to analyse the breeding goal of organic dairy farmers in relation to their farming practices; and
d. to describe and discuss the consequences of the results of a, b and c for a genetic improvement strategy for organic farming.

The focus of this research was on dairy farmers and their farming practices. The reason for this is that the success of implementing new organic breeding strategies depends on strong, broad support in the field. Farmers are also seen as 'experience scientists' who have the basic knowledge needed for changes to be made (Baars and De Vries, 1999; Baars, 2002; Stuiver *et al*., 2004; Kroma, 2005). The implementation of organic breeding will require new knowledge and the rediscovery of traditional knowledge; farmers' knowledge will have to be combined with new methods based on the outcome of research.

Reading guide

Chapter 2 describes the research that was carried out in 1999-2000 on views on organic breeding among Dutch organic dairy farmers and various stakeholders. Discussions were organised with organic dairy farmers throughout the country. Farmers' views and ideas were collected during these discussions, and they were also asked to give their optimum breeding strategy for organic breeding.

Chapter 3 identifies the differences between conventional and organic dairy production, and presents an analysis of the effect of conversion on various production, fertility and health traits based on data collected between 1990 and 2004.

Chapter 4 gives the results of the first-ever study on G x E between organic and conventional dairy production based on the same data sets. This information is important in determining whether or not the organic sector would benefit from a separate organic breeding programme. No information on G x E was available at the beginning of this study, which examines the effect of G x E between milk production and udder health of first lactation Holstein cows on organic and conventional farms in the Netherlands. The study was based on data from milking cows of the Holstein Friesian breed, as this is was the main breed used by Dutch organic farmers.

Chapter 5 gives information on the choices that organic dairy farmers made in 2005 concerning the breeding goal, and type and breed of cows in relation with their farm management. It reveals the diversity in organic farming and describes farmers' search for dairy cows that fit the specific needs of organic farming.

In Chapter 6 the implications of selection and breeding in organic farming are discussed in relation to three breeding options for the organic sector: using conventional breeding, breeding within the organic production chain and breeding based on natural mating. An outline for further action is given, with 'flexibility' as an important ingredient for the diverse sector of organic dairy farming.

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Chapter 2

Animal breeding in organic dairy farming: an inventory of farmers' views and difficulties to overcome

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Abstract

Currently, most organic dairy farmers in the Netherlands use conventional breeding methods and production stock. In view of the organic objective of closed chains, organic dairy farmers discussed in workshops the desirability and practical merits of different possible scenarios for realizing breeding programmes that are more in line with organic farming principles. Generally, farmers concluded that there is a need for organic breeding practices to support the sector's credibility towards consumers and society. The first step in developing organic breeding practices, is to ban the indirect use of artificial embryo reproduction technologies, but there was no consensus on which selection strategies best fit organic principles. Most organic farmers preferred to uphold the familiar breeding structure of index selection and artificial insemination. Since the scale of organic farming remains small, a distinct breeding structure for organic farming will be difficult to achieve.

Customizing conventional breeding values and an international co-operation between breeding programs may be (temporary) solutions. In organic farming, farm-based regional breeding strategies based on kin-breeding may be more appropriate but farmers lack knowledge of these practices. Also decision-makers need more knowledge on the influence of the (yet not quantified) genotype-environment interaction on the estimation of breeding values for sires when considering organic and conventional farming as different environments. Substantial genotype-environment interaction would support selection under conditions representative for organic environments. It was concluded that realizing distinct organic breeding practices will take time and will require institutional changes.

Additional key words: animal breeding scenarios, vision development

2.1 Introduction

Organic agricultural production in Europe, including the production of food of animal origin, is growing steadily (Anon., 2001b). Between 1993 and 1998 the total area under organic agriculture in Europe increased by almost 30%. The current organic area is about 3.8 million hectares, or 3% of the total European agricultural area. In the Netherlands, organic farming accounts for about 3% of its total agricultural area. The sector's current and predicted growth can be attributed to the broad appeal of organic farming principles (De Wit & Van Amersfoort, 2001) and to the support from government policy (Anon., 2000b; 2001a). There is a risk, however, that the sector will turn to more conventional methods in order to meet the growing market demand, thus compromising its identity. In the light of this it is vital that the sector continues to invest in its own qualitative development.

In conventional agriculture there is in general a tendency to control production conditions in order to maximize animals' yield. By contrast, organic agriculture is based on natural processes and closed cycles, which implies equilibrium rather than control and a less intensive land use. Organic production should be tied to the land, with farms preferably being mixed and self-sufficient (Haiger *et al*., 1988; Baars, 1990a, 1998; Van Veluw, 1994; Alrøe *et al.*, 1998; Nauta *et al.*, 1999). It is hypothesized that animals from conventional breeding programmes are not optimal for use in organic farming and that the genetic disposition of animals should be dovetailed to the organic production system (Nauta *et al*, 2001).

The reproduction techniques used in conventional animal breeding are also a point of concern. According to organic principles and guidelines, animal production should take account of naturalness, authenticity, animal welfare and agribiodiversity (Anon., 2000a; Baars & Nauta, 2001). Artificial insemination (AI) and embryo transfer (ET) are commonplace in conventional animal breeding, but these techniques are artificial, depriving animals of natural mating behaviour and affecting animal welfare and integrity negatively (Rutgers *et al.*, 1996; Christiansen & Sandøe, 1999; Haiger, 1999; Spranger, 1999). Furthermore, due to the pressure of competition between breeding companies, the way these techniques have been used has lead to a decline in diversity as fewer breeds and founder ancestors are used for reproduction (Roughsedge *et al.*, 1999). Using Breeding stock from conventional agriculture directly connects organic farming with the use and consequences of these techniques. In the legislation for organic farming it is stated that ET on the farm is forbidden (Anon., 1999). So at this point organic farming is using double standards.

In order to enhance product traceability and clarity of product origin, policy makers want to establish organic food chains 'farm to fork' (Anon., 2001a). Moreover, organic livestock and arable farmers would like to establish a distinct organic breeding system, partly because of specific requirements regarding livestock characteristics, but also because of their wish to improve the transparency of their system and products.

The organic sector still heavily depends on conventional breeding programmes (Anon., 2000c), although some farmers do breed their own cattle, either as kin-breeders or as users of breeding stock from such kin-breeders (Nauta & Doppenberg, 2002). Kin-breeding is a breeding method by which farmers select breeding bulls from different cow-families in their herd. Every year these farmers select 4 to 5 bulls and use these evenly over the herd, avoiding mating of close relatives (Baars, 1990b; 2002, Nauta *et al.*, 2001). Currently, the impact of this practice on the organic cow population in the Netherlands is minimal and organic farmers do not generally regard it as a serious alternative because kin-breeding is expected to increase inbreeding rates.

At the same time, the lack of an organic alternative seems to be an excuse for allowing the use of conventional breeding stock. Animal breeding is not included directly in the international regulations of organic farming (Anon., 1999). New legislation of organic seed production, however, is in development (Baker *et al.*, 2002; Lammerts Van Bueren, 2002). In order to support decision-making on organic animal breeding regulations, we initiated a project to develop a vision of organic animal breeding and to define different strategies that are more in line with the principles of organic farming. In this paper we describe some of the possibilities and dilemmas of animal breeding in organic farming.

2.2 Materials and Methods

The research, which was initiated by the Louis Bolk Institute and supported by the Dutch Ministry of Agriculture, Nature and Food Quality, was participatory in nature, i.e., it was carried out in close co-operation with organic farmers who were considered pioneers in their field (Baars & De Vries, 1999; Baars, 2002).

First, an inventory was carried out to establish a clear view on the current situation of animal breeding in conventional and organic farming. This inventory included a study of the literature, interviews with ten organic farmers who were interested in livestock breeding and a questionnaire distributed to all 350 (in 1998) Dutch organic dairy farmers The interviews focussed particularly on the view of farmers on using indirectly artificial reproduction and the use of cows with a high genetic potential for production at their farms. The questionnaire focussed on the use of AI bulls (type, breed) and the experience with the offspring of these bulls. There were 160 respondents, covering all types of dairy farming and years of conversion (Anonymous, 2000c). The results of the inventory were compiled for a discussion paper entitled 'Organic breeding, a way to go' (Nauta *et al.*, 2001). The discussion paper also presents six different scenarios for organic breeding (see Table 2.1) that are based on different assumptions regarding more natural breeding (e.g. no ET and AI) and more specific selection (e.g. regional or farm based).

As a second step of the research project, six workshops were held in different regions of the Netherlands, where farmers discussed the paper 'Organic breeding. A way to go', including the six possible breeding scenarios for organic dairy farming. All Dutch organic dairy farmers (at that time about 450) were invited to these workshops, but only 50 farmers attended.
Each workshop started with one or two short presentations in which the main topics were addressed and the structure for discussion was explained. The discussions were held in groups of 5 to 6 persons including a discussion leader who also took notes on the discussion and the different viewpoints. The discussions focused on the different breeding scenarios presented in the discussion paper. Finally, the outcome of each workshop was presented and discussed in a plenary session.

At the end of a workshop the farmers were asked to fill in an additional form on the breeding scenarios they personally preferred including their arguments, and if possible to provide a time-scale or suggestions as to how their preferred breeding strategy could be implemented. They were furthermore asked to give their preference for the organic dairy sector as a whole. The farm of each participating farmer was characterized by size of herd, year of conversion to organic, and breed of their cattle. This paper presents the results of the choices of the farmers and the discussions in the workshops.

2.3 Results

The 50 participating farmers had on average 53 milking cows, which is roughly the average size of a Dutch organic dairy herd (55) (De Jong & Van Soest, 2001) and 8 cows less than the average size of a Dutch dairy farm (Anon., 2003). The farmers' average experience in organic farming was approximately 7 years. About 70% of the farms had Holstein-Friesian dairy cattle. The others ones used breeds like Montbéliarde, Brown Swiss, Jersey, Dutch Friesian, Maas-Rijn-IJssel, Red and White and Groninger Blaarkop, or different crosses of these breeds. This indicates that the farmers who attended the workshops represented a good average of the Dutch organic farms regarding farm size and cattle breeds used. On average they had a relatively long experience in organic farming, since most farmers had converted during the second half of the 1990's (Anon, 2001b).

Farmers' preference ratings for the different breeding scenarios are presented in Figure 2.1. Ninety-five per cent of all farmers liked to see a ban on the use of bulls from ET (scenarios II–VI). Fifty-one per cent of all farmers preferred breeding to take place within the organic production chain (scenarios IV–VI). For 60% of this group this meant that breeding and selection should be based on a general breeding approach within organic farming; i.e., that estimated breeding values are based on information from cows that are kept on organic farms (scenario IV). The remaining 40% preferred kin-breeding on organic farms (scenarios V & VI).

Overall, farmers preferred a more organic breeding strategy, more or less adapted to or based on organic farming (Table 2.1; scenario's III–VI). Farmers questioned the use of conventional breeding schemes. They did not like the use of breeding programmes that are based on artificial reproduction technologies and selection of high-producing animals. In the first place they regarded it as inappropriate to use conventional breeding, because it is contrary to consumers' expectations. Secondly, also their individual motives for producing organically were an important consideration to choose for organic animal breeding.

The use of embryo transfer and artificial insemination

An important reason to ban embryo transfer (ET) was the organic farming's image with consumers. In ET technology, hormones are used for synchronization and super-ovulation, which is in conflict with organic principles and standards. The general view among participating farmers was that "*consumers are not yet aware about this practice, but we have to work on solutions before they* *find out*". A ban on the indirect use of ET was mentioned as a first step in the development of a wholly organic breeding system. Farmers did realize that a strict ban would reduce the supply of bulls used through artificial insemination (AI), especially Holstein bulls. It was unclear to them whether conventional breeding companies could produce special ET-free bulls and to what extent this would affect costs and supply.

Some of the arguments in favour of a ban on the use of ET also apply to the use of AI (AI is unnatural and gametes are taken out of their natural environment). Indeed, many livestock farmers considered the possibility of a ban on AI. However, in view of logistic and animal welfare aspects, participants recognized the absence of a practical alternative to AI. In this case, most farmers are very pragmatic, but they also said that they have no choice, as long as there was no serious alternative available. Many farmers bypassed AI to some extent by keeping a young bull at the farm for serving heifers.

Among the workshop participants there were two kin-breeders of the Dutch Friesian dual-purpose breed. They actually use their own selected bulls in an on-farm kin-breeding scheme. They were convinced that selecting and using one's own bulls did not have to be a problem. To them it was "*just the normal way of doing things*". They got good results and consider bulls to be part of the system. The use of natural mating bulls has the additional benefits of reduced expenditure on AI and extra income from selling bulls for meat or as breeding stock.

Adaptation of conventional breeding to organic farming

Many farmers (49%) did not see any possibility for a special organic breeding programme. They considered the market too small and the possible selection intensity and supply of breeding bulls too limited. They placed faith in their co-operative breeding company and in the structure of breeding programmes that had been used for several generations. Many farmers did not want to give up this historic social relationship. Should breeding have to be organic, they then liked it to be organized along similar lines.

At the same time, many farmers had doubts about the value of conventional breeding for their own organic farm. They had often observed that pure-bred milk-type Holstein cows with high breeding values for production *"give away too much of themselves"* when kept on an organic feeding regime, i.e., low in concentrates and high in grass with a lower caloric content.

Farmers had also noticed that cows from conventional breeding programmes matured too early. They believed that this was due to selection being too strongly based on the performance of young animals, a criterion used by the breeders to shorten the generation interval. By contrast, organic farming strives for long productive lives of animals so that the animals are used efficiently, also out of respect for integrity of animals. Farmers therefore liked to see breeding strategies and values adapted to organic goals.

Table 2.1: Breeding scenarios for organic animal production (source: Nauta *et al.*, 2001)

Scenario I: Use of conventional breeding Organic farmers continue to make use of AI bulls of current conventional world-wide breeding schemes and make no demands with respect to taking into account specific organic considerations.
Scenario II: Conventional breeding without ET Farmers continue to benefit from conventional breeding, on condition that animals used on their farm are not born from ET. As a start for this approach, only bulls will be used which are not born from ET. Breeding organisations will be urged to work on a sufficient pool of ET-free bulls of good genetic level.
Scenario III: Conventional breeding adapted to organic agriculture Breeding is based on data of performance of conventional cattle. To overcome possible influence of G x E in estimated breeding values; (1) additive information is used for the selection of breeding stock for organic farming and (2) breeding goals are adapted to organic farming.
Scenario IV: Breeding based on organic principles The organic sector will establish its own breeding and selection of organic livestock. Bulls from organic farms will be selected and daughters of these bulls will be tested on organic farms to estimate 'organic' breeding values for the desirable traits. The keeping and housing of the bulls is based on the rules for organic dairy farming.
Scenario V: Regional breeding A selected group of breeders will provide breeding stock and semen for reproduction. These breeders practice family or kin breeding as described by Baars (1990b). Other farmers use bulls from these breeding farms.
Scenario VI: Farm-specific breeding Each organic farm will practice family or kin breeding. Therefore, each farm has its own stock of breeding bulls or frozen sperm doses of these bulls . The bulls are randomly mated avoiding close relationships and inbreeding. Cows are served naturally or inseminated artificially.

Farmers also liked to actually see the bulls so that they could personally approve of the animal. Nowadays, farmers must decide on a bull on the basis of standard photos and index values. Farmers realized that this request might be difficult to honour because of international veterinary restrictions. Smaller, local breeding companies might offer more scope in this respect.

Breeding based on organic standards – 'organic breeding'

The general opinion among participating farmers was: "*We must slowly work towards an organic breeding system but not throw away what we have now*". Many farmers are aware of the need to also include breeding in the organic production chain. However, there was little consensus on how to reach this goal. Many farmers thought that the organic sector was too small for an effective breeding programme. It was not clear how many animals would be needed for a specifically organic breeding syndicate. *"How many bulls can be tested?"* Farmers mentioned the possibility of international co-operation to increase the organic population and the selection possibilities. (Fig. 2.1)

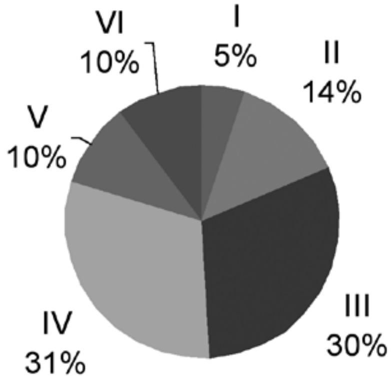

Figure 2.1: Dairy farmers' preferences in percentages based on the scenarios as described in Table 2.1. I = conventional breeding, II = conventional breeding without ET, III = conventional breeding adapted to organic farming, IV = Organic breeding (Based on organic data), V = regional breeding (based on kin-breeding), and VI = kin-breeding.

Another question for the development of a closed organic chain was whether the housing and management of AI bulls should be organic. Most farmers did not have a clear view on this matter. The general opinion was that *"the regulations for dairy cattle could be applied here"*. Organic housing and management for bulls are important to achieve a fully organic chain, but were not considered urgent.

Collective versus individual approach

For most farmers kin-breeding and breeding one's own bulls were not serious propositions.
Many farmers were against kin-breeding, using arguments like the danger posed by bulls, the risk of inbreeding depression, slow genetic gain and too much idealism. It appeared that farmers in

general no longer have the knowledge required for this breeding system. Some liked to learn more about it. Most farmers had become used to the large stock of selected AI bulls and could not believe that selection in a small population on a farm is possible without inbreeding depression.

Farmers also complained about the distance between them and the breeding organization: they had no influence on decision-making and there were not enough organic farmers to change this situation. With kin-breeding and regional breeding farmers would regain control of breeding. But farmers were also afraid of putting breeding in the hands of a few kin-breeders. *"This was why it went wrong in the old days*" was their argument, referring to the small Dutch Friesian type that was preferred in the 1950s and 1960s in the Netherlands. So kin-breeding, if applied, should be well organized.

Introducing kin-breeding on every organic dairy farm was seen as very unrealistic. Most farmers were not breeders and kin-breeding requires special skills. *"It has to be in your blood."* a farmer said. In this scenario, breeding would be based only on inbreeding without crossbreeding; heterosis would not be used, which – as one farmer noted – would be rather inefficient. Most farmers saw themselves as commercial users of genetic material rather than breeders of new outstanding genetic material. Crossbreeding between pure-bred lines from kin-breeders at commercial farms would create strong hybrid animals.

2.4 Discussion

Our results show that in general the Dutch organic farmers' view on animal breeding is that it has to become more firmly based on organic principles and that it should, ideally, become part of the organic production chain. However, different organic farmers had different preferences, making that there was no consensus on possible breeding strategies in organic farming.

The discussion about breeding was linked to the broader discussion about developments in organic farming. In the 1990s, organic production in the Netherlands grew rapidly as more conventional farmers converted to organic. This resulted in an organic sector that can be seen as a reflection of the conventional sector (Baars, 1998), with many highly specialized and industrialized features (Roep, 2000). Verhoog *et al.* (2003) described three directions of development within the organic sector in the Netherlands. The development of the sector as a whole is aiming for more closed cycles and production chains and is therefore moving towards the agro-ecological and intrinsic approach (Verhoog *et al.*, 2003). Figure 2.2 shows that animal breeding on a converting farm can be seen as a dynamic and variegated transitional process and can develop along different directions. The development towards organic farming is also a matter of time (Østergaard, 1997). For example, a farm may have a very conventional symptom-focused approach to organic farming but may grow towards multi-functionality and dual-purpose cattle. But a mono-functional farm (only dairy cattle and milk production) may also develop a highly natural and organic approach without diverting from its single purpose: milk production. The challenge is to develop breeding strategies for organic farming that fit organic principles in general and at the same time acknowledge the actual differences and dynamics of organic farming and animal breeding.

The organic sector as a whole is developing towards a more closed organic production chain, including the input of breeding material. For example, the worldwide umbrella organization for organic farming, the International Federation of Organic Agriculture Movements (IFOAM), is currently implementing the first rules for organic plant breeding (Baker *et al.*, 2002; Lammerts Van Bueren, 2002). Only a few years ago the topic *animal breeding* was included for the first time in the programme of the IFOAM World Conference (Anon., 2000a). Animal breeding for organic farming is expected to become an important issue in the near future. However, there are some important dilemmas to overcome.

Artificial reproduction technologies - naturalness

For most Dutch farmers, a ban on AI is no option. The arguments against AI are very much the same as those against ET. Spermatozoa are taken out of their natural context, diluted and frozen for distribution, natural mating behaviour is excluded and more offspring per bull is created (Spranger, 1999). However, AI was developed to prevent the spread of animal diseases (Den Daas & Van Wagtendonk-De Leeuw, 1993), and – as interviewed farmers noticed – bulls on the farm can be dangerous. So the choice of the Dutch organic dairy farmers is very pragmatic by considering AI as an indispensable technology. On the other hand, some organic kin-breeders did not see natural mating and bulls on the farm as a problem. Experiences of such farmers were studied by Nauta & Doppenberg (2002) and the results can be used to teach other farmers so that they can make new choices regarding farm-based breeding or more collective strategies.

A ban on ET and AI would put the organic sector in a difficult position. It is clear that conventional breeding companies cannot easily provide a special ET-free breeding programme for organic farming: the cost would be too high. In the Netherlands, excluding ET would have a great impact on organic dairy farmers who use Holstein stock (Anon., 2000c; De Jong & Van Soest, 2001). For these farmers the supply of AI bulls would decrease dramatically if ET by descent, i.e., in all previous generations, would be prohibited. However, organic farming is seen as a very natural and animal friendly production system (Bartussek, 1991; Verhoog *et al.*, 2003) and this is also laid down in the aims of organic farming (Anon., 2002). Internationally, researchers and other stakeholders strive for more natural breeding in organic farming (Haiger, 1999; Spranger, 1999; Bapst, 2001; Bapst & Zeltner, 2002).

A ban on ET would safeguard organic farming from indirectly using other technologies like cloning and genetic engineering. To overcome this dilemma, a ban on ET could be imple-

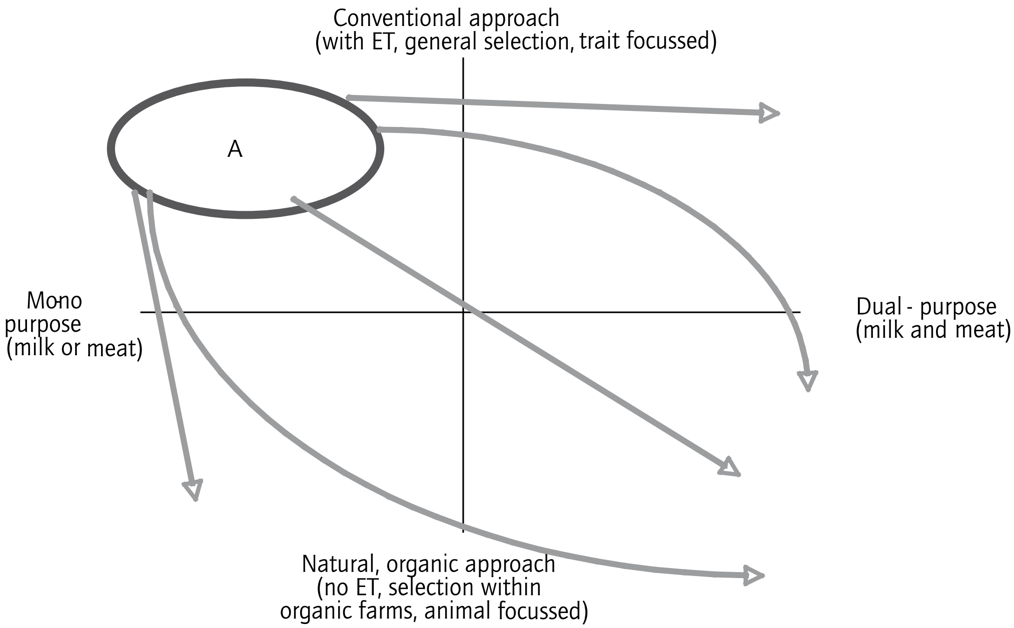

Figure 2.2: Potential courses of development for a mono-functional farm with a conventional approach (A) converting to organic a more organic and/or multi-functional approach, based on naturalness/organic and level of specificity.

mented in stages, as was proposed in Switzerland (B. Bapst, personal communication). Breeding companies must consider their possibilities for developing a supply of ET-free bulls. If they cannot provide this, a special breeding programme for organic farmers would have to be developed, especially for Holstein cattle. A survey in the Netherlands yielded 120 ET-free bulls, supplied by five commercial breeding companies (Nauta, 2003). Fifty-four per cent of these bulls still were black and white Holstein and red Holstein, breeds in which normally ET is used.

To avoid ET, farmers could also use breeds in which ET is less commonly used. In Switzerland, for example, only 30% of the total number of AI bulls (mainly Holstein) was produced through ET (Bapst, 2002). In the Netherlands, organic farmers use also breeds like Jersey, Brown Swiss and Montbéliarde (Anon., 2000c). These breeds accounted for 18% of the ET-free bulls on the Dutch list. However, the use of ET technologies in these breeds is on the rise. The percentage of the traditional Dutch breeds Dutch Friesian, Groninger Blaarkop and Maas-Rijn-IJssel, was about 30%. For these breeds, the use of ET is low as they are not popular on the market. These breeds could be a starting point for ET-free breeding. To completely avoid artificial reproduction some farmers select and breed animals exclusively on their own farm (Baars, 1990b; Nauta & Doppenberg, 2002).

Specific organic breeding

Almost 50% of the farmers agreed that there is a need for animal breeding within the organic production chain and 30% saw the adaptation of conventional breeding to organic farming as a starting point for this. At the moment, however, there is no information available on how to customize conventional breeding values for organic farming. In this discussion two aspects are important. The first aspect is the choice of specific 'organic' traits and their weighting in a breeding goal. The introduction of durability traits in breeding indices for conventional farming is increasing (e.g. Vollema, 1998; Van Der Beek, 2003; VanRaden, 2004). Although these initiatives are not specially dovetailed with organic farming, they are a step in the 'organic' direction.

The second aspect is the influence of the (yet not quantified) genotype x environment interaction (G x E) on estimated breeding values (indices) for sires when considering organic and conventional farming as different environments. Examples of special sire indices for ecological breeding are available in Germany (Postler, 1998, Wittenberg, 2003). The G x E interaction is related to the phenomenon that different genotypes (of animals) apparently have different levels of expression in different environments. This is generally modelled by defining the phenotypic expression (Pij) for animal i in environment j as a function of a genotypic component (Gi) plus an environmental component (Ej) plus an interaction component (Gi x Ej) (Falconer & Mackay, 1996). The magnitude of the G x E interaction can be defined as the amount of variance in P that is explained by the interaction component.

In dairy cattle breeding it is common practice to ignore the G x E interaction when estimating breeding values of sires from data recorded within one country. In theory this means that estimated breeding values are a composite of both Gi and Gi x Ej. In practice this is not a problem as long as recording environments are uniform and the G x E interaction explains only a small portion of the variance in the records observed. However, if environments (for example conventional versus organic farms) interact significantly differently with different genotypes (in the extreme situation leading to a re-ranking), either the G x E interaction is to be modelled as a (correction) factor when estimating breeding values from records of multiple environments or breeding values need to be estimated from and for its use in single type of environments. The variance in performance records or durability traits explained by the G x E interaction when considering conventional and organic farms as different environments is not yet quantified (Nauta *et al.*, 2002; Boelling *et al.*, 2003). In the near future, regulations for organic farming will be tightened (Anon., 2002). In particular, further restrictions on the use of conventional concentrates, resulting in an increased price of organic concentrates, will result in a lower energy uptake of cattle in organic farming systems. This will cause a further increase in the differences between conventional and organic environments and therefore will potentially increase the variance caused by the G x E interaction, especially for durability traits (Buckley *et al.*, 2000; Berry *et al.*, 2003).

More information on the G x E interaction could facilitate the choice between a collective or more farm-based and individual approach to breeding in organic farming. Given the size of the organic dairy sector (Anon., 2001a) and the variety of breeds used (Anon., 2000c), the suitability of a general approach within organic farming based on breeding value estimates and progeny testing is questionable. At present the Dutch organic dairy sector comprises 550 farms and about 30,000 lactating cows, about 20,000 of which are Holstein. With such numbers, only a breeding programme for Holsteins with about 35 testing bulls (500–700 inseminations) might be feasible. The Dutch Government's target for the organic sector in 2005 is 10% of total agricultural production (Anon., 2000b). If this target would be realized, it would increase the scope for organic breeding for other breeds too. Today, however, we are seeing a decline in the number of farms converting to organic as markets are unstable and financial support is limited. An international approach could solve this breeding problem.

If the sector does not grow substantially, recording information from conventional farms could be used. Recording information from only extensively managed farms could be used too, possibly minimizing disturbing effects of the G x E interaction on breeding values. Similarly, the estimation of breeding values could be based on a smaller group of farms, for example kin-breeding (Baars, 1990b; Nauta & Doppenberg, 2002), again avoiding disturbing effects of the G x E interaction. Both suggestions, especially the second one, lead to a reduction in number of records used and therefore to reduced accuracy of estimated breeding values of sires.

Postler (1998) described an 'ecological index' for dual-purpose breeds in southern Germany, with production persistence and animal health and vitality as important organic traits. Another breeding strategy that is often mentioned as an opportunity for organic farming is the selection of animals with high lifetime productions (Bakels, 1988). Bakels suggested that selecting for high lifetime production would automatically result in the selection of all the necessary traits for longevity. However, both, the ecological index and the longevity approach lead to longer generation intervals, and therefore slow down genetic progress as one has to wait for three or more lactations to be completed before a breeding value can be estimated.

In line with organic farming principles, kin-breeding on the farm is based on natural breeding and stimulates diversity between farm populations as every environment has its own effect and every farmer his own idea about selection (Nauta & Doppenberg, 2002). In this way the introduction of kin-breeding on organic farms could have a positive effect on the image of organic farming. However, breeding at farm level means that populations are small and genetic progress per trait will be relatively small too (Rendel & Robertson, 1950). For increasing the genetic progress, the kin-breeding approach could also be used by (regional) breeding groups as was suggested in scenario V (Table 2.1). It seems to be worthwhile to study the possibilities of kin-breeding for organic farming on the bases of the natural character of this system.

2.5 Conclusion

A relatively small part of the Dutch organic dairy farmers appeared to have interest in animal breeding, but these farmers were well experienced in organic farming. We observed a strong wish among dairy farmers for more organic-oriented animal breeding. The farmers were concerned about the public's image of the sector and about consumer confidence. They wanted to guarantee a 100% organic production chain, avoiding the direct or indirect use of unacceptable reproduction technologies in the chain and enhancing the adaptation of animals to the organic farming environment.

On the other hand, we did not find consensus on how a more organic based animal breeding is to be achieved. The development of organic breeding strategies is related to the dynamics of the organic sector, which is in the process of transition towards a production based on organic principles. Organic breeding strategies should be in harmony with these developments.

Development of organic animal breeding requires a restructuring of (conventional) breeding. However, there are practical and institutional obstacles to overcome. A total ban on the use of ET would diminish organic farmers' choice of breeding bulls. At the national level, the sector is still small for an all-organic general breeding strategy with a possible exception for organic Holsteins. For the smaller local breeds, genetic progress would be small. Here an international approach might broaden the possibilities.

Another breeding option would be a more individual approach, like with farm based kin-breeding. This would avoid the problems of using conventional breeding. However, most farmers did not have the knowledge of kin-breeding and did not feel ready for it. The challenge seems to be how to combine the need for a farm-based selection and a collective approach. If an international approach is chosen, the effects of the genotype x environment interaction on the estimation of breeding value may increase. Further research is required for developing information and tools to support organic farmers in realizing organic breeding.

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Chapter 3

Converting to organic dairy farming: consequences for production, somatic cell scores and calving interval of first parity Holstein cows

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Abstract

This paper aims to describe the changes prompted by conversion to organic farming for milk production and fertility of first parity Holstein cows. Data was collected for Dutch organic farms, with a distinction made between long-standing-organic farms, converted organic farms and a reference group of conventional farms. The percentage Holstein blood in the herds, milk production (Kg milk, % milk fat, % milk protein), somatic cell scores (SCS), calving interval (CI) and age at first calving (AFC) were described over time. An animal model was used to estimate the effects of conversion on different traits based on data from converted organic farms.

Milk production was lower and somatic cell counts were higher on long-standing-organic farms than on conventional and converted organic farms. Interestingly, at pre-organic farms, i.e. before their conversion, the milk production level was already lower than at conventional farms.

The estimates from our statistical analysis showed a highly significant decrease in milk yield and protein percentage due to conversion. Also fat content decreased, SCS increased and AFC increased significantly.

It can be concluded that the conversion to organic farming is a gradual process over years. Dutch farmers who decided during the late 1990's to convert to organic farming, represented a specific group of farmers distinct from conventional farmers, which was reflected by lower milk yields, milk fat percentage and protein percentage before conversion as compared to conventional farms. During conversion, significant changes in milk production, protein and fat contents and somatic cell scores took place. Age of first calving is an important difference between organic and conventional farming.

Key words: conversion, organic farming, milk production, calving interval, somatic cell score, age at first calving

3.1 Introduction

Converting to organic production necessitates changes in farm management which in turn can be expected to have consequences for a farm's characteristics and output. By the end of the 20th century, about 3% of European farmers had converted to organic farming (SÖL, 2003) in response to a growing market for organic products. In order to plan a conversion to organic production, basic information about expected changes is required. Little information is available about milk production, fertility and health of animals that experience a farm's conversion to organic. Information that we do have is based on questionnaires (Nauta *et al.*, 2001; De Jong and Van Soest, 2001) and studies of relatively small groups of organic herds with or without statistical analyses to account for differences in breeds and relationships between animals (Kristensen and Kristensen, 1998; Toledo *et al.*, 2002; Kristensen and Mogensen 2000; Bennedsgaard *et al.*, 2003; Vaarst *et al.*, 2003; Hovi *et al.* 2003). For our research we were able to use all the available production and fertility records from calvings from 1990 to 2003 at almost all organic dairy farms in the Netherlands, precluding the risk of selecting a specific group of organic farms and giving us insight into the development of production and fertility over more than a decade.

Differences between organic and conventional dairy farming can be expected due to restrictions on the use of chemical fertilizer and concentrates (EU, 1999). Organic roughage is produced without chemical fertilizer and consequently has lower energy and protein compounds (Padel, 2000). Organic farming regulations also restrict the use of concentrates and set a limit on the content of conventional ingredients in the concentrates (EU, 1999). In practice, the latter restriction will act as a financial restraint on the use of concentrates as well. On top of this, many organic farmers simply opt for a low input of concentrates from an organic point of view. With more organic roughage in the diet and a lower intake of energy and protein from concentrates, milk production is expected to decrease. It is also expected that cattle with high genetic potential for production will have particular difficulty coping with organic environments (Kristensen and Pedersen, 2001; Nauta *et al*, 2001). Our interest, therefore, is directed especially at Holstein cattle.

The aim of this paper was to describe the changes prompted by conversion to organic farming, focusing on milk production traits, somatic cell score and calving interval of first parity Holstein cows in those herds.

3.2 Material and Methods

Data and edits

The data used were 305-days milk production records and accompanying fertility records, somatic cell count records of first lactations. Data were obtained from the Dutch Herd Book and milk recording organization (NRS). The data on organic farms were identified by using the addresses of all Dutch organic dairy farms in 2002. For the organic farms also their date of conversion was known. This information was obtained from Skal, the Dutch organic certification organization for organic farming. In 2002, 472 organic dairy farms were registered with Skal. The NRS database contained production records of 404 of these farms. Data from conventional farming was collected by a random selection of 966 conventional farms. These farms were situated in the same areas as the organic farms.

The data was edited in such way that it only contained records that would meet the criteria as described by the NRS (NRS, 2002) e.g. only selected only records of cows with a calving between 17 and 36 months of age and days open between 30 and 250 days. Additionally, in this study we excluded data from animals which moved between farms during their lactation. We could select 46,282 first lactation records from 367 organic farms and 184,993 first lactation records from 966 conventional farms. All cows calved between January 1990 and April 2003.

Three different data sets can be distinguished:

Conventional	= data from the 966 conventional farms.
Converted-to-organic	= data from 325 farms that converted to organic production some where between 1990 and 2003, records were available from the period before and after conversion.
Long-standing-organic	= data from 42 organic farms that were already organic before 1990, only records produced under organic conditions were available.

Figure 3.1 depicts the distribution of data from converting-to-organic and long-standing-organic farms and shows that most farms converted in the second half of the 1990s. To describe the changes in breed composition per calving year of conventional, converted-to-organic and long-standing-organic farms between 1990 and 2003 we used 46.282 records for converting-to-organic, 5400 for long-standing-organic and 184.992 records for conventional farming. The breed composition was calculated by adding the breed composition of each animal and dividing this by the total number of animals.

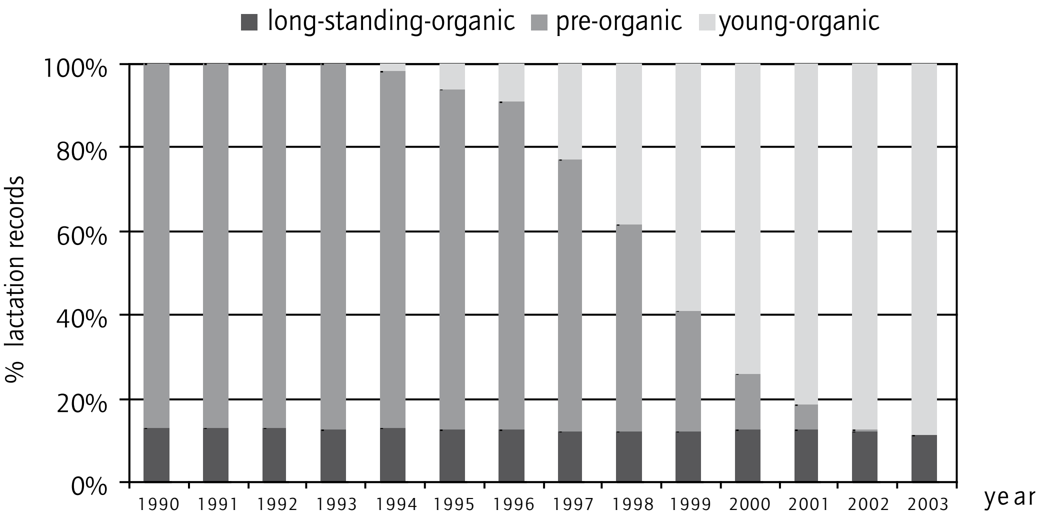

Figure 3.1: Distribution of first parity records in percentages of organic farms over calving years 1990-2003 of Long-standing-organic, pre-organic (organic farms before conversion) and young-organic (after conversion) farms.

Phenotypic trends based on unadjusted data for milk production, fat and protein percentages, somatic cell scores (SCS), calving interval (CI) and age at first calving (AFC) were estimated using data from the HF breed only. Therefore we selected 1st lactation records of animals with at least 87% HF blood. This resulted in 22.184 records for converting-to-organic, 3066 records for long-standing-organic farms and 132.747 records for conventional farming.

Records for CI between first and second calving and SCS were added to these data. The average SCS per lactation were based on somatic cell counts from test day records. The average somatic cell count per lactation was estimated as the mean of all available test day somatic cell counts records. The somatic cell counts per lactation were transformed to SCS by SCS=$\log_{10}$(somatic cell count).

Not all cows with milk production records did have records for SCS and/or CI. For SCS 19.107 record from converting-to-organic farms, 2639 records from long-standing-organic farms and 115.398 records from conventional farms were available. For CI we got 92.228 records from converting-to-organic farms, 2048 records from long-standing-organic farms and 115.058 records from conventional farms. The phenotypic trends were calculated as the averages per trait per calving year from 1990 to 2002.

The "effect of conversion" was estimated for milk production, fat and protein percentages, SCS, CI and AFC. This study was based on records from converted-to-organic farms only. In addition, only daughters of sires with at least 4 offspring were selected. This resulted in 17.389 lactation records. For SCS 15.419 records and for CI 11.992 records were available.

Models

We used ASREML (Gilmour *et al.*, 1999) to quantify the "effect of conversion" to organic production. The "effect of conversion" was quantified by the variable BIO which was equivalent to the time span between calving date and conversion date, and was divided into year-classes with a range from 9 years before conversion to 7 years after conversion, or -9 years and +7 years respectively. Because there was a sharp decline in the number of records per BIO-class smaller than -6 (6 years or more before conversion) and larger than +5 (five years or more after conversion), we combined all records under -6 into a single ≤ -6-year class and records over +5 into a single ≥ 5-year class . Production traits (kg milk, % milk fat, %milk protein) an SCS were analysed using the following model:

[1] $$\mathbf{Y_{ijkl} = mu + H_i + YS_j + ß_0 * AFC_{ijkl} + ß_1 * (AFC_{ijkl})^2 + ß_3 * DO_{ijkl} + ß_4 * (DO_{ijkl})^2 + BIO_k + Animal_l + e_{ijkl}}$$

Y_{ijkl} trait x,
mu overall mean,
H_i fixed effect of herd i, (i = 1, 254),

YS_j fixed effect of year-season of calving , the YS effect was based on 4 seasons; January-March, April-June, July-September and October-December,
$ß_0$ to $ß_4$ regression coefficients for linear and quadratic regression on age at calving in months **($ß_0$ and $ß_1$)** and days open **($ß_3$ and $ß_4$)**,
AFC_{ijkl} covariable of age at first calving for observation **ijkl** (in months),
DO_{ijkl} covariable days open for observation **ijkl** (days between calving and conception),
BIO_k fixed effect of years being organic **k** (ranging from ≤-6,-5 .... 4, ≥5 years),
$Animal_l$ random additive genetic effect of animal **l**,
e_{ijkl} residual.

An animal model was used to account for genetic relationships between animals. The covariance structure for this model was:

$$\mathrm{var}\begin{bmatrix} \mathrm{Animal} \\ e \end{bmatrix} = \begin{bmatrix} A\sigma_a^2 & 0 \\ 0 & I\sigma_e^2 \end{bmatrix}$$

Where **A** was the additive genetic relation between animals, σ_a^2 was the additive genetic variance between animals and σ_e^2 was the residual variance. Pedigree information was traced back five generations and was included in the analyses.

In the analyses of SCS, phenotypic observations were weighed according to the number of test day records that contributed to the mean.

Age at First Calving (AFC) *in months* was analysed using the following model:

[2] $\mathbf{Y_{ijkl} = mu + H_i + YS_j + Bio_k + Animal_l + e_{ijkl}}$

Calving Interval (CI) between first and second calving was analysed using the following model:

[3] $\mathbf{Y_{ijkl} = mu + H_i + YS_j + ß_0{*}AFC_{ijkl} + ß_1{*}(AFC_{ijkl})^2 + Bio_k + Animal_l + e_{ijkl}}$

3.3 Results

Changes in breed composition

Holstein Friesian (HF) was the predominant breed in all subsets (see Figure 3.2). On organic farms, the average fraction of HF blood in first parity cows increased from about 60% in 1990 to about 82% in 2002. The fraction of HF blood was approximately 12% lower on organic farms compared to conventional farms. The increase of HF blood at organic and conventional farms occurred mainly

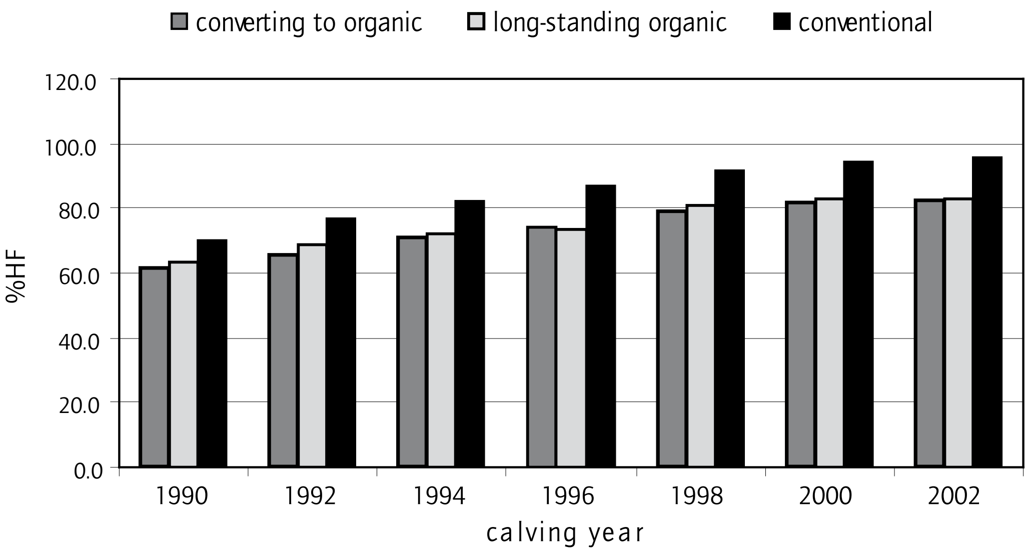

Figure 3.2: Percentage of Holstein Friesian (HF) breed on conventional, long-standing-organic and converted-to-organic farms from 1990 to 2003.

at the expense of two traditional Dutch breeds, Dutch Friesian (DF) and Maas-Rijn-IJssel (MRY). After 1998, the HF fraction on organic farms stabilized at about 82%. In 2002, the long-standing-organic and converted-to-organic farms still had both about 5.0% MRIJ blood. The long-standing-organic farms did have more DF blood (4.7%) than the converted-to-organic farms (1.9%). Half of the DF cattle on long-standing-organic farms were purebred DF. Between 1996 and 2002, the contribution of other breeds on the recently converted-to-organic farms increased slightly: from 0.5 to 3.5% for Jersey; from 0.2 to 2.0% for Montebéliarde; from 0.6 to 1.1% for Brown Swiss. Most Jersey cows were pure bred.

Phenotypic trends in production, somatic cell count, calving interval and age at first calving of first parity Holstein cows

Figure 3.3 depicts the phenotypic trends in milk production of first parity Holsteins on the different types of farms (long-standing-organic, converted-to-organic, conventional) between 1990 and 2003. In the early nineties, when most converted-to-organic farms were still conventional, first parity Holstein cows at these farms produced about 150 kg milk less than on the reference conventional farms. On long-standing-organic farms, first parity Holstein cows produced approximately 830 kg less milk than their conventional counterparts. In the heyday of organic conversion (between

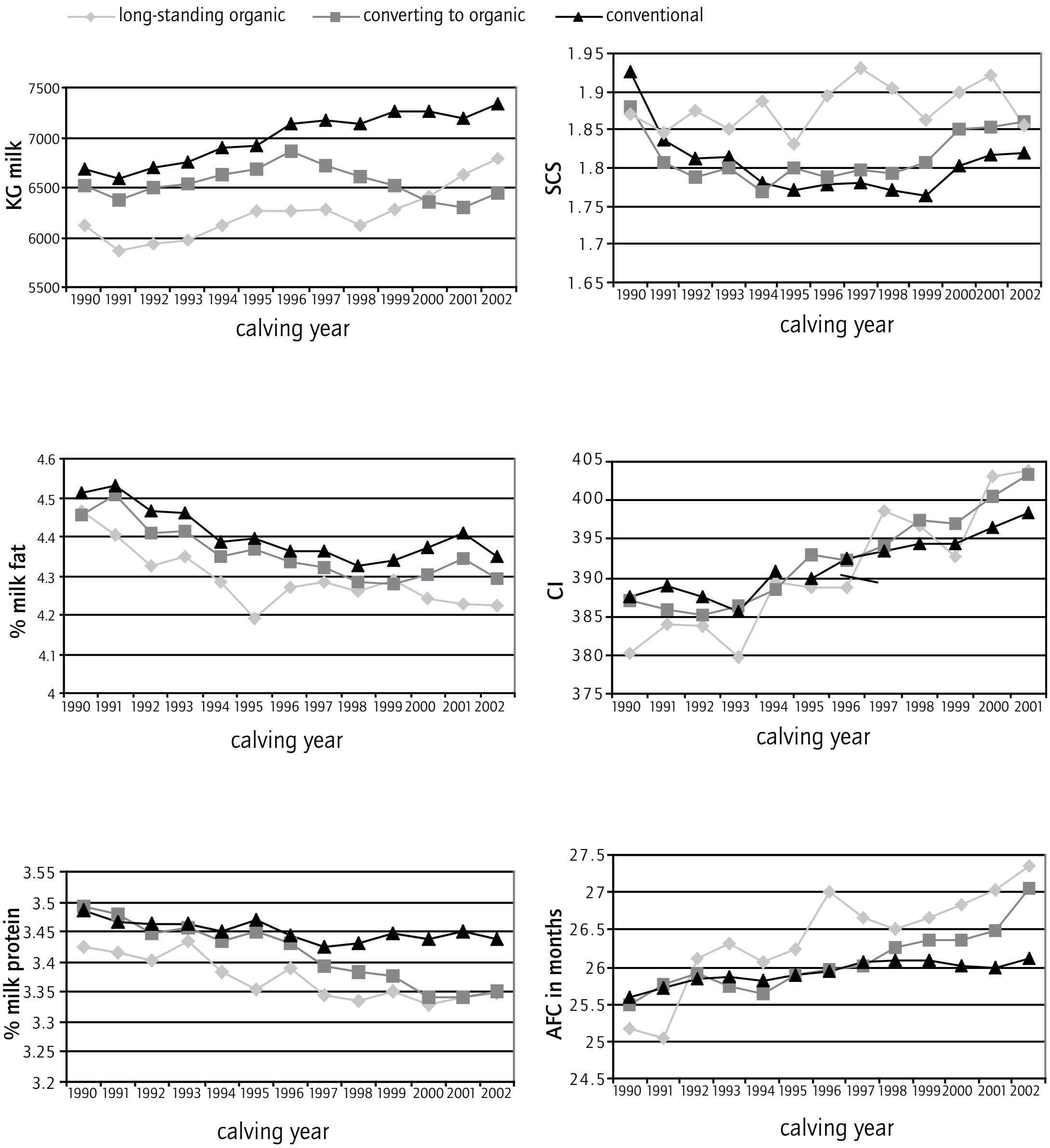

Figure 3.3: Trends in KG milk, % milk fat, % milk protein, somatic cell score (SCS), Calving interval (CI) and Age at first calving (AFC) for first parity 87-100% Holstein cows which calved from January 1990 to 2002 on long-standing-organic, converting-to-organic and conventional farms.

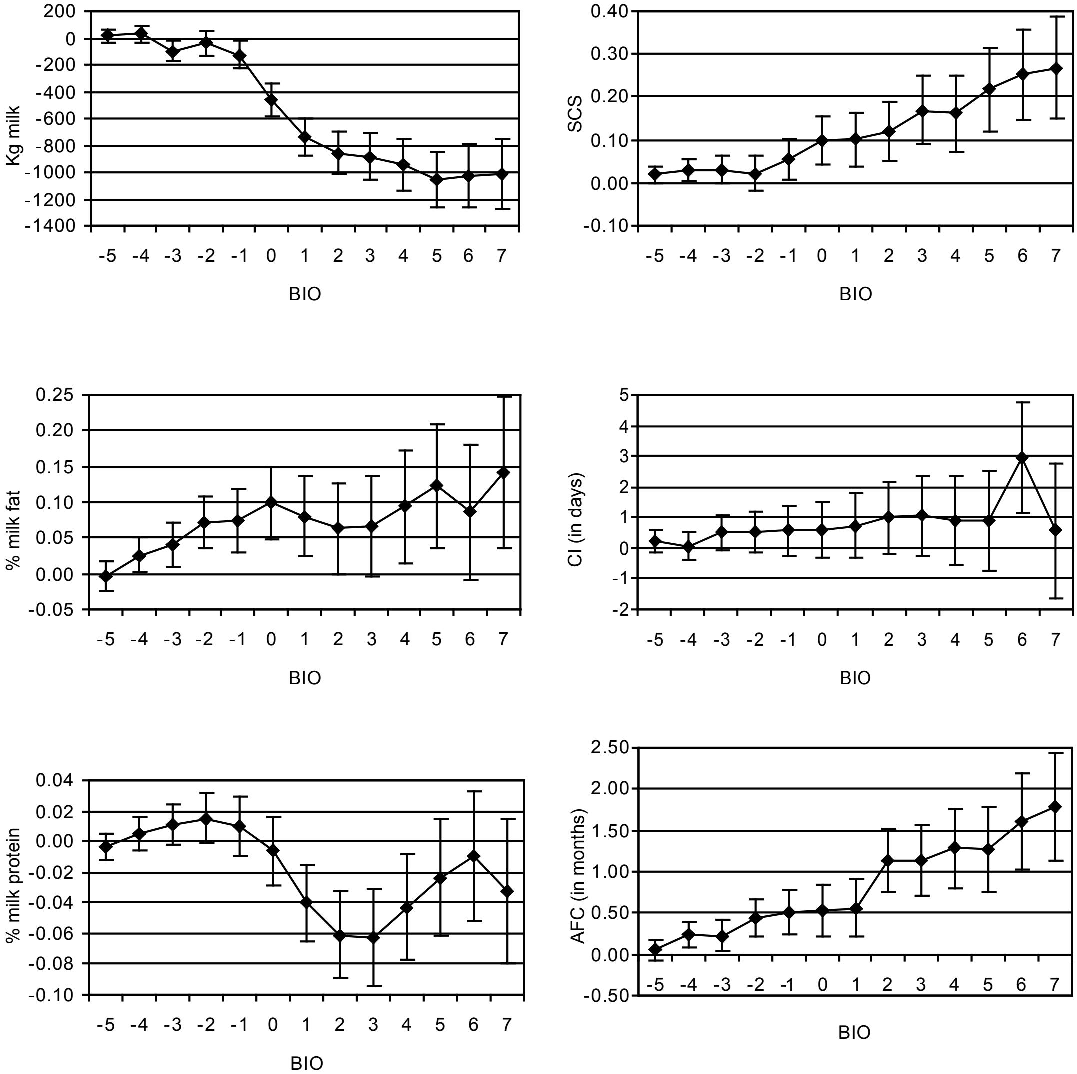

Figure 3.4: Effect of conversion to organic farming (BIO) on milk production (KG milk, % milk fat, %milk protein), somatic cell scores (SCS), calving interval (CI) and age at first calving (AFC) of first parity Holstein cows. SE are shown in bars. BIO = 0 at the date of conversion to organic farming. Values at the y-axes are relative values.

1996 and 2001), the first parity milk production of Holstein cows on converted-to-organic farms dropped below the average production of such cows on long-standing-organic farms.
Compared to the conventional farms, long-standing-organic and converted-to-organic farms had a 0.12% and 0.05% lower milk fat percentage respectively over the years. The phenotypic trend of al groups followed a fairly steady pattern, decreasing from 4.5% in 1990 to 4.3% in 2003.

The percentage protein in the milk produced on long-standing-organic and converted-to-organic farms was respectively 0.08% and 0.04% lower than the protein percentage of conventional farms. At converted-to-organic farms, protein percentage in milk declined after conversion and stabilized at the level of long-standing-organic farms.

Based on phenotypic information, long-standing-organic farms had a higher mean somatic cell score (SCS) than conventional farms. Before conversion, the SCS on converted-to-organic farms was similar to that of conventional farms. After 1998, the difference between converted-to-organic farms and conventional farms was 0.04 points. Between 1990 and 2001, the calving interval (CI) increased by about 23 days for long-standing-organic and 16 days for converted-to-organic farms. For conventional farms the increase in CI was about 12 days.

From 1991 onwards, Holstein cows on long-standing-organic farms had a higher age at first calving (AFC) than on conventional or converted-to-organic farms. Between 1997 and 2002, when most farms converted to organic, AFC at these converted-to-organic farms increased from 26 to 27 months while AFC of conventional farms stayed at 26 months.

Effects of conversion on production, somatic cell score and fertility traits

Figure 3.4 presents the estimated "effect of conversion" (BIO) on milk production, % milk fat and protein, SCS, CI and AFC, obtained from model 1-3. The analysis of the data showed that BIO had significant effects on milk production ($P<0.001$), milk fat percentage ($P<0.05$), milk protein percentage ($P<0.001$), SCS ($P<0.01$) and AFC ($P<0.01$). CI was not significantly influenced by conversion.

Conversion decreased milk production in first lactations by about 1000 kg. This decline started some years before conversion. After conversion, it took 5 years before production showed no further decline. The biggest decline in production occurred in the period from one year before to two years after conversion, the decline being about 790 kg.

Before conversion to organic, we found that milk fat increased. In the first two years after conversion the percentage of milk fat decreased with 0.04%. After two years of conversion the percentage fat increased again.

Before conversion, there had been a steady increase in protein level. From one year before to two years after conversion the protein level decreased 0.075%. Three years after conversion, however, protein level increased again.

SCS started to increase steadily at about 2 years before the conversion date. After conversion, SCS increased by 0.17 units . Assuming a population mean of 150.000 cells per ml, this increase is equivalent to approximately 50,000 cells per ml. Apparently, SCS continued to rise still after 6 years of organic production.

CI did not change due to conversion. AFC increased by 1.75 months over the total time period, with a rapid increase of about 0.75 months in the second year after conversion. The total increase after conversion was 1.3 months over a period of 7 years.

3.3. Discussion

This paper describes the first longitudinal study on breed composition, milk production, SCS and CI of organic dairy cattle. In this study we looked at the performance of Holstein dairy cattle which have a relatively high genetic potential for milk production as compared to other breeds. This might have resulted in the exclusion of certain specific farming styles, as farming style is connected with the choice of breeds and choice for crossbreeding (Groen *et al.*, 1995). Farms with other breeds and cross-bred cows (more dual-purpose) might, for example, have a more extensive character, with a stronger accent on more robust animals and with meat production playing a role in farm income. The majority of Dutch organic farms, however, stock Holstein cattle, so that this study can be considered as representative for Dutch organic dairy farming in general.

Changes preceding conversion

Farms that convert to organic farming have a lower milk production level before conversion than conventional farms (see Figure 3.3, between 1990 and 1996). This indicates that, on the whole, these farms represented a specific stream of Dutch dairy farms and are different from the conventional mainstream. Other researchers have described organic farmers as representing specific styles of farming, such as 'low cost farmers', extensive farmers, 'economy farmers, seeking a better income' or farmers taking care of intrinsic values of animals and production systems (Jonkers, 2000; Midmore *et al.*, 2001, Verhoog *et al.*, 2003).

Conversion to organic farming has mostly been described as a gradual process that takes place after conversion (Østergaard, 1997). We also looked at the years preceding conversion and found that, some years before conversion changes in milk production, SCS and AFC take place towards organic farming, indicating that farmers already seemed to be anticipating, in their management methods, a move in the organic direction (see Figure 3.4). Traditionally, problems with conventional farming, especially in the areas of animal health and soil fertility motivated farmers to convert to organic production (Midmore *et al.*, 2001). More recently, many farmers have converted both because of problems in conventional farming (BSE and FMD and dioxins in animal feed) and the economic prospects of organic farming. (Midmore *et al.*, 2001). While considering conversion to organic, farmers might already be making changes in certain aspects of farm management, for example less use of concentrated feed and antibiotics.

Breed composition

Conversion to organic in general did not seem to influence breed preferences. Organic farmers continued using Holstein bulls after conversion and the trends in production were similar to conventional trends. Previously it was found that young organic farmers used the same bulls as their conventional colleagues (Nauta *et al.*, 2001). If a serious genotype-environment interaction (Falconer and Mackay, 1996; Nauta *et al.*, 2002) would exist, one would expect converting farmers to seek other genetics more suited for the new farm environment. But only a small group of farmers consciously chose breeds other than Holstein. The farmers were also not familiar with alternatives, in the sense of organic breeding and were very much used to selecting bulls from the conventional supply and the use of AI which they see as a very easy method (Nauta *et al.*, 2001). Another important point is that issues of breeding are not uppermost in farmers' minds when they are making the conversion to organic. The focus was on other aspects, like grass growth and animal health (Nauta *et al.*, 2001).

Effects of conversion on milk production

We found a decline in milk production in first lactations of about 1000 kg milk or 14% (Figure 3.4). It is difficult to compare our results direct with other studies on milk production in organic farming. Firstly, our results were based on first lactations of relative high yielding Holstein cows and high-yielding cows will respond more strongly to conversion than low-yielding cows (Padel, 2000). Secondly we must consider that our results were estimated effects of conversion which were estimated using a model that adjusted the data for several effects. In other studies, phenotypic production levels on organic farms were found to be between 80% and 112% of production levels on conventional farms (Bennedsgaard *et al.*, 2003; Kristensen and Kristensen, 1998; Padel, 2000; Kristensen and Mogensen, 2000; Toledo *et al.*, 2002; Haas and Bapst, 2004; Zastawny *et al.*, 2004; De Jong and Van Soest, 2001). The decrease of approximately 1000 kg (14%) milk production found in our study agrees with reports based on cows with similar production levels (Kristensen and Kristensen, 1998; Kristensen and Mogensen, 2000; Jong and Van Soest, 2001; Bennedsgaard *et al.*, 2003). Bennedsgaard *et al.* (2003) looked in their study also at the milk production in first lactations over the conversion period. Based on data from 18 farms which converted in 1999-2000 they found a decrease of 300 kg ECM, but after 2 years the production level at these organic farms was already nearly the same as at the year before conversion. This was not the case in the present study. This might be due to a more farm based feed production including cereals in Denmark while in the

Netherlands milk production is more based on imported conventional concentrates which are restricted by the organic legislation (EU,1999).

The decline in milk production can be explained by the reduced input of concentrates and a lower roughage quality in terms of energy and protein content. Dutch farmers traditionally feed large quantities of concentrates and they have to drastically cut back their use of concentrates when converting to organic production. In a four-year study of ten organic Dutch farms, the average annual concentrate consumption was found to be 1200 kg per cow, resulting in an average production of 6860 kg milk in 305 days (Plomp, 2001). Feeding less concentrates stimulates the uptake of roughage which however contains about 10% less energy per kg of dry matter (Padel, 2000). The lower milk yield achieved by organic farmers might also partly be due to a lack of knowledge among newly converted organic farmers about feeding, grazing and housing high-yielding cows under organic conditions.

Using estimates of model 1 we estimated that the 1.3 months increase in AFC in organic farming corresponded to +190 kg milk (not shown). In the "organic system" AFC increased by 1.3 months and this has a relatively strong effect on milk yield in the first lactation. The increase of AFC is probably due to energy and protein shortages in their juvenile period resulting in slower growth (Smolders, 2001). Organic farmers must deal with restrictions on the use of concentrates - which applies to the herd as a whole - and with greater variation in roughage quality (harvested from grassland and nature reserve land). In the interests of milk yield, organic farmers tend to feed the best roughage plus the available supply of concentrates to their milking cows. As a result, young stock grows more slowly and are older when they reach the standard body weight for insemination. Also parasitic infections can slow down the growth of the young animals (Hovi *et al.*, 2003; Svensson *et al.*, 2000) and result in an increase of AFC.

Composition of milk

For the unadjusted data (phenotypic trend) we found that the trend for fat percentage on converting-to-organic farms followed the trend on conventional farms which was in general decreasing (Figure 3.3). The estimated effects of conversion based on our model showed a general increase of fat percentage (Figure 3.4). This is probably due to the correction in the model for genetic effects (genetic trend). The phenotypic trend of the protein level dropped to the level of long-standing-organic farms.

For both the percentage fat and protein, we saw that the estimated effects of conversion, i.e. after adjusting for HYS, animal, AFC and DO, showed a decline after conversion to organic farming (Figure 3.4). This decline was stronger for percentage protein than for fat percentage. Also from other studies it is known that percentage fat and protein in the milk are lower at organic farms as compared to conventional farms.(Lund, 1991; Kristensen and Mogensen, 2000; Toledo *et al*, 2002;

De Jong and Van Soest, 2001). However, Toledo *et al.* (2002) did not find a difference in protein level between organic and conventional farms in Sweden. The fat percentage only decreased in the first two years after conversion. This is probably due to the decrease in energy in the roughage and a lower amount of concentrate feeding in the first years of conversion (Padel, 2000).

Overall we see an increase of percentage fat which is probably because of more roughage in the diet at organic farms (Padel, 2000). The decrease of the percentage of milk protein under organic conditions is probably a consequence of a lower input of energy at organic farms and a lower supply of proteins in concentrates. Suitable proteins are either expensive or difficult to obtain due to contamination with GMO (soybean, maize) which for that reason are prohibited for organic farming (EU, 1999). After 3-4 years of organic farming the results show an increase of protein percentage in the milk. This might be due to a more balanced forage production and stocking rate after some years of organic farming (Padel, 2000).

SCS on organic farms

The higher phenotypic trend of SCS on long-standing-organic farms (see Figure 3.3) and a significant effect of conversion on SCS agreed with our expectations. Restrictions on the use of antibiotics and the greater prevalence of deep litter stalls on organic farms are expected to increase SCS. Other studies, based on bulk tank scores or herd averages, also showed higher SCS for organic farming (Kristensen and Mogensen, 2000; Vaarst *et al.*, 2003; Smolders and Baars, 2004).

Surprisingly, SCS did not stabilize after some years but increased even 6 years after conversion (Figure 3.4). This suggests that, after conversion, the organic environment continues to change over several years. Older cattle which tend to have higher SCS (Smolders and Baars, 2004) might raise the environment's infectiousness thus making first parity cows more susceptible. But farmers' attitude towards SCS can also change. Jonkers (2000) noticed that organic farmers were not anxious about slightly raised SCS, as they assumed that this was normal in an organic environment and reflected better immune activity. The latter was recently described by Van Groenweghe (2004). However, Bennedsgaard *et al.*(2003) found a significantly lower bulk tank SCS for long-standing-organic farms in Denmark. These farmers were actively trying out alternative methods to control mastitis and SCS, such as frequent milking by hand of clinical cases, drying a gland, or letting cows suckle calves (Vaarst and Bennedsgaard, 2001).

Calving interval

The phenotypic trends for CI on converted organic farms showed a clear increase in time. An extended CI can be the result of a longer interval between calving and first insemination due to different management decisions. CI was however not significantly affected by conversion (Figure

3.4). Hovi *et al.* (2003) also concluded that conversion to organic did not affect the fertility status of the animals at organic farms.

General performance (cooping with organic)

In general, based on this study, the performance of the Holstein Friesian cows during their first lactation seems to be continued at a lower production level and an increased SCS and CI. However, the increased AFC indicates that farmers adjust their management (by inseminating the heifers at a higher age) so that the young animals reach a better body weight at the age of first calving. In this way farmers help their animals to coop with the organic conditions resulting in a higher production.

In this longitudinal study also the developments in organic farming; i.e. development in regulations, might have had an effect on the performance of cattle. Especially during the last 3 calving years used in this research, organic farmers were able to use more concentrates with conventional ingredients due to a change in the EU regulations for organic farming (EU, 1999). These concentrates are cheaper then 100% organic concentrates. However, from January 2005 onwards, organic farmers have to use complete organic feed stuff, including concentrates. This will probably result in a further decrease of the supply of concentrates and good performance of the Holstein cows will get more dependent of farmers skills and possibilities to help the animals to coop with this.

3.4 Conclusions

It can be concluded that the conversion to organic production is a gradual process and that Dutch farmers who decide to convert to organic farming represent a specific group of farmers distinct from mainstream conventional farmers, with different averages for breed composition, milk production levels and somatic cell counts in the milk. Most organic farmers in the Netherlands kept on using Holstein cattle after conversion.

During the conversion process, there were highly significant changes in milk production and protein percentages in the milk. Also fat contents and somatic cell counts in the milk changed significantly over the conversion period. Age at first calving at organic farms clearly differs between organic and conventional farming, indicating that farmers with Holstein cattle adjust there management to organic conditions.

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Chapter 4

Genotype by Environment Interaction for Milk Production Traits between Organic and Conventional Dairy Cattle Production in the Netherlands

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Abstract

Estimates of genetic parameters for organic dairy farming have not been published previously, and neither is information available on the magnitude of genotype by environment interaction (G x E) between organic and conventional farming. However, organic farming is growing worldwide and basic information about genetic parameters is needed for future breeding strategies for organic dairy farming. The goal of this study was to estimate heritabilities of milk production traits under organic farming conditions and to estimate the magnitude of G x E between organic and conventional dairy farming. For this purpose, production records of first parity Holstein heifers were used. Heritabilities of milk, fat and protein yield, and somatic cell score (SCS) were higher under organic farming conditions. For percentages of fat and protein, heritabilities of organic and conventional production were very similar. Genetic correlations between pre-organic and organic, and organic and conventional milk production were 0.79 and 0.80, respectively. For fat yield, these correlations were 0.86 and 0.88, and for protein yield, these were 0.78 and 0.71, respectively. Our findings indicate that moderate G x E was present for yield traits. For percentage of fat and protein and SCS, genetic correlations between organic and conventional and pre-organic production were close to unity, indicating that there was no G x E for these traits.

Key words: genotype by environment interaction, organic dairy production, somatic cell score

4.1 Introduction

Organic farming in Europe has developed into a small (about 3% of total agricultural area) but important factor in agricultural production (Organic Centre of Wales, 2005). In the Netherlands, organic dairy farming grew rapidly in the late 1990s. Farmers who converted to organic production had to undergo some major changes in their farm management. The most important changes were no use of chemical fertilizers, restricted use of concentrates (cattle diets should have a minimum of 60% DM conserved or fresh forage), and limited use of antibiotics (prophylactic use of antibiotics and some other drugs is prohibited on a herd basis; European Union, 1999). Consequently, cows in organic farming have a lower intake of energy and protein and antibiotics are only administered in case of severe infections. The change in feed has the greatest effect on high-producing cows (Padel, 2000), usually Holsteins. Most organic dairy farmers in the Netherlands milk Holstein cows (Nauta *et al.*, 2001). Significant changes in milk production have been observed at these farms and SCS have increased significantly since conversion (Nauta *et al.*, 2006).

In this organic environment, dairy farmers have continued to use the same breeding bulls supplied by AI companies as their conventional colleagues (Nauta *et al.*, 2001). European Union legislation currently gives few specific guidelines for selective breeding other than farmers must account for the “capacity of animals to adapt to local conditions, their vitality and disease resistance” and that indigenous breeds are preferred (European Union, 1999). However, Dutch farmers mainly use Holstein cattle, which have a high genetic potential for production. Increasingly, questions are being raised by farmers and researchers about the use of highly productive animals under organic conditions. There are indications that such animals cannot cope with the organic environment (Hardarson, 2001; Nauta *et al.*, 2001), which raises the question whether organic dairy production needs a specific selection program for breeding bulls.

At this time, it is not clear whether organic dairy production requires specific selective breeding programs distinct from programs for conventional production. An important parameter to consider is the magnitude of genotype by environment interaction (G x E), which occurs when different genotypes react differently to different environments (Falconer, 1989).

At present, no information is available on the magnitude of a possible G x E between organic and conventional production. The existence of G x E might lead to a re-ranking of bulls and might have consequences for the organic farmer’s choice of genetic material. A useful way to quantify G x E is the genetic correlation between traits as expressed in 2 environments (Falconer, 1989). Environmental changes can also cause changes in phenotypic and genotypic variances of traits and differences in heritability may occur (Brotherstone and Hill, 1986). There is no information available about these parameters for organic dairy production.

The aim of this study was to estimate the heritabilities of different milk production traits including SCS for organic dairy farming and to quantify the magnitude of G x E between organic and conventional dairy production.

4.2 Materials and Methods

Data

First-parity 305-d lactation records of Holstein cows from organic and conventional farms in the Netherlands were used in the present study. The data was from calvings between January 1990 and March 2004. The data were selected as described by Nauta *et al.* (2006). In brief, only records of cows that calved between 17 and 36 mo of age were included in the analysis. Days open were days between calving and last insemination and only records of cows with days open between 30 and 250 d were included. Records of cows that switched during the lactation from one farm to another were excluded from the analysis. Only 305-d records predicted based on more than 180 d in lactation were used.

The data set consisted of 188 organic farms; i.e., farms that converted to organic farming

between 1990 and 2002, and 152 conventional farms. Conventional farms were randomly selected from all conventional farms located in the same postal areas as the organic farms. Lactation records before conversion were also available from the organic farms. Based on the date of conversion of each organic farm, the data from organic farms were
divided into 3 environmental groups:

(1) **Pre-organic:** data from lactations belonging to calving dates from at least 9 mo before the date of conversion.

(2) **Converting-to-organic:** data from lactations between 9 mo before the conversion date until two yr after the conversion date.

(3) **Organic:** data two years after conversion and onwards.

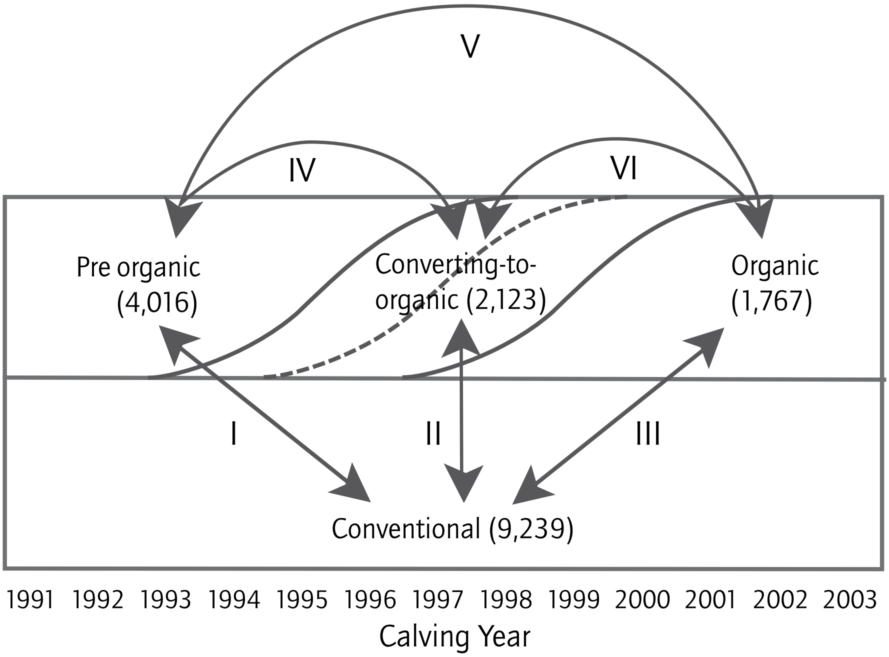

Figure 4.1: Schematic overview of the data and estimated genetic correlations (arrows I to VI). The lower part of the figure represents the data from conventional farms between January 1990 and March 2003. The upper part (pre-organic + converting + organic) is from farms that converted to organic farming between 1990 and 2003 and were all organic in 2002. The dotted sigmoid curve reflects the dates of conversion to organic of the farms. Number of records per environmental group is shown in parenthesis.

By defining pre-organic as records from at least 9 mo before conversion, we avoided having records of lactations that were partly under organic conditions. Definition of groups was based on the findings that the milk production level started to decline about 1 yr before conversion and stabilized 2 yr after conversion to organic farming (Nauta *et al*., 2006). After initial edits, 21,364 first-lactation records from organic farms were available with 11,028 records from the pre-organic period, 5,518 records from the converting-to-organic period, and 4,818 records from the organic period. The conventional data set consisted of 21,138 first-lactation records. Additional restrictions were that herd-year-season (**HYS**) classes should have at least 4 observations and each sire should have at least 4 daughters in the complete data set; that is, the combined organic and conventional data sets. An overview of the data is given in Figure 4.1 and Table 4.1.

The average SCS per lactation were based on SCC from test-day records. Only SCS were used of lactations with at least 5 and no more than 12 test days. Firstly, the SCC per test day were transformed to SCS using the formula: SCS = log10(SCC/1,000). The average SCS per lactation was estimated as the mean of the test-day SCS per lactation. Not all cows with milk production records had records for SCS. Records with an SCS were also edited to get at least 4 records per HYS class and per sire. After the edits, pedigree information was traced back 5 generations and was included in the analysis.

Genetic connectedness between the different environmental groups is illustrated in Table 4.2, which shows the number of bulls in each environmental group as well as the number of bulls that had daughters in one group as well as in another. Heritabilities of milk production traits for each defined group and correlations between the different groups for milk yield, fat yield, protein yield, fat and protein percentages, and SCS were analyzed using ASREML (Gilmour *et al*., 1999). The 4 groups were analyzed simultaneously in a multivariate analysis; that is, a trait recorded on animals in each of the groups was considered as a different trait.

Table 4.1: Number of herds, number of records and mean values of milk production traits and SCS with standard deviations (within parenthesis) of the four environmental groups: conventional, pre-organic, converting-to-organic and organic production.

	Environmental groups			
	Conventional	Pre-organic	Converting-to-organic	Organic
Number of Herds	152	138*	135*	109*
Number of records	*9239*	*4016*	*2123*	*1767*
Kg milk	7156 (1203)	6991 (1219)	6622 (1145)	6440 (1158)
Kg Fat	310 (48.6)	299 (49.5)	284 (49.5)	274 (48.9)
Kg Protein	246 (39.1)	240 (40.7)	223 (38.6)	214 (38.1)
% Fat	4.36 (0.46)	4.32 (0.45)	4.31 (0.45)	4.29 (0.46)
% Protein	3.45 (0.19)	3.44 (0.20)	3.37 (0.20)	3.34 (0.19)
Number of SCS rec.:	*5193*	*2316*	*1457*	*1120*
SCS	1.77 (0.34)	1.75 (0.34)	1.79 (0.33)	1.84 (0.31)

*) Some of the herds appear in more than one of the three environmental groups. The organic group data comprised188 farms that converted to organic farming between 1990 and 2002.

Model for Analyses

The model used was:

[1] $$Y_{ij} = mu + HYS_i + ß_1 * AFC_{ij} + ß_2 * (AFC_{ij})^2 + ß_3 * DO_{ij} + ß_4 * (DO_{ij})^2 + Animal_j + e_{ij}$$

- Y_{ij} observation on animal **j**,
- **mu** overall mean,
- HYS_i fixed effect of herd-year-season of calving **i**, the HYS effect was based on 4 seasons; January-March, April-June, July-September and October-December.
- AFC_{ij} covariable of age at first calving for observation **ij** (in months),
- DO_{ij} covariable of days open for observation **ij** (between calving and new conception),
- $ß_1$ **to** $ß_4$ regression coefficients for linear and quadratic regression on age at calving in months ($ß_1$ **and** $ß_2$) and days open ($ß_3$ **and** $ß_4$),
- $Animal_j$ random additive genetic effect of animal **j**,
- e_{ij} residual

Random animal effects were assumed to be normally distributed with mean 0 and variance $A\sigma^2_A$ where A is the additive genetic relationship matrix. The residual terms were assumed to be normally and independently distributed with mean zero.

In the multivariate analysis, 6 different genetic correlations were estimated simultaneously. This is schematically illustrated in Figure 4.1. Preliminary, bivariate analyses were performed for every combination of environmental groups (results not shown). Bivariate analysis that resulted in estimated correlations close to unity were fixed in the multivariate analysis at a value of 0.999.

To test the significance of G x E between conventional and organic farming conditions, the likelihood ratio test was used. Genotype by environment interaction is reflected by the genetic correlations between pre-organic and organic and between conventional and organic. Therefore, the log likelihood of a full model was compared to the log likelihood of a model in which the genetic correlations between conventional and organic and between pre-organic and organic were fixed at unity. A $\chi 2$ test with 2 degrees of freedom was used to test for the significance of G x E.

Table 4.2: The number of bulls with daughters in each of the 4 environmental groups and the number of bulls with daughters in one as well as in another group, which reflects the connectedness between data sets. The total number of bulls in all groups was 634.

	Conventional	Pre-organic	Converting-to-organic	Organic
Conventional	**543**	294	253	202
Pre-organic		**346**	170	91
Converting-to-organic			**291**	153
Organic				**237**

4.3 Results

Variances and Heritabilities

Table 4.1 shows that milk, fat, and protein yields were about 10% lower in organic farms compared with conventional farms. The standard deviation for milk yield tended to be slightly lower under organic farming conditions compared with conventional farming. However, the coefficient of variation was slightly higher for organic farms than for conventional farms (18.0 vs. 16.8%, respectively). Compared with conventional production, fat and protein yields per first lactation in organic farming were 36 and 23 kg lower, respectively. The coefficient of variation of both traits was higher in organic farming compared with conventional farming (17.8 vs. 15.8%). Compared with conventional production, fat and protein percentages in organic production were 0.07 and 0.11% lower, respectively. Their coefficients of variation were very similar.

A total of 5,193 production records of conventional farms and 4,893 production records of organic farms had a record of SCS. The SCS in organic production was 0.07 points higher than in conventional production and the coefficient of variation of SCS was lower in organic production (16.8 vs. 19.2%).

The estimated phenotypic variances ($\sigma 2p$), i.e., after adjusting for the fixed effects in the model, were lower in the organic environment than in the conventional and pre-organic environment groups (Table 4.3). Similar differences were found for fat and protein yields. The heritability of milk yield was 0.48 for conventional farms and 0.70 for organic farms. The heritabilities of fat and protein yield in conventional farming were 0.39 for both traits, whereas these were 0.58 for fat yield and 0.59 for protein yield in the organic environment.

For fat and protein percentages, the phenotypic variances of conventional and organic farming were very similar. In conventional farming, the heritabilities were 0.79 for fat percentage and 0.72 for protein percentage, whereas for organic farming these heritabilities were 0.79 and 0.70, respectively.

For SCS, the phenotypic variances for all environmental groups were between 0.094 and 0.099. The heritability of SCS was 0.15 for conventional, 0.28 for pre-organic, and 0.23 for organic production.

Table 4.3: Estimates of phenotypic variances (σ^2p) and heritabilities (h^2 , SE in parenthesis) of milk production traits and SCS of the conventional, pre-organic, converting-to-organic and organic production environments

		Conventional	Pre-organic	Converting	Organic
Milk yield	σ^2_p h^2	871,190 0.48 (0.03)	839,087 0.39 (0.04)	735,170 0.59 (0.07)	734,014 0.70 (0.08)
Fat yield	σ^2_p h^2	1,411 0.39 (0.03)	1,359 0.37 (0.05)	1,174 0.44 (0.07)	1,138 0.58 (0.08)
Protein yield	σ^2_p h^2	786 0.39 (0.03)	762 0.31 (0.04)	651 0.45 (0.07)	663 0.59 (0.09)
% Fat*	σ^2_p h^2	0.202 0.79 (0.03)	0.195 0.83 (0.03)	0.184 0.82(0.05)	0.187 0.79 (0.06)
% Protein	σ^2_p h^2	0.035 0.72 (0.03)	0.033 0.76 (0.04)	0.033 0.77 (0.06)	0.031 0.70 (0.07)
SCS	σ^2_p h^2	0.099 0.15 (0.03)	0.094 0.28 (0.06)	0.098 0.15 (0.06)	0.099 0.23 (0.08)

* Estimates obtained from bivariate analyses of % fat while multivariate analyses were fixed at boundaries and no standard errors could be estimated.

Connectedness and genetic correlations

The lowest connectedness (19%) was found between the pre-organic and organic groups (Table 4.2). The other percentages of connectedness ranged between 35 and 50%.

The bivariate analyses for milk and protein yield showed that the genetic correlations between conventional and pre-organic production were equal to 1. In the multivariate analysis, therefore, the correlations were fixed at a value of 0.999 (Figure 4.2) for these traits. The bivariate analyses for fat yield showed that the genetic correlation between converting-to-organic and organic was equal to 1. Therefore, in the multivariate analysis, this correlation was also fixed at a value of 0.999. For fat and protein percentages, the bivariate analyses showed that 4 of the 6 correlations were very close to unity. These correlations were fixed at 0.999 in the multivariate analyses of fat and protein percentage. For fat percentage, it was necessary to fix the other 2 correlations to let this analysis converge. These correlations were therefore fixed at the values 0.946 and 0.973, which were obtained in the bivariate analyses.

Multivariate analysis produced a genetic correlation of 0.80 between conventional and organic milk yield. Between pre-organic and organic milk yield, the correlation was 0.79 (see Figure 4.2). The likelihood ratio test showed that, from a genetic point of view, milk yield under organic farming conditions was significantly different from milk yield under conventional conditions ($P < 0.01$).

For fat yield, the genetic correlation between conventional and pre-organic production was close to unity (0.97) and the genetic correlations between conventional and organic, and pre-organic and organic were 0.88 and 0.86, respectively. The likelihood ratio test did not give any evidence to support the assumption that fat yield under organic and conventional production circumstances were genetically different traits.

For protein yield, the genetic correlation between conventional and organic was 0.78, and between pre-organic and organic production, 0.71. The correlations for protein yield were found to be significantly different from unity ($P < 0.05$) showing that protein yield was different trait in organic production compared with conventional conditions. In the multivariate analyses, correlations could be estimated only for protein percentage. These correlations were close to unity and did not differ significantly from unity. The bivariate analyses showed that the genetic correlations for SCS were close to unity for all 6 combinations of environmental groups and therefore no likelihood ratio test was performed for this trait.

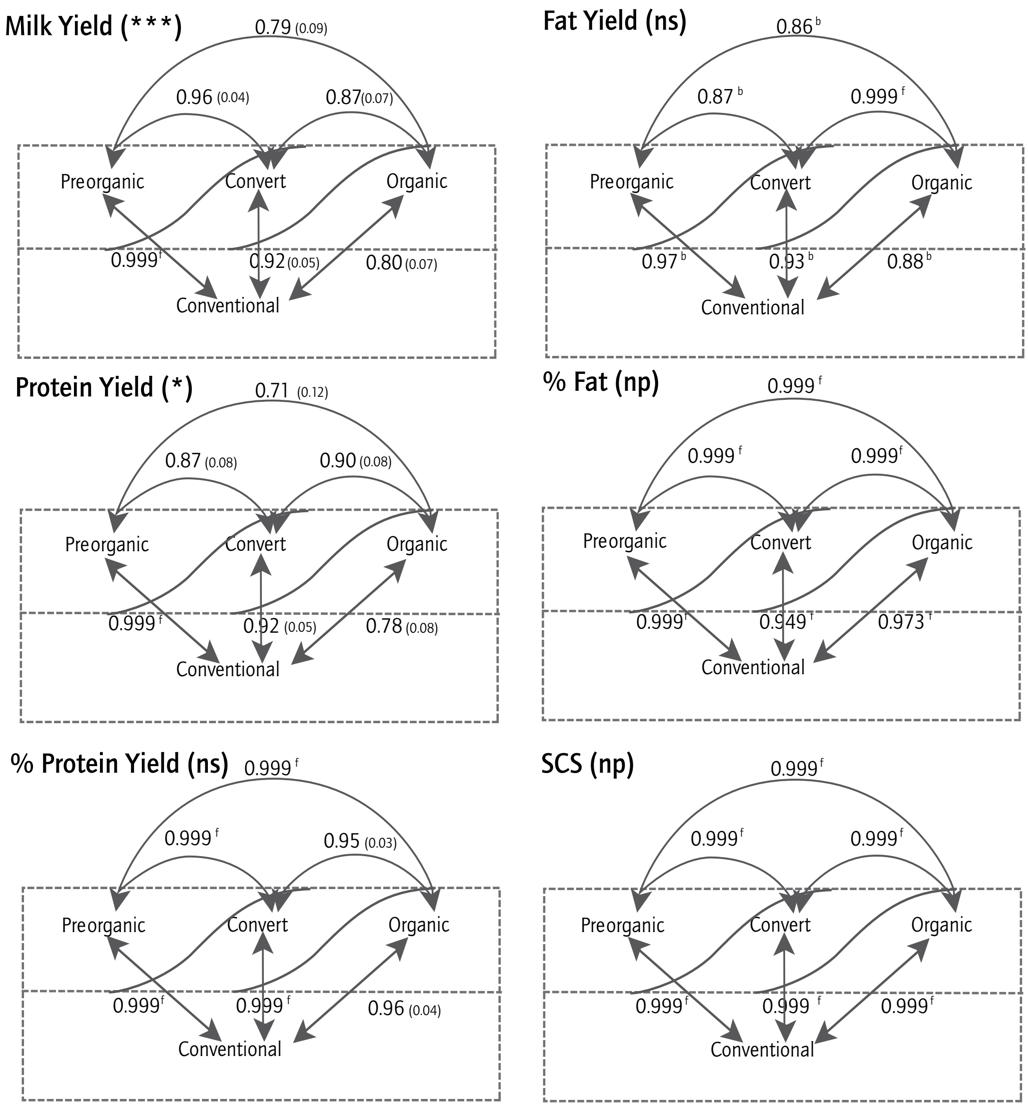

Figure 4.2: Genetic correlations of milk production traits between the different farm environments. For description of figure see Figure 4.1. Significance was tested with a likelihood ratio test between the log likelihood of a full model and a model in which the genetic correlations between conventional and organic and between pre-organic and organic were fixed at unity. A $\chi 2$ test with 2 degrees of freedom was used to test for the significance of the genotype by environment interaction.

[f] correlation fixed , s.e. between brackets, *** $P < 0.01$, * $P < 0.05$, ns= not significant, np = not performed

As a by-product of the genetic analysis, breeding values of all animals were estimated for the different traits. Ten bulls had at least 20 daughters in the conventional and organic groups, enabling the estimation of breeding values based on both environments. Figure 4.3 shows the estimated breeding values of these 10 breeding bulls for milk production in the conventional and organic environments. Distinct breeding values for conventional and organic farming resulted in a considerable reranking of bulls with respect to milk yield.

4.4 Discussion

Multivariate Analyses

The present study combined 2 different ways of estimating genetic correlations between traits measured in different environments: 1) within farms, based on data from farms that switched from conventional to organic production and 2) between farms, based on data from organic farms and a random selection of conventional farms. The data obtained from farms that switched to organic farming were divided into 3 different farm environment groups: pre-organic, converting-to-organic, and organic. The converting-to-organic group was introduced because a period of about 3 yr was observed in which milk production of cows decreased during conversion to organic production (Nauta *et al*., 2006). Estimated parameters for this group were of no particular interest, but the data were kept in the analysis because it provided genetic links between the pre-organic and the organic group. Using multivariate analysis, all the evidence for the presence of G x E interaction could be combined: within farms switching from conventional to organic farming, as well as between conventional and organic farms.

Phenotypic Variances and Heritabilities

Variances and heritabilities of yield traits of conventional production in this study were similar to other studies (e.g., Van Vleck and Van Dong, 1988; Van der Werf and de Boer, 1989). Surprisingly, the estimated heritabilities of yield traits in organic production circumstances were higher than in conventional production systems. The main reason for this was the residual variance ($\sigma 2_e$) of yield traits, which was lower for organic farms. Also, the estimate for the additive genetic variance ($\sigma 2_a$) of yield traits was higher under organic production circumstances than for conventional or preorganic production. In low-input production environments, production traits are generally found to have a lower heritability (Castillo-Juarez *et al*., 2002; Berry *et al*., 2003; Raffrenato *et al*., 2003). Compared with conventional production, organic production can be considered a low-input production system: fewer concentrates are fed (W. J. Nauta, unpublished data) and organic roughage generally contains less energy (Plomp, 2003). Also, the use of veterinary drugs is limited in organic production, including a ban on preventive use of antibiotics for udder health (European Union, 1999).

When HYS classes were put in the model as fixed classes (instead of random), they explained a substantially larger part of the variation under organic farming conditions than under conventional conditions. The increased importance of HYS effects might reflect differences in management between organic farms, which could be caused by the fact that most organic farmers converted between 1998 and 2001 and were therefore relatively "young" organic farms still adjusting their management to the new organic situation (Østergaard, 1997). Regarding the percentages of fat and protein, the variance components of conventional and organic production agreed with other studies on conventional farming (Cue *et al*., 1987; Schutz *et al*., 1990; Campos *et al*., 1994). The heritability of these traits did not differ much between organic and conventional production.

The heritability of SCS in first-lactation heifers in conventional farming was higher than the heritability of SCS found in other studies (Schutz *et al*., 1990; Reents *et al*., 1995; Castillo-Juarez *et al*., 2000; Mulder *et al*., 2004). Banos and Shook (1990) found a similar heritability of SCS of 0.13 in first-parity Holstein heifers. The phenotypic variance of SCS in organic production was similar to conventional production, but due to a lower residual variance in organic production and a higher genetic variance of SCS, the heritability of SCS in organic production was 0.25. Castillo-Juarez *et al*. (2002) also found a higher heritability of SCS in a lowyield environment compared with a high-yield environment, but the difference was only 2%. A higher heritability of SCS in organic production could increase the possibilities for selecting for this trait within the organic production environment. However, standard errors of the heritability estimates of yield traits and SCS were considerable, especially for organic conditions.

Genetic Correlations

The genetic correlation of about 0.80 for milk yield can result in a considerable re-ranking of bulls (Figure 4.3). However, Figure 4.3 shows only bulls that were used mostly by farmers and can therefore be considered as being top bulls. Re-ranking due to G x E is more likely with high-ranking bulls (Mulder *et al*., 2004). It is also remarkable that there were so few bulls with at least 20 daughters in the data from organic production. Organic farmers probably use other breeding bulls than their conventional colleagues. It was recently found that organic farmers put more emphasis on functional traits (W. J. Nauta, unpublished data; P. Rozzi, OntarBio, Guelph, ON, Canada, personal communication), which might be a reason for a different selection.

The genetic correlation between organic and conventional milk yield was low (0.80) compared with other studies on conventional production in the Netherlands (Ten Napel and Van der

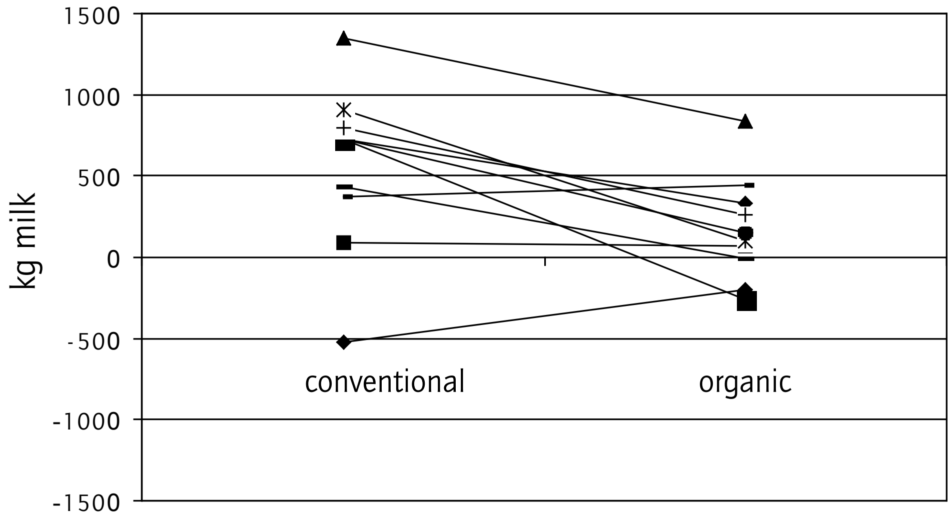

Figure 4.3: Breeding values for milk yield of 10 bulls based on the environmental groups: conventional and organic. Each bull had at least 20 daughters in each environment

Werf, 1992; Calus *et al*., 2002; Mulder *et al*., 2004), in which genetic correlation was close to unity. The correlations in the present study between conventional and organic production for fat yield (0.86 to 0.88), and especially protein yield (0.71 to 0.77) correspond more with correlations found between New Zealand and North American and European countries, which were around 0.72 for milk yield (Interbull, 2003). Weigel *et al*. (2001) also found low genetic correlations (between 0.80 and 0.90) between rotational grazing systems and intensive management systems. Low genetic correlations (0.48 to 0.66) were found between high- and low-opportunity environments for yield traits in Sicilian herds (Raffrenato *et al*., 2003); Berry *et al*. (2003) estimated a genetic correlation of 0.63 between high and low concentrate feeding level groups in Ireland.

The low correlations are thought to be due to differences in feeding level or feeding systems between the countries or farm environments. In New Zealand, dairy farming is primarily based on grazing and is therefore, to some extent, comparable with the Dutch organic dairy-farming sector, which is also more grass-based with lower concentrate inputs (Plomp, 2003; W. J. Nauta, unpublished data). The estimated correlations for milk yield traits in the present study were based on information from farms that converted to organic in the late 1990s. At that time, organic farmers could still feed relatively large quantities of concentrates, up to 1,800 kg per lactation (W. J. Nauta, unpublished data). Since August 2005, the European organic farmers are required to use concentrates that contain at least 95% organic ingredients (European Union, 1999). This will probably increase the cost of concentrate feeding, so that organic dairy production may resort increasingly to roughage. Genetic correlations between conventional and organic production might therefore decline further in the near future.

For SCS, it was not possible to make an estimation of genetic correlations, probably because all genetic correlations were close to unity as shown in the bivariate analyses.

When genetic correlations of traits decrease, the need for a separate breeding program increases (Mathur and Horst, 1994; Mulder and Bijma, 2005). In the current study, the estimated standard errors of the genetic correlations were high and definite conclusions cannot be drawn yet. However, with decreasing differences between organic and conventional production as mentioned above, the need for a separate breeding program for organic farming may grow. However, the organic dairy sector is still relatively small and farmers increasingly use a variety of different breeds and crossbreeds (W. J. Nauta, unpublished data). Currently, there are still about 10,000 Holstein dairy cows on organic farms in the Netherlands. Only a small number of bulls of this breed could be tested under organic conditions each year. It could be a start for organic-based cattle breeding, but the organic sector must still decide whether a separate breeding program is preferable or not.

4.5 Conclusions

Heritabilities of production traits and SCS tended to be higher in organic than in conventional farming, which creates possibilities for selection and genetic progress under organic production circumstances.

Based on the results of this first study, the magnitude of G x E between conventional and organic milk yield and fat and protein yield is of importance and comparable with G x E between a grass-based system as in New Zealand and high-input systems as in North America or Western Europe.

The magnitude of G x E will result in a re-ranking of breeding bulls for organic milk and protein production, based on their breeding values for these traits. The magnitude of G x E will probably increase when restrictions on concentrate feeding are increased in the future, especially for high-yielding cows. When genetic correlations fall below 0.80, specific breeding values for organic dairy production with high yielding cows become more important in making an adequate selection of breeding bulls for organic dairy production.

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Chapter 5

Farming strategies in organic dairy farming: Effects on breeding goal and choice of breed. An explorative study

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Abstract

Organic farming principles give rise to multifunctionality: different activities are combined at farm level to create ecological and economic synergies. These principles do however allow for different operationalisations and different farm development strategies, for example with regard to the use of external inputs or the decision whether or not to use advanced breeding technologies such as artificial insemination. Maintaining and improving diversity are therefore characteristic to organic farming.

Since organic farming took off in the early 1990's, many specialised dairy farms which tend to be more mono-functional in nature, have converted to organic, adding a new farming strategy to the diverse collection of farming strategies in organic dairy farming. All these farming strategies actually create different organic production environments for cows, which might result in different demands on selective breeding and breeding technology. This differential demand was explored in a survey, among 151 organic dairy farmers, on general farm strategy, milk production, breeding goal, choice of breed and approach to reproduction. Farmers were divided into one of two groups on each of three strategic options: a) diversification in farm business—Specialised Dairy Farming vs. Multifunctional Farming; b) intensity of milk production—Low Input vs. High Input Farming and c) naturalness of breeding—Farming with Artificial Insemination vs. Farming with Natural Service.

A pair-wise comparison within each strategic option showed that each pair differed significantly with regard to farm characteristics, farm goal and animal production goals. However, there were only minor or no significant differences within each pair with regard to overall breeding goal. For each strategic option, big differences were found within each pair as regards preferred cattle breeds and crossbreeds. Farmers in the Specialised Dairy Farming and High Input Farming groups preferred milk-type cattle (Holstein and Holstein crossbreeds), while farmers in the Multifunctional Farming and Low Input Farming groups preferred various native Dutch breeds. But even farmers with a similar strategy (within one group) differed strongly in their choice of breeds and crossbreeds.

These results indicate that organic farmers are going through a process of learning by doing and experimenting as they search for breeds or crossbreeds that are optimally suited to their farm environment and that best agree with their farm development strategy. In this, the growing preference for keeping bulls on the farm for natural service is remarkable.

Key words: organic dairy farming, farming strategies, breeding goal, breeds, crossbreeds

5. 1. Introduction

Different farming strategies occur in organic farming. They have their origin in different backgrounds like diversity, ideology and agri-ecology (Darnhofer *et al*., 2005; Verhoog *et al*., 2003; Padel, 2000). As a matter of principle, organic farming strives for a multifunctional farming system. In the Netherlands, organic farming started with biodynamic farming, which was based mainly on traditional mixed farming with integrated crop and animal production (COBL, 1977). In the 1980s the EKO-movement was established and due to the booming milk market in the 1990s, many specialised dairy farms converted to organic farming. While some continued to specialise many farmers (up to 80%) transformed their business into a multifunctional farm (Anonymous, 2006a; Ventura and Milone, 2000; Van der Ploeg and Renting, 2000), taking up activities such as: cheese making, farm gate shops (i.e. milk and meat products), nature development and conservation, rotating crop production, care farms and recreation.

Farmers' own ideas about best 'organic farm practices', as well as new rules and market prices result in different farming strategies. There are differences, for example, in the extent that farmers purchase external inputs (high input vs. low input farming) or take natural farm processes as starting principle (Van der Ploeg, 2003). Verhoog *et al*. (2003) observed that there are pragmatic organic farmers who formally comply with the rules of organic farming, but continue to have a conventional problem-solving approach, seeking to maximise their level of external inputs. This farming style is characterised as 'non-chemical approach'.

There are also farmers who opt for a more systemic approach and closed cycles, which is called the 'agroecological approach'. In this style of faming closed cycles at farm level and systemic solutions are more important rather than end-of-pipe-solutions. The third category of farmers is focused on the intrinsic values of the farm, the animals, their landscape and includes natural service. This is called the 'integrity approach' (Verhoog, ibid.).

Such differences in farming strategies may imply different demands on breeding (Groen *et al*., 1995). On a multifunctional farm, for example, milking cows may need to have other characteristics than milk production alone, such as high protein milk for cheese making, meat production (dual purpose breeds) or a friendly nature for farm visitors. If a farm has a surplus of land area in relation to its milk quota, it will produce milk economically on roughage, choosing to have milking cows with lower yields (Van der Ploeg, 2003). Farmers who then want to improve the animals' natural behaviour and allow them to breed in a natural way, must then give important consideration to the character of the bulls used for safety reasons. On-farm breeding may also require more young stock to select from (Nauta *et al*., 2005a,b) and may therefore require dual-purpose breeds as more animals are culled per year.

Currently, breeding demand in organic dairy farming is not clear. In a 1999 survey, organic dairy farmers reported that they mainly used breeding bulls of conventional origin through

AI (Nauta *et al*., 2005a). They also pointed out that they needed more robust cows, but the conventional breeding programs did not provide suitable Holstein Friesian breeding bulls (Nauta *et al*., 2003). A recent study about the effects of conversion showed that organic dairy farmers have started crossbreeding with breeds other than Holstein (Nauta *et al*., 2005a). The aim of this study was to investigate the effects of current farming strategies on breeding goal and choice of breed in the Dutch organic farmer's population. To this end, information from 151 organic dairy farmers was collected by a short questionnaire (quick scan). These farmers were subsequently divided in one of two opposite groups on each of three important strategic options faced by Dutch organic dairy farmers today: diversification in farm business, intensity of milk production and naturalness of breeding. Farmers stance on these strategic issues was expected to affect breeding and choices of breeds.

5.2 Materials and Methods

In a previous project, we surveyed organic farmers' views on animal breeding by means of interviews with farmers, a questionnaire distributed to Dutch organic dairy farmers in 1998 and focus group discussions in 2001 (Nauta *et al*., 2001 and 2005a). The information obtained in that project together with current trends in organic farming and dairy cattle breeding in general (Anonymous, 2002), served as the basis for the current study. For the current study, a short, explorative questionnaire was sent to 326 Dutch organic dairy farmers certified by Skal, the Dutch certification association for organic farming. The questionnaire provided the following information:

- Overall farm characteristics: farm size, crop information, no. of animals, % Holstein cows, use of concentrates, milk quota, milk yield per cow, housing system.
- Farming strategy: farmers could classify their farm as a Specialised Dairy Production farm (i.e. farm income depends mainly on milk production) or a Multifunctional Farm (i.e. farm income depends on the combination of multiple on-farm economic activities such as nature management, recreation facilities, milk processing, a farm shop),
- Breeding strategy: use of Artificial Insemination (AI) or Natural Service (NS) for breeding;
- Farmers' preference for a certain cattle breed or crossbreed: the breed or crossbreed they want to work with.

For each of the aspects farm goal, animal goal and breeding goal, and each of the three aspects of production, conformation and functionality, farmers were asked to distribute 100 points over the listed sub-aspects (Figure 5.1). The points given reflect the relative weight each farmer contributes to each sub-aspect. A weighted score was calculated for the subaspects by multiplying the points given to the sub-aspects by the points given to the corresponding breeding goal aspect and divided by 10. For example, if 45 points were given to the breeding goal aspect functionality, the points given to the subaspects of functionality were multiplied by 45 and divided by 10.

For each of the three strategic choices identified above, farmers were divided into groups reflecting opposite choices:

1. Diversification of farm business: Specialised Dairy Farming versus Multifunctional Farming;
2. Intensity of milk production: High Input Farming versus Low Input Farming;
3. Naturalness of breeding: Farming with AI or Farming with NS by bulls.

Farmers' answers to specific questions in the questionnaire determined which group they were divided into for diversification of farm business and naturalness of breeding. The division for intensity of milk production was based on the amount of concentrates purchased per milking cow. The Low Input Farming group purchased less than 801 kg concentrates per cow and High Input Farming purchased more than 1199 kg concentrates per cow. To distinguish more clearly between low and high input milk production, farms with medium input from 800 to 1200 kg concentrates input per cow were left out of the comparison. This division resulted in 48 farms with a relatively low input and 63 farms with a relatively high input of concentrates. Means and standard deviations of farm characteristics were estimated for each group. Within a group, differences between means of the breeding goal aspects and (sub)aspects of production, conformation and functionality were tested by analyses of variances and Bonferroni post hoc tests (SPSS 12.0). The significance of differences in means between two opposite groups was tested with an independent T-test (SPSS 12.0). Response to the questionnaire was 47%. There was overlap between different groups (see Table 5.1). The greatest overlap was between the groups High Input Farming and Farming with AI (45%), and High Input Farming and Specialised Dairy Farming (34%). The Low Input Farming group had similar overlaps with the Specialised Dairy Farming and Multifunctional Farming groups, about 24% in both cases.

Figure 5.1: Score chart reflecting farmers' choices as regards farm goal, goal for animals and selection of breeding animals (including some examples). The points given reflect the relative weight each farmer contributes to each sub-aspect. A weighted score was calculated for the sub-aspects by multiplying the points given to the sub-aspects by the points given to the corresponding breeding goal aspect and divided by 10. * The Dutch overall production index based on euro currency, ** Animal Analyses Association, this system evaluates 6 strong and weak point in a cow and bull's physique and combines the weak and strong points resulting in more harmonious build offspring. (Anonymous., 2004), *** Dutch durability index = based on breeding values for udder health (14%), fertility (10%), calving ease (7%), viability after birth (5%), legs and body (5%), other (5%) (Anonymous, 2002).

farm goal aspects:	score	
spreading income:	....	
increasing milk production per cow:	....	
increasing scale economies:	....	
decreasing production costs:	....	
closing cycles at the farm:	....	
TOTAL:	...100..	
animal goal aspects: importance of:		
milk yield:	....	
fat and protein yield:	....	
increasing productive life:	....	
natural service:	....	
preference for the breed of the cows:	....	
TOTAL:	...100..	
	score	weighted score
breeding goal aspects: importance of:		Multiplied by corresponding breeding goal aspects and divided by 10.
yield traits:	...20...	
body conformation traits:	...35...	
functionality traits:	...45...	
TOTAL:	...100..	
aspects of animal production: importance of:		
yield per lactation:	...20...	.x 20 x 10^{-1} = 40
life time milk yield:	....	....
fat and protein yield:	....	....
fat and protein percentage:	....	....
milk production index (INET*):	....	....
TOTAL:	...100..	
aspects of animal conformation: importance of:		
legs and claws conformation :	...10...	.x 35 x 10^{-1} = 35
udder conformation :	....	....
body conformation (frame):	....	....
balance in body conformation (Triple A score**):	....	....
body condition and muscularity:	....	....
TOTAL:	...100..	
aspects of animal functionality: importance of:		
udder health:	...40...	.x 45 x 10^{-1} = 180
fertility:	....	....
character:	....	....
calving ease:	....	....
durability index (DU***):	....	....
TOTAL:	...100..	

Farm characteristics of opposite groups

Farms in the Specialised Dairy Farming and Multifunctional Farming groups had a similar land area (51 ha), but the Specialised Dairy Farming group had significantly more milking cows (+9 cows) with a higher milk yield per cow (+620 kg/cow/year) and thus a higher total milk quota and quota per ha than farms in the Multifunctional Farming group (see Table 5.2). The Specialised Dairy Farming group also stocked on average significantly more Holstein cows (+32%) and fed significantly more concentrates per cow (+175 kg/ cow/year). Farms in both groups purchased most of their concentrated feed. On Specialised Dairy Farming farms cows were more often kept in loose housing with cubicles (78%), compared with Multifunctional Farming farms (61%).

Table 5.1: Number of farms in the opposing groups: Specialised Dairy Farming (SDF) and Multifunctional Farming (MFF), Low Input Farming (LIF) and High Input Farming (HIF), Farming with Artificial Insemination of cows (FwAI) and Farming with Natural Service of cows (FwNS).

	Specialised Dairy Farming	Multi functional Farming	High Input Farming	Low Input Farming	Farming with AI	Farming with NS
SDF	**82**	0	37	22	69	13
MFF		**59**	22	21	45	14
HIF			**63**	0	52	6
LIF				**48**	28	15
FwAI					**114**	0
FwNS						**37**

Total number of farms per group is given in the diagonal.

The High and Low Input Farming groups also had a similar land area (53–56 ha), but the High Input Farming group had a more intensive character with significantly more total milk quota (+77 tonnes) and 7 more milking cows on average (P=0.07). Cows also produced more milk (+766 kg) on average, than cows in the Low Input Farming group (Table 5.2). High Input Farming farms had significantly more Holstein Friesian cows (+24%) and fed twice as much concentrates per milking cow, all of which was bought. Farms in the Low Input Farming group produced 44% of their concentrates requirement themselves. The two groups had similar housing systems. Farms in the Farming with NS and Farming with AI groups did differ significantly in land area (8 ha) but not in farming intensity. The Farming with NS group had a significantly lower preference for Holstein cattle than the Farming with AI group (–24%). The Farming with AI group fed greater quantities of concentrates per cow and purchased more concentrates per cow (+214 kg). Farming with AI farms also had a higher milk production per cow (+607 kg). The housing systems of both groups were similar.

5.3 Results

Farm goal and goal for animals

Overall scores

In general (see Figure 5.2), concerning the farm goal, all farmers, regardless of their strategic choices, were significantly most focussed on 'low costs' and 'closing cycles'. Farmers with the Multifunctional Farming choice were strongly focused on spreading income (ANOVA, Bonferoni post hoc tests). As regards the goal farmers had for their animals, the most important aspects in all groups, except for Farming with NS, were a 'high age' per cow and 'milk components'. However, 'milk components' was not significantly more important than the other aspects (ANOVA, Bonferoni post hoc tests).

Diversification: Specialised Dairy Farming vs. Multifunctional Farming

We also examined the influence of opposite choices on each strategic issue on farmers' farm goals and goals they had for animals (Figure 5.2). The farm goal aspects 'increasing scale' and 'low costs' were significantly more important for farmers in the Specialised Dairy Farming group while, as expected, 'spreading income' was more important for farmers in the Multifunctional Farming group. The aim for 'natural breeding' and the 'preference for breed' of cows were significantly more important goals for the animals for the Multifunctional Farming group. Farmers in the Specialised Dairy Farming group were more focussed on 'milk yield', 'milk components' and a 'high age' per cow, although this was not significant within the 95% confidence interval (P=0.05 to 0.07).

Intensity of milk production: High Input Farming vs. Low Input Farming

Depending on farmers' strategic choices regarding intensity of milk production, they were divided into high input and low input groups (Figure 5.2). These groups differed significantly on the farm goal aspects 'increasing scale' (more important for the High Input Farming group) and 'closing cycles' (more important for the Low Input Farming group). The two groups differed slightly but not significantly as regarded their goals for their animals, with the aspect 'milk yield' being more important for the High Input Farming group and 'natural service' more important for the Low Input Farming group.

Naturalness of breeding: Farming with AI vs. Farming with NS

Farmers were divided into two opposite groups on the issue naturalness of breeding depending on their preference for AI or natural service (Figure 5.2). The groups did not differ significantly on farm goal aspects, except that closing cycles was more important for farmers who breed their animals by natural service. Farmers in the Farming with AI group attached significantly more importance to ‘milk components’ while farmers in the Farming with NS group, as expected, put more emphasis on breeding with ‘natural service’. They also attached slightly more importance to the sub-aspect ‘preference for breed’.

Breeding goal and breeding aspects

Overall scores

The results of all 151 farms together are presented in Figure 5.3. This figure shows the distribution of scores over different aspects for all six groups together. As regards the overall breeding goal, significantly more importance (Pb0.001)was placed on functionality (43%) than on production (32%) and conformation (25%) (ANOVA, Bonferoni post hoc test). Looking at production aspects, farmers attributed most points to ‘lifetime production’, resulting in a weighted score of 103, significantly higher than all other aspects. ‘Fat and protein yield’, ‘fat and protein percentage’ and ‘lactation milk yield’ were all similarly rated and shared second place. The overall Dutch production index (INET) was considered least important. The difference with the other aspects was significant. The emphasis of conformation was mainly on ‘conformation of legs and claws’, ‘udder conformation’ and ‘body condition/muscularity’. These three aspects were rated significantly higher than ‘frame’ and ‘Triple A’. Farmers considered ‘udder health’ to be the most important functional aspect. ‘Fertility’ came second, while ‘character’ and ‘ease of birth’ were also important aspects for farmers. The ‘durability index’ was less important.

Diversification: Specialised Dairy Farming vs. Multifunctional Farming

As regards the breeding goal, the choice between Specialised Dairy Farming and Multifunctional Farming significantly influenced the emphasis on conformation traits, with the former considering it more important than the latter (Figure 5.4). In particular, significant differences in scores were found for ‘udder conformation’ and ‘conformation of legs and claws’, with the highest scores given by farmers in the Specialised Dairy Farming group. The Multifunctional Farming group attached significantly more importance to the functionality aspects ‘character’ and ‘ease of birth’ while the Specialised Dairy Farming group was on average more interested in the ‘durability index’ (DU).

Intensity of milk production: High Input Farming vs. Low Input Farming

As shown in Figure 5.5, the Low Input and High Input Farming groups resulted in significant differences concerning the breeding goal, in particular, in the emphasis put on production (higher for High Input Farming) and functionality (higher for Low Input Farming). As regards the different production aspects, the High Input Farming group put more weight on ‘milk per lactation’ than farmers in the Low Input Farming group. On conformation, ‘frame’ and ‘Triple A’ weighed heavier for farmers in the High Input Farming group. As regards functionality aspects, ‘udder health’, ‘character’ and ‘ease of birth’ were significantly more important aspects for the Low Input Farming group.

Table 5.2: Farm characteristics of the opposing groups: Multifunctional Farming and Specialised Dairy Farming, Low Input and High Input Farming, Farming with Natural Service and Farming with Artificial Insemination of cows.

	Multifunctional Farming	**Specialised Dairy Farming**	**Sign. difference**
	Mean (s.d.)	Mean (s.d.)	
Farm area (ha)	51 (28)	51 (21)	ns.
Natural grass (%)	18 (23)	13 (17)	ns.
Corn (%)	2 (5.0)	4 (6.7)	ns.
Cereals (%)	5 (8.7)	4 (4.6)	ns.
Milk quota (tons)	282 (163)	367 (147)	**
Milk quota per ha (kg)	5786 (2160)	7525 (2300)	***
Milking cows (nb.)	47 (24)	56 (21)	*
Holstein Friesian cows (%)	38 (31)	70 (32)	***
replacement rate (%)	38 (20)	34 (10)	ns.
concentrates/milking cow (kg)	980 (396)	1155 (432)	*
purchased conc./milking cow (kg)	928 (515)	1050 (524)	ns.
milk yield per cow per year (kg)	5892 (780)	6512 (1087)	***
loose housing with cubicles (%)	61	78	-
	Low Input farming	**High Input farming**	
Farm area (ha)	53 (30)	56 (25)	ns.
Natural grass (%)	16 (18)	18 (20)	ns.
Corn (%)	3 (7.2)	3 (5.3)	ns.
Cereals (%)	6 (8.6)	3 (6.7)	ns.
Milk quota (tons)	288 (161)	365 (138)	**
Milk quota per ha (kg)	5511 (1863)	6990 (2163)	**
Milking cows (nb.)	48 (23)	55 (20)	ns.
Holstein Friesian cows (%)	44 (35)	68 (32)	***
replacement rate (%)	35 (15)	38 (18)	ns.
concentrates/milking cow (kg)	674 (427)	1381 (290)	***
purchased conc./milking cow (kg)	380 (269)	1491 (242)	***
milk yield per cow per year (kg)	5811 (1106)	6577 (1056)	***
loose housing with cubicles (%)	65	70	-
	Farming with Natural Service	**Farming with Artificial Insemination**	
Farm area (ha)	45 (15)	53 (26)	*
Natural grass (%)	14 (21)	17 (21)	ns.
Corn (%)	3 (6.8)	3 (5.6)	ns.
Cereals (%)	5 (7.4)	5 (7.5)	ns.
Milk quota (tons)	296 (128)	343 (165)	ns.
Milk quota per ha (kg)	6550 (2125)	6840 (2480)	ns.
Milking cows (nb.)	50 (19)	54 (23)	ns.
Holstein Friesian cows (%)	38 (34)	62 (34)	***
replacement rate (%)	34 (16)	36 (15)	ns.
concentrates/milking cow (kg)	938 (427)	1125 (411)	*
purchased conc./milking cow (kg)	845 (554)	1059 (507)	*
milk yield per cow per year (kg)	5757 (813)	6364 (1071)	***
loose housing with cubicles (%)	57	65	-

Ns.= non significant; * = P<0.05; ** = P<0.01 ; *** P< 0.001.

Naturalness of breeding: Farming with AI vs. Farming with NS

Regardless of whether farmers preferred AI or NS, they pursued similar breeding goals (Figure 5.6). No significant differences between the groups were found on production and functionality aspects. Looking more closely at conformation aspects, 'Triple A' was rated as significantly more important for the Farming with AI group, while 'body condition and muscularity' was significantly more important for the Farming with NS group.

Breeds or crossbreeds

Diversification: Specialised Dairy Farming vs. Multifunctional Farming

Of the Specialised Dairy Farming group, 33% opted for purebred Holstein Friesian cattle while only one farmer did so in the Multifunctional Farming group (Figure 5.7). In both groups, more than one third opted for a Holstein crossbreed. None of the farmers in the Specialised Dairy Farming group opted for Dutch breeds. Of farmers in the Multifunctional Farming group, by contrast, 41% wanted to work with a Dutch breed, such as Meuse–Rhine–Yssel (MRIJ), Groninger White Face cattle (GB) or Dutch Friesians (FH). Other desirable crossbreeds named by farmers were mostly MRIJ crosses with Brown Swiss or Montbéliarde.

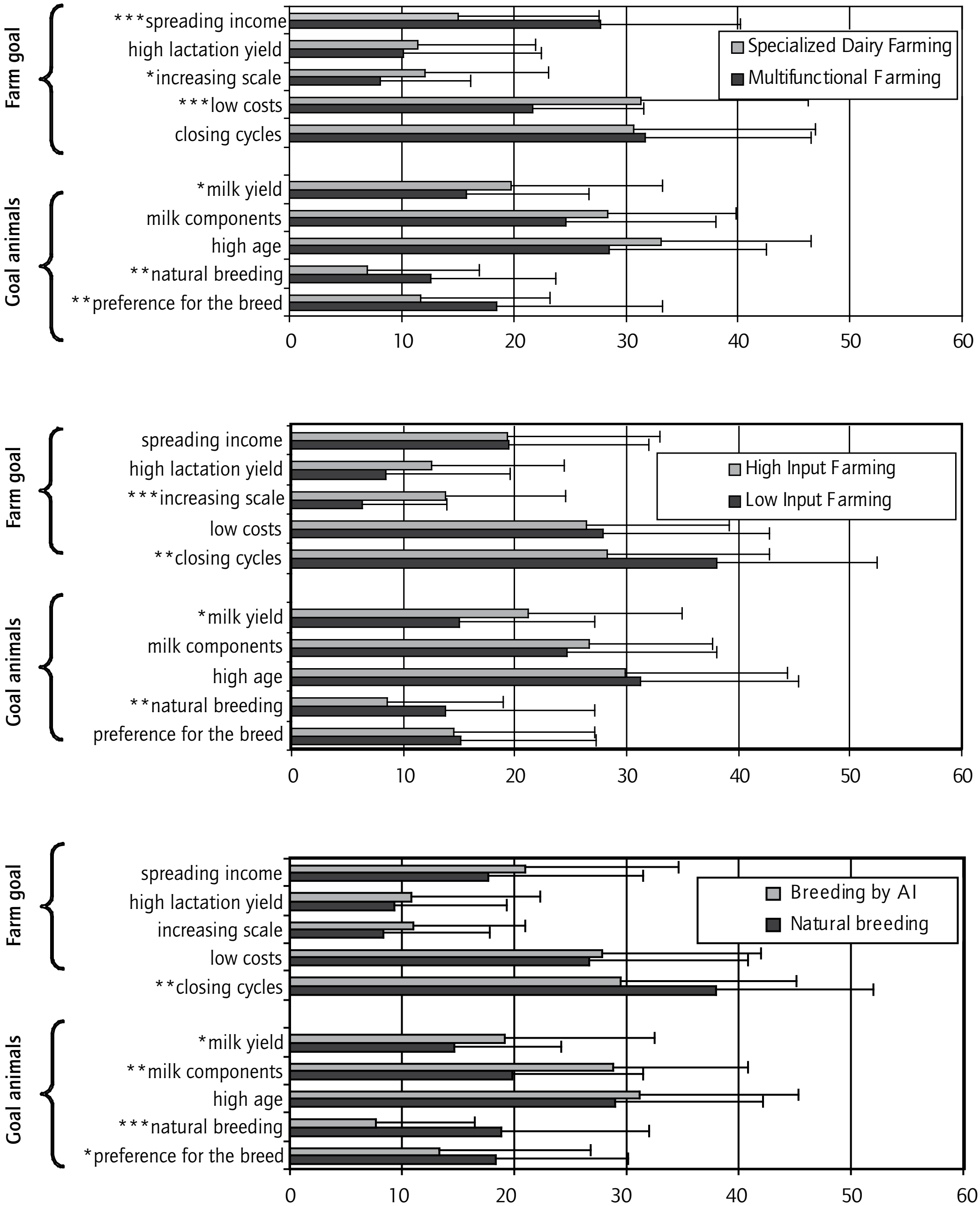
Production intensity: High Input Farming vs. Low Input Farming

Farmers who chose a High Input Farming approach had a stronger preference for HF cows (25%) than Low Input Farming farmers (6%). Conversely, Dutch breeds were opted for twice as often by the Low Input Farming group (35% versus 17%). While the preference for HF crossbreeds was similar for both groups, the High Input Farming group expressed a preference for foreign breeds and the Low Input Farming group preferred other crossbreeds.

Naturalness: Farming with AI vs. Farming with NS

Compared to farmers who chose natural service, twice as many farmers using AI opted for Holstein cattle and Holstein crossbreeds. The popularity of preference for Dutch breeds and foreign breeds was similar for both groups, but the Farming with NS group was more inclined towards other breeds, i.e. crossbreeds of Dutch and foreign breeds.

Figure 5.2: Mean scores for aspects of farm goal and goal for animals for the opposing groups of diversification of farm business: Specialised Dairy Farming versus Multifunctional Farming, intensity of milk production: High Input Farming versus Low Input Farming and naturalness of breeding: Breeding by Artificial Insemination (AI) versus Breeding by Natural Service (NS). Significance between (sub)aspects of the breeding goal, production, conformation and functionality was tested within a group by analyses of variances; s = significant ($P<0.0001$). For each (sub) aspect the significance was tested between opposing groups by an independent T-test (SPSS, 12.0), * $P<0.05$, ** $P<0.01$, *** $P<0.001$.


Farm goal
Goal animals
***spreading income
high lactation yield
*increasing scale
***low costs
closing cycles
*milk yield
milk components
high age
**natural breeding
**preference for the breed
Specialized Dairy Farming
Multifunctional Farming
0
10
20
30
40
50
60
Farm goal
Goal animals
spreading income
high lactation yield
***increasing scale
low costs
**closing cycles
*milk yield
milk components
high age
**natural breeding
preference for the breed
High Input Farming
Low Input Farming
0
10
20
30
40
50
60
Farm goal
Goal animals
spreading income
high lactation yield
increasing scale
low costs
**closing cycles
*milk yield
**milk components
high age
***natural breeding
*preference for the breed
Breeding by AI
Natural breeding
0
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50
60

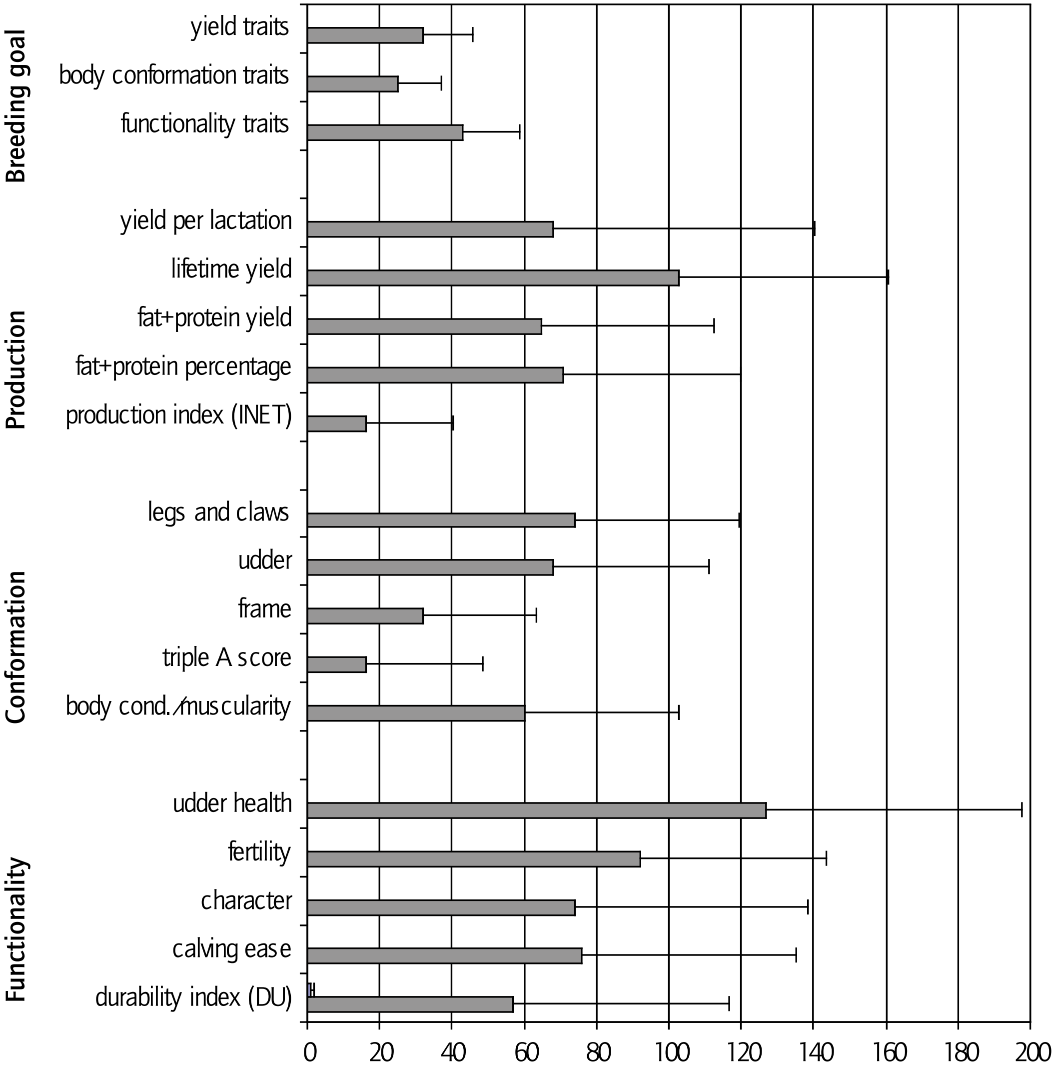


Figure 5.3: Mean scores of the aspects of the breeding goal and different sub-aspects of production, conformation and functionality from all farms (N= 151). Significance between (sub) aspects of the breeding goal, production, conformation and functionality was tested by analyses of variances; s = significant (P<0.0001).

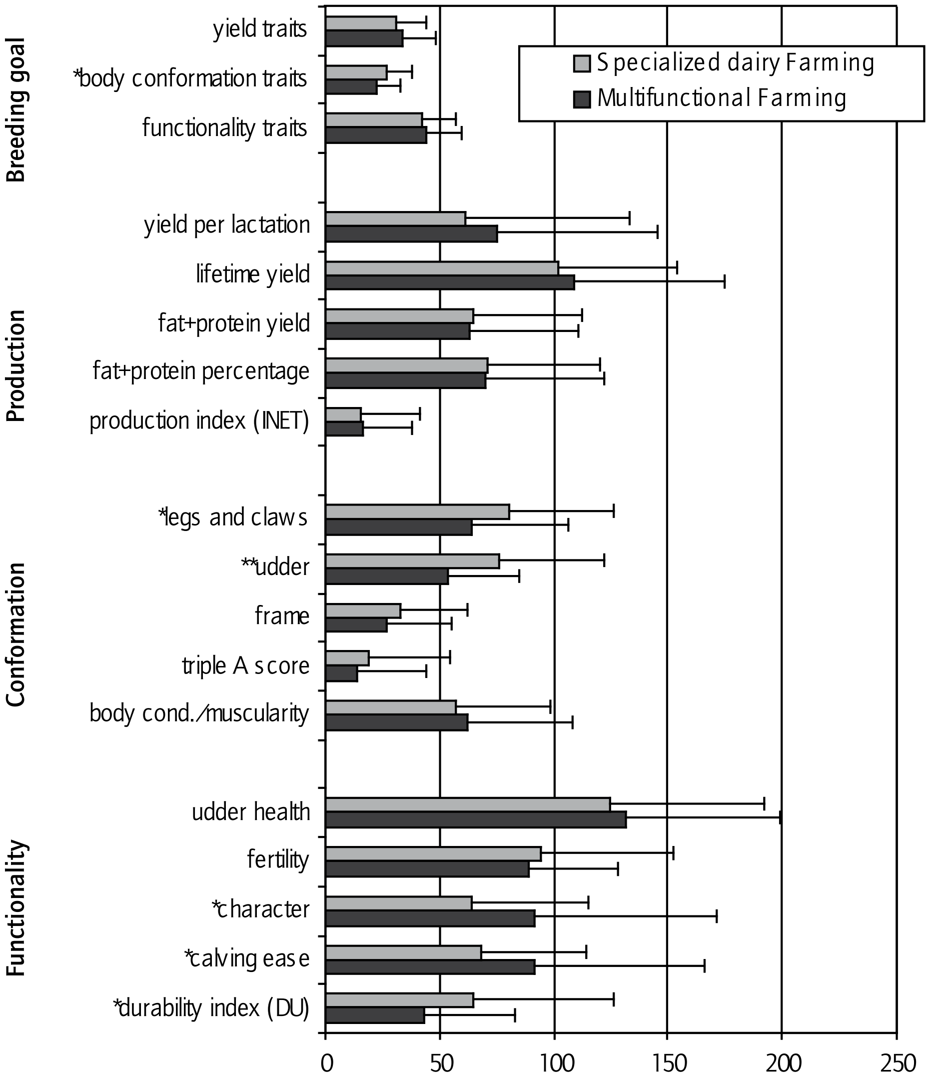


Figure 5.4: Mean scores of the breeding goal aspects and different sub-aspects of production, conformation and functionality from the opposing groups of diversification of farm business : Specialised Dairy Farming and Multifunctional Farming group. For each (sub) aspect significance between opposing groups was tested by an independent T-test (SPSS, 12.0), * P<0.05, ** P<0.01.

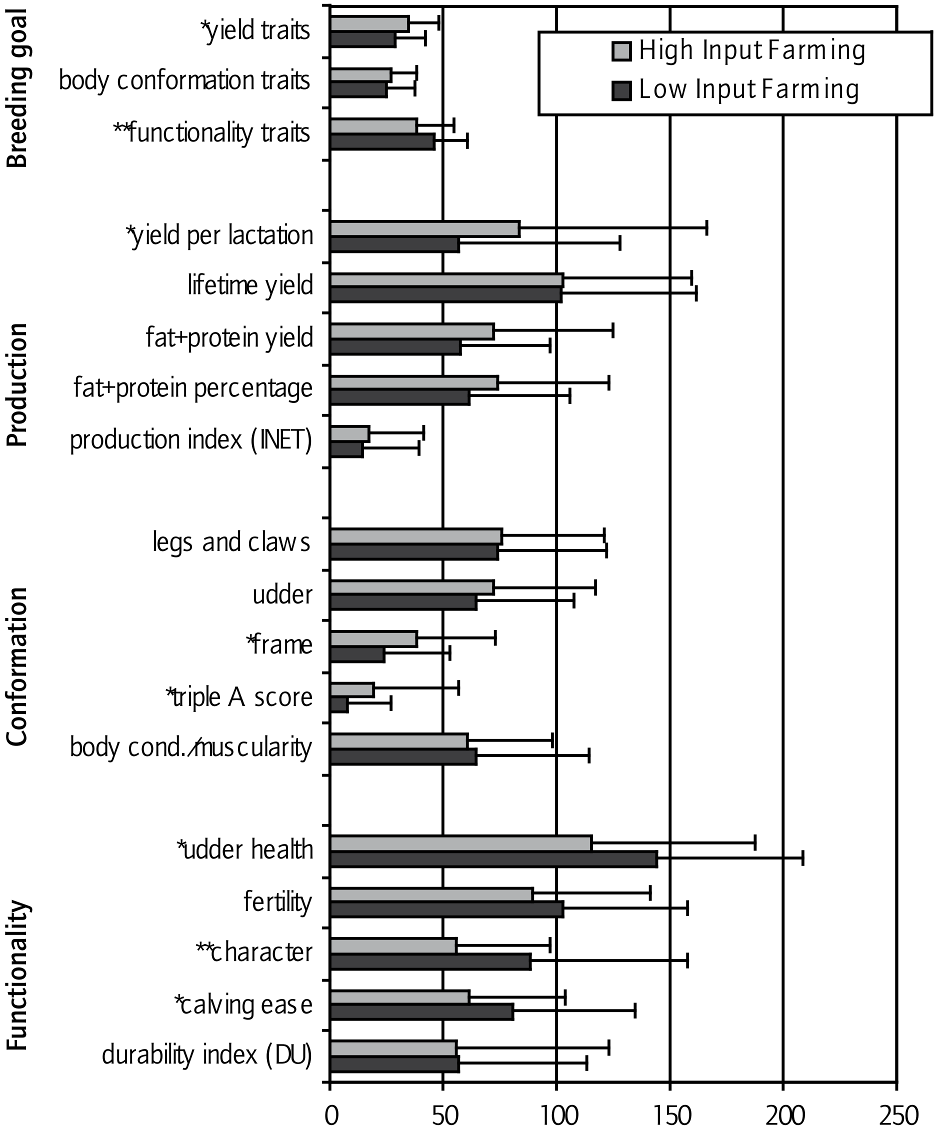


Figure 5.5: Mean scores of the aspects of the breeding goal and different sub-aspects of production, conformation and functionality from the opposing groups of intensity of milk production: High Input Farming and Low Input Farming group. For each (sub) aspect significance between opposing groups was tested by an independent T-test (SPSS, 12.0), * P<0.05, ** P<0.01.

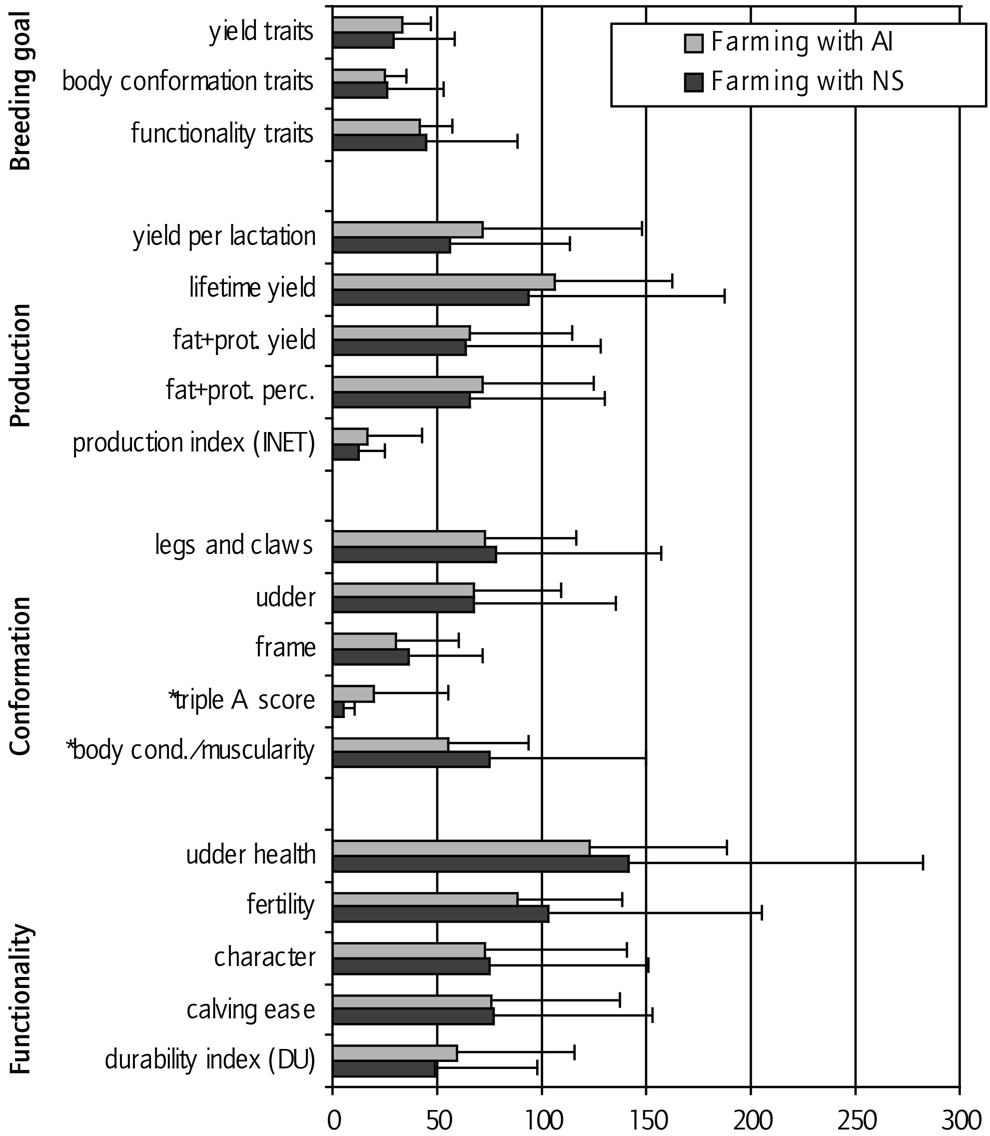


Figure 5.6: Mean scores of the aspects of the breeding goal and different sub-aspects of production, conformation and functionality from the opposing groups of naturalness of breeding: Farming with AI and Farming with NS group. For each (sub) aspect significance between opposing groups was tested by an independent T-test (SPSS, 12.0), * P<0.05, ** P<0.01.

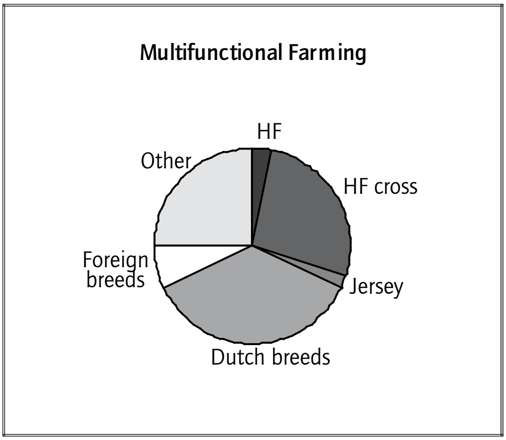
5.4 Discussion

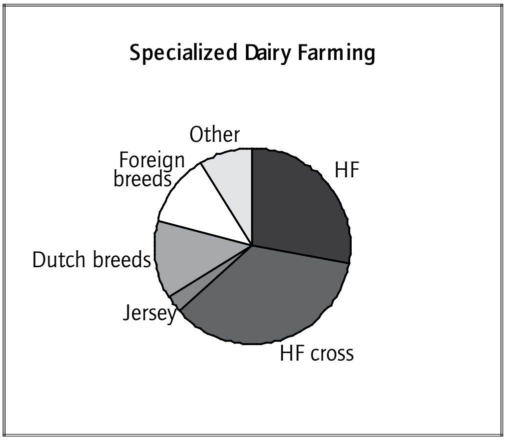
While opposite choices in the strategic issues diversification and production intensity led to clear differences in farm characteristics and farm goals, we found few differences in farmer' demands with regard to breeding goal and various breeding aspects. In general, good udder health was paramount for all farmers, followed by a long productive life, good legs and claws and body condition. Farmers in the Specialised Dairy Farming group were more focussed on conformation of 'legs and claws' and 'udder' and the durability index (DU). This appears to be in agreement with their overall farming goal of low production costs. Vollema and Groen (1997) also found longer lifetime production having a strong relationship with the conformation of a cow's legs, claws and udder.
Loose housing stalls with cubicles were the most popular housing for farmers in the Specialised Dairy Farming group versus deep litter stalls of the Multifunctional Farming group. Cows in loose housing must have strong claws as they walk on concrete.

The Multifunctional Farming group often aims to spread income through activities involving more on farm visitors and interaction of these visitors with the animals (Anonymous, 2006a). It is not surprisingly then, that the Multifunctional Farming group put more emphasis on the character of cows. By contrast, the High Input Farming group sought to increase milk yield per lactation, which is consistent with the higher input of concentrates and intensive farming strategy. They also opted for more frame in their cows, which gives a more milk-type, 'open' cow stature. Together with that the triple-A score was important to them keeping the cows build more in balance, which is again, more needed for cows with a more open frame (Anonymous, 2004).

Important differences were found with regard to preference of breed and crossbreed. Farmers who chose Specialised Dairy Farming, High Input Farming and Farming with AI showed a greater preference for Holstein cattle and Holstein crossbreeds, and farmers in the opposing groups were more focused on dual-purpose breeds, from foreign or native origin. However, taking a look within the different groups, where farmers had a similar breeding goal in mind, farmers opted for different breeds and crossbreeds to reach that goal. The question is how to explain these findings. The weights attributed to breeding aspects mostly had a high standard deviation. This could suggest that the method used was not accurate enough to reveal the specific needs of organic farming. A multivariate analysis was performed but did not result in consistent results. Selective

Figure 5.7: Distribution of breeds and crossbreeds preferred by farmers in the opposing groups of diversification of farming: Specialised Dairy Farming versus Multifunctional Farming, intensity of farming: Low Input Farming versus High Input Farming and naturalness of breeding: Farming with Natural Service (NS) or Farming with Artificial Insemination (AI). HF = Holstein Friesian, HF cross = HF with one or two other breed(s), Dutch breeds = Dutch Friesian or Meuse-Rhine-Yssel (MRIJ) or White face cattle, Foreign breeds = Montbéliarde or Brown Swiss or Fleck Vieh or Swedisch Red.


Multifunctional Farming
HF
HF cross
Jersey
Dutch breeds
Foreign breeds
Other


Specialized Dairy Farming
HF
HF cross
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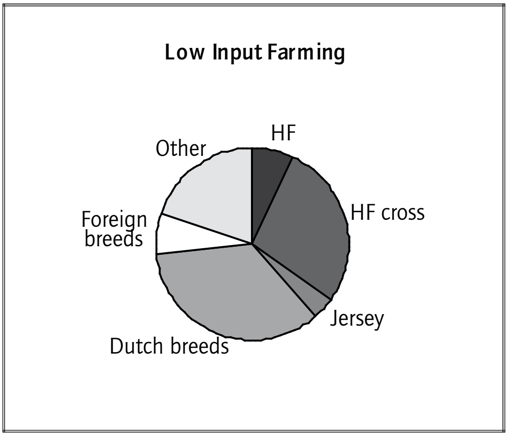
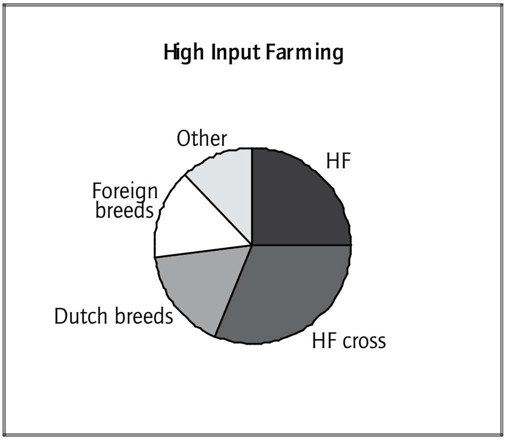
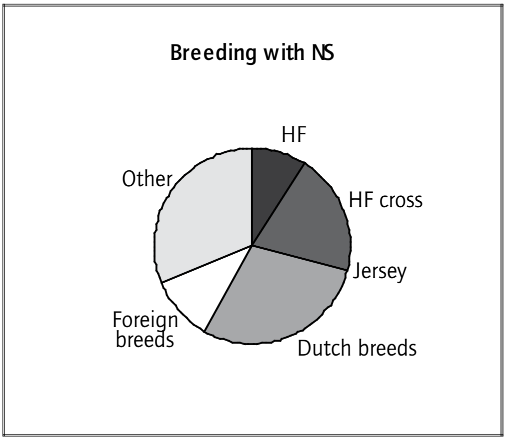
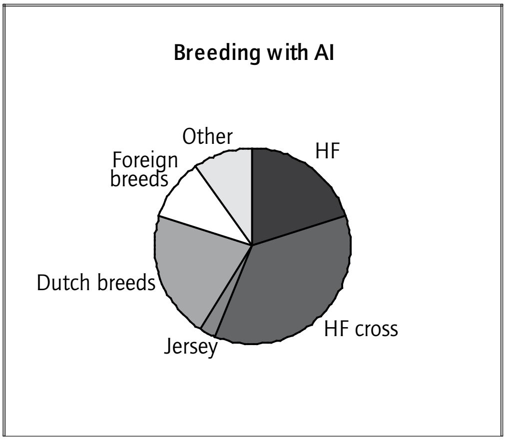
Foreign breeds
Other


Low Input Farming
HF
HF cross
Jersey
Dutch breeds
Foreign breeds
Other


High Input Farming
HF
HF cross
Dutch breeds
Foreign breeds
Other


Breeding with NS
HF
HF cross
Jersey
Dutch breeds
Foreign breeds
Other


Breeding with AI
HF
HF cross
Jersey
Dutch breeds
Foreign breeds
Other

breeding might also be influenced by factors that are not easily revealed by a questionnaire.

The overall picture of the breeding goal, with a strong focus on functional traits, did agree with other findings (Rozzi *et al*., 2007), while important aspects of the different breeding goals, such as good udder health and body condition, reflect the current needs of organic dairy production, (Vaarst *et al*., 2003; Hovi *et al*., 2003). The fact that farmers were generally interested in the same aspects might be due to organic farming standards and principles applying equally to all farmers. In general, organic farming can be regarded as an animal- and environment friendly low-input system (Anonymous, 1999; Anonymous, 2001),which puts more pressure on animals' production (Nauta *et al*., 2006a), health and fertility (Margerison *et al*., 2002; Hardarson, 2001; Vaarst et al., 2003). Preferences might also be influenced by general perceptions of what constitutes important good, 'organic' traits. Farmers might have been sensitised by many projects and study groups, which focus on health and fertility in organic dairy farming and such discussions may have had an influence on the answers given in the questionnaire.

A remarkable finding was the general lack of importance attached to the Dutch milk production index (INET). Likewise, the durability index (DU) rated lowest scores of the aspects of animal functionality. Apparently, organic farmers look at specific traits that are put under pressure in organic environments, such as protein production and udder health (Nauta *et al*., 2006a; Hovi *et al*., 2003). Organic farmers therefore seem to prefer putting together their own breeding goal, with a weighing of traits that fits their specific strategy. The animal conformation tool triple-A score also received little consideration. Perhaps few organic farmers are acquainted with triple-A, or perhaps they get stronger cows through crossbreeding instead of using the triple-A system. Another reason for the various preferences might be the explorative and experimental nature of organic farmers. One motive for converting to organic is that organic farming lowers the threshold for other farm activities (Darnhofer *et al*., 2005). Other breeds might thus be more accepted in organic farming and even stimulated by the wide variety of foreign breeds now available with robust characteristics.

The growing preference for Dutch breeds is striking. The MRIJ breed already enjoys a strong position in Dutch organic dairy production (Nauta *et al*., 2001). The preference for Groninger White face cattle (GB) might be influenced by the fact that this breed is promoted as an efficient producer of milk on a low-input grazing system (Anonymous, 2005). The preference for Dutch native breeds also suggests that there may be an additional dimension to breeding for organic farmers: the wish to preserve traditional native breeds, in keeping with the organic farming principle of diversity (IFOAM, 2001). Finally, at a more practical level, keeping a traditional breed might be used to present a clear and distinct organic identity to society and consumers.

The focus in the quick scan was on milk production in general. Meat production was regarded as additional value and not considered a specific breeding goal. The growing choice for foreign and native breeds might however reflect a switch to more meat production, also by means of cross breeding. Most of the selected breeds like Montebéliarde, MRIJ and Dutch Friesians have dual-purpose characteristics. Next to the preference for robust cows, this might be due in part to a growing niche market for dairy farmers to sell meat at the farm gate. Several farmers did concede that they selected a particular breed or crossbreed because of the 'residual value' of dairy cows (results not shown). The influence of meat production on organic breeding choices could be explored in a follow up.

The results also show a remarkable increase in the use of natural service, to 24%, meaning that about 80 of the 326 organic dairy farmers in the Netherlands in 2005 were using natural service for breeding. In 1998, only a few organic farmers preferred natural service (Nauta *et al*., 2005a). Recently 65 Dutch farmers joined a new network for farmers that use natural service on the farm (Anonymous, 2006b). The use of a bull might also be stimulated by growing awareness among farmers that conventional breeding does not agree with organic principles, which also emerged during ongoing discussions on the principles and standards of organic breeding (Nauta *et al*., 2001, 2003). Lund (2006) described that animal welfare in organic farming was interpreted by organic farmers as aiming for 'natural living', which may also include natural service.

The wide variety of breeding preferences among organic dairy farmers and their on-farm experimentation with breeds and crossbreeds seems to sustain the proposition that organic dairy farming is dynamic and still in development. The apparent contours of an overall breeding goal and the input of various breeds is comparable to the situation in Norway in the 1960s, where an overall breeding goal and the input of different native and foreign breeds eventually resulted in the Norwegian Red cattle (Anonymous, 2006c). In time, Dutch organic dairy farming may similarly produce a new Dutch organic dairy breed.

Organic farmers appear to lack the information they need to assess the suitability of different breeding bulls, breeds and crossbreeds in relation to their demands at farm level. This also leads them on a search for the animals they need. Current breeding values are based on a conventional production environment and are influenced by G x E between organic and conventional production (Nauta *et al*., 2006b). Information on G x E between organic and conventional production is still limited and more information is needed to adapt breeding values for organic production. For now, the development of organic breeding values and breeding values of breeding bulls, breeds and crossbreeds for organic production is one way to support farmers in selecting the most suitable cows (whether purebred or crossbred) given their principles, their strategy and the production regime on the farm.

5.5 Conclusion

Organic dairy farmers express similar, rather general wishes with regard to breeding goal and the different aspects of production, conformation and functionality of animals. By contrast, their actual choices and expressed preferences with regard to breeds or crossbreeds is quite varied. A plausible explanation for this incongruence is that the organic dairy sector is still young and developing and still searching for a suitable animal. In addition, organic farmers lack good information on the qualities and performance of breeds and crossbreeds for organic production. Many farmers are experimenting with crossbreeding and very little information is available about the resulting crossbreeds.

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Chapter 6

General discussion:

Factors and considerations for breeding in organic dairy farming

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6.1. Introduction

In organic agriculture there is increasing debate about the use of conventional breeding methods. The debate revolves around two issues: 1) how the principle of naturalness in organic agriculture (that is, going along with natural processes wherever possible) can be reconciled with the increasing use of modern reproduction techniques in conventional breeding, and 2) whether the production animals produced by conventional breeding are actually suitable for organic agriculture. These issues gave rise to the doctorate research reported in the preceding Chapters.

The studies and their findings are briefly summarised in section 6.1. Section 6.2 then reviews three options for breeding in organic dairy farming. Various factors and considerations concerning significant aspects of breeding are discussed in relation to each of these options in section 6.3. Finally, in section 6.4 conclusions are drawn from the research and discussion, and a proposal is made for a system innovation towards a suitable breeding system based on grounded choice.

Background to the research

Some 80% of organic dairy farmers in the Netherlands converted to organic dairy farming in the late 1990s. Most continued to milk Holstein cows (Nauta and Elbers, 1999) and experienced a significant decline in milk production, particularly in the case of cows of the Holstein Friesian breed. Cows with a high genetic potential for milk production tend to be more sensitive for differences in environment (Padel, 2000; Midmore, 2001; Bytiqi *et al*., 2006). Moreover, many cows on organic farms developed health and fertility problems (Hardarson, 2001, Vaarst *et al*., 2003, Hovi *et al*., 2003; Borell and Sorensen, 2004; Margerison *et al*., 2002), likely due to a lower intake of energy and protein from organic fodder, a lower concentrate ratio in the diet and limited use of antibiotics. Research in Ireland and New Zealand showed that Holstein cows are less suitable for extensive milk production based on grass diets (Buckley *et al*., 2000; Harris and Kolver, 2001; Dillon *et al*., 2003; Macdonald *et al*., 2008), and even high-producing Holstein cows in conventional agriculture show signs of health and fertility problems (Rauw *et al*., 1998). Thus the question arose as to what type of cow would be suitable for the extensive production environments in organic agriculture, given the differences with conventional farming.

At the same time, questions arose about the use of conventional reproduction techniques, such as artificial insemination (AI), embryo transplantation (ET), super ovulation (by means of hormone treatments) and in vitro production (IVP) of embryos following ovum pick up (OPU) and in vitro fertilisation (IVF).Organic agriculture uses these techniques indirectly through the use of AI breeding bulls from conventional breeding, too. Through their use of AI, they also use conventional breeding techniques directly. The artificiality of these techniques conflicts with the principle of naturalness in organic agriculture (Varekamp, 1997; Spranger, 1999; Haiger, 1999). Furthermore, they often contribute to loss of genetic variation in dairy cow populations (Weigel, 2001) and so hamper the pursuit of biodiversity in agriculture (IFOAM., 2002; EU, 1999; Haas and Bapst, 2004; Nauta *et al*., 2001).

The debate about a suitable cow type and the direct or indirect use of conventional reproduction techniques formed the basis for this doctorate research.

Research approach

Before statements could be made about these questions, several studies were carried out, starting with an investigation into organic dairy farmers' and other stakeholders' visions on breeding. A discussion document was drawn up and individual talks and joint discussions were held with organic dairy farmers, Biologica (the Dutch organic farmers' association) and two relevant civil society organisations (Nauta *et al*., 2005a, see Chapter 2).

Next, organic dairy farmers were asked to answer questions about their breeding goals in relation to their business strategy, and the choices they made in the selection of breeding animals (Nauta *et al*., 2009, see Chapter 5). Data on the milk production and fertility of dairy cows on conventional and organic dairy farms were analysed for differences between conventional and organic milk production (Nauta *et al*., 2006a, see Chapter 3), and for the difference in the effect of genotype-environment interaction (G x E) between the conventional and organic production environments (Nauta *et al*., 2006b, see Chapter 4). The results are summarised in the next section.

Results

The vision of breeding in organic dairy farming

Organic dairy farmers indicated that they want a breeding system which is in keeping with the principles of organic agriculture, based primarily on the conviction that breeding should be part of a closed (milk production) chain, such as pursued on their own holdings and by the organic sector as a whole (Nauta *et al*., 2005a; see Chapter 2). They also indicated that cows from conventional stock did not perform well on their farms: these cows persistently gave too much milk in relation to the amount of feed they could take in, which led to health and fertility problems.

To bring breeding more into line with organic principles, 95% of the 50 participating farmers were keen to use bulls that were not produced by embryo transplantation (ET). Around 50% of farmers wanted to work towards a breeding programme based entirely on organic stock. The other half, however, wanted to retain the option of selecting bulls from the entire range, including the conventional sector, mainly because of the greater genetic variation this offers. Some respondents wanted breeding based on natural mating rather than artificial insemination (AI).

The organic farmers' association Biologica, the Dutch Association for the Protection of Animals (Dierenbescherming) and the animal welfare group Stichting Wakker Dier considered that the image of organic agriculture would be enhanced by a specific organic breeding system without the use of ET and other modern reproductive technologies, although AI was regarded as indispensable. They also thought that organic breeding should in due course be subject to national or international regulations and certification for organic production.

Organic dairy farmers had no clear vision on a possible structure for a separate breeding system for organic dairy farming. In general, they wanted a breeding system to be set up for organic agriculture as it had been for conventional agriculture.

Differences between organic and conventional milk production and the effect of G x E

This study tested the hypothesis that the ranking of Holstein bulls from conventional breeding programmes, based on their breeding values, would be significantly different for production under organic conditions, due to the magnitude of the effect of genotype-environment interaction (G x E). To test this hypothesis, first, the differences were analysed between conventional and organic milk production of Holstein heifers. There proved to be significant differences in levels of milk production, percentage of protein in the milk, milk cell count and fertility between Holstein heifers on the two types of holding (Nauta *et al*., 2006a, see Chapter 3).

Next, the difference in the magnitude of the effect of G x E between conventional and organic milk production was investigated. G x E means that different genotypes are expressed differently in different environments (Falconer and Mackay, 1996). If there is a significant difference in the G x E effect between conventional and organic milk production, the ranking of bulls in conventional breeding does not hold for organic agriculture, so that organic farmers are less accurate in selecting bulls that inherit the characteristics required for their herd. The effect of G x E can be measured by calculating the genetic correlation between the breeding values of related animals which produce in different environments (Falconer and Mackay, 1996). A genetic correlation of 0.80 (error of estimation: 0.07) was found for milk production and 0.78 (error of estimation: 0.08) for protein production between the breeding values for milk production traits, estimated on the basis of data from conventional and organic production environments in the Netherlands (Nauta *et al*., 2006b, see Chapter 4). Such a correlation indicates that G x E has a fairly large impact on the production traits of dairy cows in conventional and organic agriculture. This effect is probably due to the lower uptake of energy by cows in organic agriculture, due to both a lower energy content in organic fodder and a smaller proportion of concentrate in the diet. However, there are still significant errors of estimation, due to the paucity of data (1767 organic milk yield records of Holstein heifers dating from 1990-2002) on the organic side.

As a result, no hard conclusions can be drawn as yet. The study presents a snapshot of conditions at the time. In many cases, the concentrate intake per cow per year was still high during this period because of the regulations permitted organic concentrates to comprise up to 60% conventional, and therefore cheaper, ingredients. Tightening of the regulations in this area (EU, 1999) is expected to lead to a decrease in the use of concentrate on organic holdings.

If the genetic correlation between the breeding values for organic and conventional environments fell below 0.75, the organic situation would be comparable to the difference in environment between New Zealand and the rest of the western world (Weigel *et al*., 2001), and a separate breeding programme would be desirable, provided there were enough animals in the organic breeding programme (Mulder and Bijma, 2006).

Organic dairy farmers' breeding aims and selections in relation to their farm management

The study into organic dairy farmers' breeding aims in relation to their farm management showed that many farmers were already experimenting with breeds and crosses in a quest for the most suitable type of cow for their farm (Nauta *et al*., 2009, see Chapter 5). Despite differences in farm management, organic farmers had more or less the same breeding aim. Compared with the conventional breeding aim, with a fifty-fifty spread over production and functional traits (Veeteelt, 2007), the organic dairy farmers give a weighting of 68% to functional traits (Nauta *et al*., 2009, see Chapter 5). It is remarkable that organic dairy farmers are now pursuing this breeding aim through the selection of different breeds and crosses, as in 1999-2000, some 80% of the farmers participating in the vision study were still using Holstein cows. Five years later, 30% of the organic dairy farmers were crossing their Holstein cows with different native and foreign breeds, such as Brown Swiss, Montebéliarde, Fleckvieh, Swedish Red, Meuse-Rhine-IJssel, and Groninger Blaarkop. These are often dual-purpose cows with a lower potential for milk yield and a better potential for functional characteristics such as fertility and health (Heins *et al*., 2006 and 2008; Dillon *et al*., 2003; Macdonald *et al*., 2008).

The study did not, however, demonstrate any relationship between the farm management system and the breed or cross used, which indicates that although farmers demand suitable animals, they do not know what type of cow this would be. This may be due in part to a lack of useful information about how different breeds and cross breeds function under different farming regimes. On the other hand, organic farmers may have started using different breeds for other reasons, such as their more individual approach to farm management, their greater readiness to experiment (Darnhofer, 2005) and their preference for certain breeds in the interests of preserving agro-biodiversity, cultural or historic values or of raising the profile of their organic production methods. The wide variety of breeds available can also be an enticement (Nauta *et al*., 2009, see Chapter 5).

A remarkable finding is that a growing number of organic farmers intend to use bulls for natural mating for various possible reasons, such as the desire for a natural and organic breeding system, to improve fertility, or to improve the image of the farm since the public appreciates the presence of a bull on the farm (Boogaard *et al*., 2008).

6.2 An organic breeding system: a discussion reviewing three options

The results showed that there are several arguments (based on principles, technical, business and social considerations and market forces) in favour of a special breeding system for organic agriculture. Organic dairy farmers and civil society organisations want a more natural approach to animal reproduction, and there is demand for a suitable cow for organic production. It might also be beneficial to set up a breeding system in a closed organic chain. The question remains as to how far-reaching the adaptations need to be, and how the sector can progress in this direction. Should breeding become entirely organic (in a closed chain), or should the option of conventional breeding methods be retained for pragmatic reasons?

Farmers are already experimenting widely with breeds and crosses and using a wide range of breeding methods. Many farmers who use AI also keep a young bull on the farm for natural mating and to breed with cows that do not respond to AI. Biodynamic farmers like to have a bull on the farm, but they are permitted to use AI, provided the semen is from an ET-free bull (Demeter, 2008).

Organic dairy farmers largely have two options: (1) either, on the principle of naturalness, to opt for breeding based on natural mating, or (2) in their quest for suitable animals and breeds, to continue to use bulls from conventional breeding programmes, though preferably ET-free bulls and bulls that inherit the traits suitable for organic environments. It may be difficult, however, to satisfy these organic requirements through the second option, since conventional breeding is largely based on ET. Moreover, the breeding aims, and hence the available range of bulls, differ between the two sectors, and the effect of G x E also comes into play. Here we see a third option emerging: (3) an entirely organic (closed) breeding chain, but still using AI.

In short, three distinct options can be formulated for the future of organic breeding (see description in Box 1), ranked in order of naturalness:

(1) Use of adapted conventional breeding (ET-free and suitable bulls);
(2) A separate breeding programme within a closed organic chain (bio-chain breeding programme);
(3) Breeding based on natural mating.

Each option has its strengths and weaknesses. Based on the findings of the research and other literature and sources, this section discusses a number of important factors to be considered.

(1) Adaptation of conventional breeding and service based on knowledge of G x E and specific organic needs

Adapting conventional breeding implies that bulls' breeding values would be adjusted for organic production requirements, i.e. taking account of the effect of genotype by environment interaction between conventional and organic production and the weighing of different traits. Adaptation would also mean address the reproduction technologies used. The indirect use of modern reproduction technologies (multiple ovulation, IVP and ET) would be limited by using bulls that were not themselves conceived by these technologies. The use of ET in previous generations would be ignored.

Information on the effect of G x E between organic and conventional production would be used to adjust the breeding values of each trait to the organic environment. These specific organic breeding values could be used to draw up an estimated overall index for production and/or durability in which durability traits would have an overall weighting of 70%, in keeping with farmers' wishes (Nauta et al, 2008, see Chapter 5). The weighting of individual traits could be adapted to the needs of organic dairy production.

(2) Distinct breeding programme within the organic chain

In a fully organic breeding programme, the selection and mating procedure for the production of breeding bulls would be based entirely on the performance of animals on organic farms. Bulls would be tested and selected based on the performance of daughters on organic farms. Multiple ovulation, IVP and ET would not be used, but AI would have to be continued in order to have sufficient numbers of daughters per bull on different farms to estimate the breeding values of the bulls. Breeding values would be estimated by the existing institutions and organic farms would use the official milk recording system.

Alternatively, the breeding goal could be adapted to the needs of organic dairy production; i.e. the selection of breeding bulls could be supported by a breeding value for lifetime production or maturity (NVO, 2008) and/or selection of bulls from cow families that have realised high lifetime productions (Okologische Gezamt Zuchtwerd (OGZ) and Lebens Leistung (LL) zucht, Postler, 1998)

(3) Breeding based on natural mating

Breeding based on natural mating is based on breeding farms which apply kin breeding and the use of breeding bulls from kin breeding systems on other farms. The structure of this option therefore differs fundamentally from breeding based on AI. Kin breeding farms breed bulls from their own herd with animals in this herd. Each farm thus produces a separate breeding line within breeds, which is adapted to the farm regime (Baars et al., 2005; Nauta et al., 2005b). The breeding farms supply breeding bulls to production farms. Production farms may choose to introduce bulls from a single breeding farm and so propagate this breeding line, or they may combine different lines or breeds by using bulls from different breeding farms.

Box 6.1: Options for a breeding system for organic dairy farming

6.3 Factors and considerations in relation to the three options for breeding

The three options, adaptation of conventional breeding, bio-chain breeding programme and breeding based on natural mating, all have their advantages and disadvantages for the organic dairy farmer. This section considers a number of important breeding aspects (naturalness, technical breeding issues, societal concerns and costs and benefits) in relation to these options.

Naturalness of breeding

How far should the organic sector go in adapting breeding to natural processes? The use in conventional breeding programmes of artificial reproduction technologies and rigorous selection of animals based on production raises various ethical issues (Schroten, 1992; Rutgers *et al*., 1996), making the use of conventional breeding programmes by organic farmers a matter for debate (Nauta *et al*., 2001; Varekamp, 1997). For many organic dairy farmers, the naturalness of the production system was an important motive for converting to organic (Lund, 2006; Østergaard, 1997; Padel, 2008, Varekamp, 1997).

Within organic agriculture, however, the concept of naturalness is interpreted in several ways (Bartussek, 1991; Verhoog *et al*., 2003). This became apparent from the survey into organic farmers' visions on breeding (Nauta *et al*., 2005a, see Chapter 2). Generally, organic dairy farmers support the idea of more natural breeding, but each has his own view of what that means. At the same time, regulations specifically concerning animal breeding in organic agriculture have little substance. This results in very diverse breeding practices, ranging from the use of conventional systems to breeding with own bulls on the farm.

Reproduction

An important aspect of naturalness is the manner of reproduction. Breeding based on natural mating is closest to the natural process of reproduction. There are differences in practical implementation within this option (Metz en Schmidt, 2005), which have varying outcomes for the naturalness of the system. But in all cases the breeding it self is natural and the semen stays *in vivo*. Keeping a bull in the herd is the most natural option, as it enables the bull to complete the entire reproductive process with the cows and better fertility results can be achieved with natural mating than with AI.

At the same time, natural mating has a number of major limitations compared with AI. Bulls are dangerous animals and should only be kept on a farm if strict safety measures are in place, including special housing (Nauta, 2004, Spengler-Neff and Metz, 2007). Natural mating carries risks in terms of fertility and disease transmission (Stegenga, 1954). Sexually transmitted diseases can render animals infertile, and diseases such as IBR, BVD and Leptospirosis may be transmitted when bulls are exchanged between farms. It was largely for these reasons that AI was originally introduced (Strikwerda, 1998). Disease transmission between farm can be avoided with natural mating by setting up a closed breeding system using bulls from the farm's own herd (Nauta *et al*., 2005b).

The other two options, bio-chain breeding and the use of an adapted conventional system, are based on AI. AI is permitted in organic agriculture for pragmatic reasons. After all, without AI, every farm would have to use a bull for natural mating, and that is thought to be impracticable in view of the disadvantages described above. Most organic dairy farmers regard AI as indispensable (Nauta *et al*., 2005a, see Chapter 2). However, AI involves taking a bull's spermatozoa from their natural environment, diluting the semen and freezing it in liquid nitrogen. These procedures are not natural and annul the entire natural reproductive process between cow and bull (Spranger, 1999).

With regard to the adapted conventional breeding option, organic farmers have a preference for bulls which have not themselves been produced by ET in order to increase the natural character of breeding. (Nauta *et al*., 2005a, see Chapter 2). The conventional breeding of commercial breeds, however, is based largely on ET and complementary technologies like hormone-induced super ovulation and/or *ovum* pick up and *in vitro* fertilization (IVF). In fact, most breeding bulls are from elite breeding programmes which make extensive use of ET (Schmidtko, 2007). Choosing ET-free bulls thus only partially resolves the dilemma. It is a pragmatic choice, as a total ban on ET in present and previous generations would leave few bulls available for organic agriculture.

Genetic diversity

Techniques such as AI and ET are often linked to loss of genetic diversity (Wickham and Banos, 1998; Spranger, 1999; Oldebroek, 2007; Weigel, 2001). Organic agriculture, however, strives for biodiversity and genetic variation (EU, 1999 en IFOAM, 2002). Natural mating forces organic farming to use more bulls, as far fewer cows can be serviced by each bull. This slows the decline of genetic variation, which is related to the number of male animals in the breeding programme (De Roo, 1988; Falconer and McKay, 1996), and thus ties in with the principles of the organic sector. If farmers use their own bulls, however, steps must be taken to prevent excessive inbreeding within farm populations. In a closed breeding herd, minimum co-ancestry among animals is necessary (Cabalero and Toro, 2000). This requires 4-5 bulls per year in a kin breeding programme and specific knowledge about running such a programme. (Nauta *et al*., 2005b).

AI need not cause a major loss of genetic variation. Genetic variation can be guaranteed by maintaining sufficient variation between breeding bulls and spreading the use of these bulls (Bijma, 2000). However, far fewer breeding bulls are required for AI and that in itself leads easily to a more rapid loss of genetic variation (Oldebroek, 2007). Efforts to achieve maximum genetic progress in the open commercial breeding market (Dekkers, 1992; Meuwissen, 1998) also lead to a great loss of genetic variation.

Following the introduction of AI, the opportunities it offered were rapidly incorporated into breeding programmes (Rendel and Robertson, 1950, Skjervold and Langholz, 1964; Van Vleck, 1964). By using AI, one can intensify selection, and reliable breeding values can be estimated based on many daughters. Therefore, AI was not only a means of guarding against the transmission of disease: it rapidly became a breeding tool (Strikwerda, 1998). AI thus resulted in a breeding system that surmounted farms . Many dedicated breeding farms disappeared, and cows of the same genetic lineage increasingly populated farms worldwide. By 1998, the effective Holstein population size had been reduced to just 50 animals worldwide (Wickham and Banos, 1998). When using AI it is therefore important to aim for gradual genetic progress and a limited increase in inbreeding.

In a bio-chain breeding programme, sound agreements would have to be made to prevent too great a loss of genetic diversity. Elite breeding farms could, for instance, be established based on kin breeding and natural mating (Nauta *et al*., 2001 and Nauta *et al*., 2005b). The basic breeding programme for Dutch Friesian cattle is an example of this model, in which 50 bulls from 45 different cow families are used per year through natural mating within the high-quality breeding population of 800 animals (Cazemier, 2008). Other farms use bulls from this programme through AI. It is also possible to build safeguards into a breeding programme based on AI, such as a maximum number of semen doses per bull and the use of outcross bulls, which have few relatives in the population. Clear agreements on these points would be beneficial for a bio-chain-breeding programme.

New technologies

Recently, marker and genome selection and the use of sexed semen have been strongly promoted in conventional breeding systems. These technologies raise several concerns in the organic sector. Introducing even more advanced technologies into breeding goes against the grain for many organic farmers, who consider the use of marker selection and sexed semen undesirable (Anon., 2007 and 2008b). Organic researchers and consultants share that view (Bapst and Zeltner, 2002). Until now, marker selection has been permitted in organic plant breeding, but this practice is not laid down in an official regulation as yet (EU, 2003; Lammerts Van Bueren, personal communication). In organic animal breeding, however, the organic sector has not yet formulated an official position on marker selection or sexed semen. The same concerns apply to these two technologies as to AI and ET: they reduce the degree of naturalness and can accelerate the loss of genetic variation, although in time they could equally be used to stimulate variation.

Genomic selection can be used in large populations to screen a large group of trial bulls specifically to find outcross bulls for greater genetic diversity (Calus *et al*., 2008). Sexed semen can produce sufficient numbers of daughters more rapidly for a reliable estimate of bulls' breeding value. This would enhance breeding in smaller populations, such as in an organic breeding programme, and facilitate breeding at farm level. The use of sexed semen enables farmers to breed heifers or bulls more rapidly at farm level from the desired cows, and thus to make more rapid progress at farm level with their own bulls. It could encourage more farmers to practice this type of breeding. Semen sexing can also contribute to the establishment of different lines and so help preserve genetic diversity. The impregnation rate with sexed semen is low as yet (Garner and Seidel, 2008), which means that this technique is less profitable at this time. Genomic selection can currently only be used efficiently in large populations because the correlations between markers and characteristics have to be estimated with a reasonably high level of reliability (Meuwissen *et al*., 2001; Van Raden *et al*., 2008). Where specific markers of even genes are known, they can be exploited in smaller populations, for example, to accelerate the breeding of hornless animals (Pryce *et al*., 2001a+b).

A purely commercial application of these new technologies could, however, easily contribute to a decline in genetic diversity in general breeding (Oldenbroek, 2007), as fewer and fewer bulls would be tested on the basis of daughters, thus narrowing the genetic population base even while accelerating genetic progress. Here, again, agreements can be made concerning the use of these techniques within organic agriculture. For example, genomics and sexed semen might only be permitted within farm herds so that this method of breeding can increase and so variation in general increases. However, every option involves increasing use of technology in the breeding system.

In the last decade even more controversial techniques come into practise like cloning and cisgenesis. Cloning is carried out in cattle, though on a small scale and mainly in the USA and research is being undertaken in Australia and New Zealand into the opportunities offered by cisgenesis, the modification of genomes within species (Brophy *et al*., 2003). While these technologies are prohibited in the EU and in organic agriculture (EU, 1999), it is conceivable that they will be introduced indirectly into worldwide conventional breeding programmes and that descendants from cloning or animals modified by cisgenesis will be offered as breeding animals through AI. At which point in the future this may happen is not clear. Nor is it clear how the organic sector will deal with the use of such breeding animals. If these techniques are introduced into conventional breeding, however, it will probably become impossible for organic agriculture to use conventional breeding programmes.

Keeping breeding animals

Currently, there are no special rules for keeping breeding bulls on organic dairy farms. Bulls are usually kept indoors for safety reasons. In the light of general organic principles, however, it is conceivable that breeding bulls would have to be managed and housed as far as possible in the same way as the other cattle, with organic feed, access to the outdoors and no preventive use of antibiotics. Bull dams and bulls in conventional breeding programmes are not kept according to organic rules on husbandry. AI bulls get conventional feed, conventional disease control and they are kept indoors to protect them from possible infections such as IBR, BVD, Leptospirosis and Para

TBC. Infected breeding bulls cannot provide EU certified semen (EU, 1992). The financial risks of outdoor access are simply too great.

In a separate bio-chain breeding programme and breeding based on natural mating, the bull dams are kept on organic dairy farms in accordance with organic requirements. It is not yet clear whether this would also apply to bulls: it depends on which system is chosen. If a bull is kept loose in the herd, management is the same as for the dairy cows and the bull is thus automatically certified organic. Where bulls are kept in separate housing, they should have some form of outdoor access. If young bulls for an organic breeding programme are reared with the herd until such time as sperm is obtained and frozen, then the management would also be almost entirely certified organic. Prior to semen collection, the young bulls would have to be kept in quarantine for at least a month at an EU-certified AI station (KI-De Toekomst, 2008). Here too, they would be unlikely to have outdoor access, but they could be given organic feed and presumably be kept free of antibiotics.

Selecting suitable breeding stock

Research into the magnitude of the genotype by environment interaction (G x E) between organic and conventional dairy production tested the hypothesis that organic dairy farmers are unable to select suitable breeding bulls from conventional breeding stock, in particular for the high-productive Holstein Friesian breed. The study identified a clear G x E effect for milk production by Holstein heifers (Nauta *et al*., 2006b, see Chapter 4). It is necessary to study the implications of this finding with regard to the various options for the future of organic breeding. In addition to the effect of G x E, important considerations are the scale at which breeding programmes are carried out, the breeding and selection technologies used, and market demand. Organic farmers prefer ET-free bulls (Nauta *et al*., 2005a, see Chapter 2) and have other breeding goals than conventional dairy farmers (Nauta *et al*., 2009, see Chapter 5). Suitable bulls must be available to meet these requirements.

Breeding programme design and G x E

All three options – use of adapted conventional breeding, a separate bio-chain breeding programme and breeding based on natural mating – concern a breeding programme in which a breeding goal is defined, animals are selected according to this breeding goal and bred in order to achieve this goal as quickly as possible. Important, interrelated factors in weighing the benefits of the three breeding options are the use of reproduction technologies, scale of breeding programmes, scope for testing bulls by their progeny and the magnitude of G x E between organic and conventional dairy production.

The application of multiple ovulation and IVF technologies followed by ET in conventional breeding intensifies the selection of female animals and reduces the generation interval, thus accelerating genetic progress (Nicholas and Smith, 1983; Meuwissen, 1998; Moore and Thatcher, 2006). Farmers using conventional breeding benefit from this genetic progress. A breeding programme within a closed organic chain (bio-chain breeding programme) would not permit ET and IVF.

Conventional breeding programmes make use of large animal populations (up to several million animals for the black-and-white Holstein Friesian breed) which facilitates faster genetic progress. The greater degree of variation in a large, open, worldwide dairy population allows for a larger selection intensity, which leads to a larger selection result in the next generation. The population pool is sufficiently large for selected animals to be tested quickly and accurately. Currently, the testing process is supported by genomic selection, which increases a breeding programme's selection response and reduces the number of animals that need to be tested (Brascamp *et al*., 1993; Schrooten, 2000). The organic dairy population is much smaller in comparison – some 22,750 dairy cows and young stock on 320 farms in the Netherlands (De Jong and Van Soest, 2001; Nauta *et al*., 2009, see Chapter 5). This particularly reduces the scope for testing bulls accurately. No information can be given yet about the potential of genomic selection in smaller organic populations. Currently, genomic selection is only proven feasible and reliable in large populations since the single nucleotide marker patterns are specific for different populations and the accuracy of information from these patterns has to be tested with large progeny groups (Meuwissen *et al*., 2001; Van Raden *et al*., 2008).

The magnitude of G x E between conventional and organic dairy production also has a role to play. If there were no G x E effect, organic farmers could select bulls from the conventional supply without any difficulty. A large G x E effect on the other hand changes the ranking of bulls in terms of their suitability for organic production and thus reduces the accuracy of selection for organic farmers. In this case, it may be beneficial to set up a separate bio-chain-breeding-programme in which the estimation of breeding values is based on organic production environments.

Table 6.1: Populations of organic dairy cows in various European countries (source: Organic Europe, 2007).

Country	No. of organic milking cows
The Netherlands	16,182
Belgium	8,297
Germany	85,000
United Kingdom	214,276
Ireland	850
France	62,140
Italy	58,443
Scandinavia (DK, SE, NO)	49,882
Total	495,070

As yet, however, a great deal of uncertainty exists about the magnitude of the effect of G x E between organic and conventional milk production. The genetic correlation between breeding values estimated for conventional and organic dairy production in the Netherlands is 0.80 (Nauta *et al*., 2006b, see Chapter 4). Opinions differ as to whether an effect of this magnitude warrants a separate breeding programme addressing specific production conditions (Robertson,1959; Falconer and MacKay, 1996; Smith and Banos, 1991; Mulder and Bijma, 2006). The answer depends on various factors such as the size of populations, the structure of the breeding program and its cost. Assuming that organic and conventional populations are of equal size, a separate bio-chain-breeding-programme would be feasible with a genetic correlation of 0.75 or lower between the two production environments (Mulder and Bijma, 2006). Considering the current size of the organic dairy cow population in the Netherlands, using conventional breeding bulls would generally be more effective and efficient. A bio-chain-breeding-programme would be more feasible with a larger organic population. But cost is also an important consideration. In Germany, Harder *et al*. (2004) and Schmidko (2007) showed that a separate organic breeding programme based on 100,000 animals was unable to compete with a conventional programme because it offered no advantages in terms of genetic progress and had greater fixed and variable costs.

In other words, the feasibility of a bio-chain breeding programme increases with growing population size. Perhaps collaboration between countries is necessary and an international breeding programme based on organic populations could be set up (see Table 6.1), as proposed by Zwald *et al*. (2003) for different environments in conventional breeding.

Larger G x E effects cancel out the shortcomings of a small bio-chain-breeding-programme. When G x E effects increase, breeding values estimated in conventional programmes become less reliable for organic dairy production environments. This degree of reliability could be matched by a smaller bio-chain programme as it could be achieved with fewer daughters (see Table 6.2). With regard to milk production with a heritability (h^2) of 0.35 and a genetic correlation of 0.80 between conventional and organic production, a 90% reliability for a breeding value based on conventional production results in a reliability of 73% for organic dairy production. Achieving this reliability within a organic breeding program requires 28 daughters per bull, which can be obtained in practice through about 225 pregnancies (G. Vosman, personal communication). Even with a relatively small organic population, it would be feasible to achieve a higher reliability for this production trait, thus ending dependence on conventional breeding.

Table 6.2: Reliability (r^2_{AI}) of breeding values for organic dairy production as dependent upon the genetic correlation between conventional and organic and the minimum number of daughters per sire needed to achieve this reliability in a organic breeding population. The number of daughters required is derived from $r^2_{AI} = (0.25*n*h^2)/(1+0.25(n-1)h^2)$. *reliability of conventional breeding value, ** number in brackets is the number of daughters needed to achieve 80% reliability for conventional dairy production.

			No. of daughters required per trait**		
Genetic correlation r	r^2	Reliability r^2_{AI} at conventional reliability 90% (80%) *	Milk $h^2 = 0.35$	SCS $h^2 = 0.10$	CI $h^2 = 0.07$
0.70	0.49	44% (39%)	9 (7)	31(25)	44 (36)
0.80	0.64	58% (51%)	15 (11)	54 (41)	78 (59)
0.90	0.81	73% (65%)	28 (20)	105 (72)	152 (105)
1	1	90% (80%)	94 (42)	351(156)	505 (225)

For functional traits like somatic cell count (SCS) and calving interval (CI), which have a lower h^2, a reliability of 70 to 80% is generally maintained because information from large numbers of daughters is needed to match this reliability. When the conventional reliability is 80%, the minimum number of daughters needed in an organic population in order to achieve the same or a higher reliability than the actual reliability based on conventional data, assuming a genetic correlation of 0.90, is 72 for SCS and 105 for CI. For this, 600 to 900 inseminations would be needed to obtain such numbers. If the genetic correlation were 0.70, respectively 25 and 36 daughters were at least needed, comparable to the situation for milk production. So, the feasibility of operating on such a scale depends on the effect of G x E and the scope for testing bulls based on their progeny. It is possible to vary progeny group size without significantly affecting genetic progress (Brascamp, 1973), when other factors are optimized. A bio-chain breeding programme on an international scale consisting of several hundred thousand animals (see Table 6.1) would yield a larger trial population, so that it would be easier to match the performance of conventional breeding in terms of reliability.

Less expensive breeding frameworks are also possible, such as the 'cold' system or the young bull system described by Bichard (2002). These could achieve equal genetic progress at a much lower cost, making them attractive options for a smaller bio-chain-breeding-programme.

In practice also various factors complicate the decision with regard to the three options. The magnitude of G x E between organic and conventional dairy production differs by country and by breed and/or genetic level of individual animals (Berry *et al*., 2003; Nauta *et al*., 2006b see Chapter 4, Bytyqi *et al*., 2006; Bapst and Stricker, 2007; Mark, 2007; Rozzi *et al*., 2007; Bryant *et al*., 2008). The effect of G x E is not the same for all organic dairy farms since organic dairy production is characterised by its diversity. Farms are closely tied to the land and animals' performance depends strongly on specific environmental conditions and the scope for management interventions is limited (COBL, 1977; Baars 1990 and 2002). Such farms develop highly divergent production environments, expressed for instance in differences in concentrate intake per milking cow (Nauta *et al*., 2009, see Chapter 5), and divergent magnitudes of G x E in relation to the conventional dairy production environment.

This diversity also results in an organic dairy population made up of several subpopulations of breeds and crosses (Nauta *et al*., 2009, see Chapter 5). In these small populations it is difficult to test bulls based on their progeny, a factor which restricts the scope for a bio-chain breeding programme. It would be possible, as proposed by Nauta *et al*. (2006b, see Chapter 4), to develop an over-all bio-chain breeding programme encompassing the entire organic population of 22,750 animals, irrespective of breed or cross, which would yield a new 'organic breed'. This could, however, undermine the use of native Dutch breeds such as Meuse-Rhine-Yssel, Dutch Friesian and Groninger Blaarkop, and therefore agro-biodiversity, a pursuit in which many organic farmers take great pride (Nauta *et al*., 2009, see Chapter 5).

A practical option for breeding in small populations would be breeding based on natural mating. In this system, breeding values can only be based on information of the animals themselves or their close relatives. The estimated reliability (r) of quantitative breeding values is low compared to the testing systems, as they are based on the heritability of the trait and the information supplied by preceding generations ($r = h^2/2$ for parents and $h^2/4$ for grandparents). In order to boost the reliability of a bull's breeding value, a bull may be bred from a cow from the farm's own herd and a tested breeding sire. The father's breeding value will supplement the son's breeding value.

Lacking such information, breeding farms sometimes adopt the kin breeding method (Baars *et al*., 2005) in which the farmers breeds its cows systematically with 4 to 5 breeding bulls out of the farm herd in order to prevent excessive inbreeding. This leads to a gradual increase in the number of animals with 'double-blood' (Baars and Endendijk, 1990). In theory, offspring becomes increasingly homozygous after several generations. Such homozygous animals will pass one type of gene or trait on to their offspring, in this way ensuring the reliability of the breeding system (Baars and Endendijk, 1990, Baars *et al*., 2005). The disadvantages of this method are that the process towards increasing homozygosis is a slow one (several generations) and that it decreases the herd's genetic variation, thus reducing the potential for genetic progress (Falconer and MacKay, 1996).

Breeding based on natural mating also involves bull exchanges. Here, also the effect of G x E comes into play due to the diversity among farms. Exchanges between farms with strongly divergent environments may result in daughters with very different performances. The effectiveness of bull exchanges also depends on the magnitude of G x E between farms, a variable on which no information is currently available. When buying breeding stock, farmers should in any case purchase a bull from a breeding farm with similar management and husbandry.

Demand and Supply

Organic dairy farmers demand breeding bulls that have not been directly obtained through ET (Nauta *et al*., 2005a, see Chapter 2; Demeter, 2008). This puts two of the organic breeding options – namely the bio-chain-breeding-programme and breeding based on natural mating – at an advantage as they do not rely on ET. Farmers' rejection of ET does not extend to preceding generations. They are pragmatic in only demanding bulls that are not produced through ET themselves. This leaves them a sufficient number of conventional breeding bulls to choose from (Nauta *et al*., 2004). A total ban on ET, including ET by descent, would leave them very little choice, especially within the Holstein Friesian breed.

It is unlikely that conventional breeding programmes would provide ET-free bulls especially for the organic sector, as this would be a costly affair (see section 6.3, Costs and Benefits). Conventional breeding programmes will probably always have some ET-free bulls, as they need an open structure (Meuwissen, 1998) which is achieved by selecting bulls from pregnancies in the population, pregnancies that in many cases are the result of AI. It is uncertain however, whether they will continue this practice in the future. Currently most ET-free bulls are of less commercial breeds like the native Dutch breeds Meuse-Rhine-Yssel, Dutch Friesian and Groninger Blaarkop (Nauta, 2004).

An extra problem is that breeding firms no longer specify whether bulls have been produced through ET or not. Yet biodynamic dairy farmers have been required to use ET-free bulls since 2008 (Demeter, 2008). ET-related information now has to be gathered by the organic sector itself, which takes time and money. Perhaps an independent organisation such as the Dutch Organisation for Cattle Improvement (NVO) could provide this vital information to the quarterly breeding value publications. ET breeding bulls are also banned in Switzerland and organic dairy farmers there are provided a special list of ET-free bulls (Baars and Nauta, 1998; Bapst, 2001). In the Netherlands some ET-free bulls are now published on the internet as a free service (Anon., 2008c).

Organic farmers also have other breeding aims than their conventional counterparts (Nauta *et al*., 2009, see Chapter 5). Organic dairy production is more extensive than conventional production and animals' intrinsic value is generally held in higher esteem. Organic farmers therefore need cows with a good milk yield produced on a roughage diet and a longevity that fits the species (see Box 2). The question is, which option for breeding would achieve these breeding aims fastest. With a different genetic trend it is uncertain whether conventional breeding programmes can offer organic farmers sufficient choice: the traits desired by organic farmers might not be present in the right degree. For instance, an organic farmer might want to breed cows with lower genetic merit for milk yield because the farm cannot provide sufficient feed for high-producing animals, which would then suffer health and fertility problems (Hardarson, 2001). Within the Holstein breed, however, few sires are available with low or negative breeding values for milk yield (NVO, 2008; T. Visser, o.r.) and the farmer would do better to cross with a less productive breed.

The question is whether a conventional breeding organisation can provide the organic sector with bulls especially suited to their needs. After all, they must focus on the needs of conventional farmers in an open breeding system in which they compete with other breeding firms (Dekkers, 1992). They need to ensure rapid genetic progress for conventional dairy production. If the organic sector were larger, it could be commercially viable for conventional breeders, but the sector's growth is currently levelling off (Willer and Yussefi, 2004; Bio-monitor, 2008) and there are no indications that this will change in the future. And again, there is widely divergent demand with regard to breeding in the organic sector, which makes the challenge even bigger.

The preferred cow type for organic dairy production

Several different types of cow are probably needed in view of the diversity in organic dairy production (Baars and Nauta, 2001). Organic farmers use a wide variety of breeds and/or crosses (Nauta et al., 2009, see Chapter 5), but despite differences in management style, they maintain more or less the same general breeding goal, with a relatively high weighting (68%) given to conformation and functionality traits, such as animal health and fertility, (Nauta et al., 2009). Generally, extensive farms need a type of cow that produces milk efficiently on a diet that is high in roughage and low in concentrates without developing health and fertility problems.

Various studies have concluded that smaller, lighter cows best suit these conditions, as they produce milk efficiently on a grass-based diet (Yerex et al., 1988; Harris and Kolver, 2001; Thomet and Burgos, 2007). Cows' production potential should be in line with the type and quantity of rations available. According to Haiger et al., (1988), maximum production efficiency is achieved when 15 to 20% of the yield's energetic value is supplied through concentrate feed. Dairy cows on Dutch organic farms have an average yield of 6250 kg milk per lactation, during which time they receive an average concentrate ration of 1080 kg (Nauta et al., 2009, see Chapter 5). Concentrates thus supply about 20% of the energetic value required for the milk yield. In conventional production this is often 40-50% (Haiger, 1998).

Finally, in view of ecological principles and animal integrity, breeders should aim for late-maturing cows with a long productive life (Bakels, 1982; Essl, 1982; Haiger, 1998; Postler, 1999; Baars and Nauta, 2001; Baars et al.,, 2005).

Box 6.2: The preferent cow type for organic dairy production

To broaden the possibilities, the market for breeding bulls for extensive organic production systems could be expanded internationally (see Table 6.1) to extensive conventional farms which share organic farmers' breeding goals. Some experts predict that in 30 years' time, one-third of the Dutch dairy sector will be made up by organic and extensive conventional farms, which will need to have stock with 'organic' traits (Anon., 2008a). Perhaps conventional breeders could viably develop a generic breeding programme for this group (see section 6.3: Selecting suitable breeding stock). Also, more market could be developed in countries like New Zealand and Ireland were a very extensive, grass-based milk production is common practice (Dillon *et al*., 2003; Harris and Kolver, 2001). Visa versa it is possible to use AI-bulls that are tested positively in these countries, in organic dairy farming.

The disadvantages of conventional breeding as described above present arguments in favour of a bio-chain-breeding programme, which pursues the specific breeding aims of organic dairy producers. This does, however, require close coordination between farmers and breeders (see section 6.3: Ownership and community building).

Breeders who use natural mating are independent: they are free to decide and pursue their own breeding goals (Nauta *et al*., 2005b; Bapst, 2003). It is only when they start working together that they need to align their breeding goals. Cooperation will therefore be most effective between farms with a similar management style and similar breeding goals.

The sector's public image

What effects do the three options have on the image of the organic dairy farming? As far as we know, indirect use of modern artificial reproduction technologies through the involvement of bulls from conventional breeding, has not, up to now, raised any problems for the image of the sector or the sale of products. Generally, consumers are unaware of breeding practices (Van Genderen and De Vriend, 1999; Nauta *et al*., 2005a, see Chapter 2), perhaps because these techniques do not directly affect the organic product. They do, however, form the basis for production (Van Genderen and De Vriend, 1999). Consumers largely buy organic products for their own perceived health benefit (De Wit and Van Amersfoort, 2001; Rosati and Aumaitre, 2004). Environmental issues and animal welfare come second and third.

However, there is a tendency for the public to become more involved in agricultural production (Neeteson *et al*., 1999; Liinamo *et al*., 2003; Hermansen, 2001; Rosati and Aumaitre, 2004). In the Netherlands campaigns like "Sex for Animals" and "Adopt a Cow" (Stichting Wonder, 2007 and Stichting Koevoet, 2008) fuel social debate on the production and reproduction of cattle, and as farms branch out and (Biologica, 2006) attract more and more visitors, the absence of bulls on farms is starting to be noticed (Boogaard *et al*., 2008). These developments work in favour of breeding based on natural mating.

A bio-chain breeding programme and the use of conventional breeding both rely on AI. It is not known whether consumers or other stakeholders appreciate the distinction between indirect use of ET and the use of AI. Both are artificial interventions and represent a technological approach to reproduction. It is easy for an outsider to lump them together. If a bio-chain breeding programme was chosen, consumers would have to be clearly informed about how that differs from indirect use of ET and IVF, and also from semen sexing.

The organic sector strives for a closed organic production chain, including the input of animals (EU, 1999). A bio-chain breeding programme and breeding based on natural mating are in keeping with this principle, while the use of conventional breeding methods leaves the chain open. For an example we can look to developments in plant breeding within organic agriculture. It is moving step by step towards propagation techniques and selection both for and within the closed organic chain. (Lammerts Van Bueren, 2002). It would be a logical next step for dairy farming to follow suit.

Organic agriculture also wants to profile itself as sustainable agriculture, which preserves biodiversity and ensures a robust production system (Tak, 2008). The use of special bulls for organic production and natural mating would mean that more bulls are used. This would slow the decline of genetic biodiversity (De Roo, 1988; Falconer and McKay, 1996; Bijma, 2000) –an extra bonus in promoting the organic product.

Ownership and community building

Breeding intended for organic agriculture depends on a person, group or business to set it up, and become the owner of the process. So, for example, conventional breeding is in the hands of various large and small cooperatives and private companies, which sometimes include individual dairy farmers. Each has his or its own part to play. In cattle breeding, the owner of an animal decides on any breeding issues affecting that animal. Genetics is not patented in livestock farming as it is in plant breeding. Special contracts are required to ensure a seller any rights to future profits from an animal. When an animal or its offspring are sold, the genetics of that animal are also sold to the new owner. Cattle breeding is thus an open market in which anyone can offer their breeding animals in any way they choose.

Currently, an organic farmer can use conventional breeding, with all the available AI bulls, and breeding bulls for natural service. Farmers themselves or the various breeding organisations can set up adapted conventional breeding, a bio-chain breeding programme or a breeding programme based on natural mating. Many organic dairy farmers however expect a suitable breeding programme to be set up for them (Nauta *et al*., 2005a, see Chapter 2). The question is now, who will take on the challenge of developing a special breeding system? It will require time and money and an organisation that is interested.

With the use of adapted conventional breeding, the first requirement is a supply of ET-free bulls. The breeder or breeding organisations must indicate whether or not a bull is the result of ET (see section 6.3: Selecting suitable breeding stock). In a pilot project in 2003 and 2004, the Louis Bolk Institute worked with various breeding organisations in the Netherlands to draw up a list of ET-free bulls (Nauta and Langhout, 2004). After that, one organisation has continued to publish a lists of ET-free bulls in a circular to members. Possibly the Dutch Cattle improvement Organisation (NVO) could publish this information impartially with the breeding values of bulls for the organic farmers (NVO, 2008).

Secondly, in the case of the use of adapted conventional breeding, someone must adapt the breeding values. The basic breeding values for each characteristic and a number of indices (INET, NVI) can be obtained from the Dutch Organisation for Cattle Improvement (NVO, 2008), but new calculations will have to be made for an "organic" index in which characteristics are given a different weighting. The effect of G x E must also be taken into account for different characteristics (see section 6.3: Selecting suitable breeding stock). The question remains who should do this and how it could be regulated financially for the organic sector. In Switzerland, a special bull selection is already available (Bapst, 2003) and in Germany and Austria various breeding organisations offer the Ökologische Gezamtzuchtwert (ÖGZ- overall ecological breeding value) (Postler, 1998; Wittenberg, 1999; Krogmeier, 2003).The market is more profitable in Switzerland, however, as 30% of dairy farms are organic.

The option of a bio-chain breeding programme also raises the question of who will implement it. Bull dams and bulls must be selected from the population, to be reared and semen has to be frozen and distributed. It is also necessary to evaluate which breeding programme is most effective. The selection of bulls, in particular, will take time. A pilot project is just starting in which a number of organic dairy farmers are going to supply breeding bulls from their own farms through AI (Anon., 2008b). The big question here is whether other organic farmers will want to use the selected bulls, or whether they may wish to work together to set up this "organic" AI programme. Perhaps a cooperative could be set up for this purpose in which clear agreements can be made. The results of the pilot project will be important for the further development towards breeding for organic dairy production.

The option of using natural mating leaves the decision directly to the farmer. Natural mating can be carried out at farm level, without any need for an external party to organise it. This is a huge advantage and probably an important reason why a growing number of organic dairy farmers are quietly adopting the practice. However, the social environment can be very significant in this option, because of the danger of bulls on a working farm, particularly if members of the public or care clients visit the farm. Working with bulls on a farm is more complicated and requires a good deal of practical knowledge. (Nauta *et al*., 2005b; Spengler-Neff and Metz, 2007).

Breeding as a basis for community building

In the organic sector, people try to form communities in which producers, processors, retailers and consumers pull together, understand each other and seek joint solutions to problems (IFOAM, 2005). Re-involving farmers in breeding, and with them, consumers and other social groups, could benefit the organic dairy sector in general. Within the sector, breeding with bulls on the farm was a reason for cooperation in the past and it often is today, too. (Strikwerda, 1998; Nauta *et al*. 2005). Breeding in organic agriculture can thus be used to increase cooperation between holdings and other stakeholders, for example for the benefit of a breed, or for a particular equivalent management regime, or to promote the production of a regional product. In addition to community building, such cooperative networks are important in extending systems for the exchange of knowledge and experience (Kroma, 2006; Grin and Van Staveren, 2007; Roep en Wiskerke, 2007). They offer advantages for each of the three breeding options – use of adapted conventional breeding, a bio-chain breeding programme and breeding based on natural mating. With the first two options, farmers can join forces with consultants and breeding experts in finding suitable bulls. This can lead to study groups working on breeding aims and bull dam and breeding bull selection. With the third option – natural mating – bulls service a more limited population and cooperation between farms can lead to the establishment of regional breeding groups.

With such new breeding structures, however, it is possible that new divisions of power will emerge within the sector, in which a small number of breeders who determine the direction of breeding and cause a loss of genetic variation, as has happened in the past (Strikwerda, 1998). Breeding is often in the hands of a small number of breeders who have a natural talent for it (Baars *et al*., 2005). On a regional scale, with cooperation between a small number of holdings, this can benefit farmers who do not wish to devote a lot of time to breeding. With larger scale structures, clear agreements have to be made (see also section 6.3: Ownership and community building) to prevent the development of power structures. This applies to all three options.

Mutual trust is also important for cooperation. In conventional breeding this is evident in, say, the reliability of the breeding values and in breeding companies' efforts to build confidence in new technologies like currently genomic selection (Veerkamp, 2008). But mutual trust is required even where bulls are exchanged within the organic sector. Information about the management of the holding, and the production data of animals must be both available and verifiable. This is probably easier to achieve in small groups where everyone knows each other. In larger groups or breeding structures, mutual trust depends more heavily on the figures and independent monitoring is needed.

Costs and benefits

On balance, where the breeding aims are the same, the use of the large conventional breeding structure provides a better return. The costs of a separate organic breeding programme are higher and there is no greater increase in genetic progress (Harder *et al*., 2004; Schmidko, 2007; Simianer, 2007). In the Netherlands it costs around EUR 30,000 to test a breeding bull. The calculation of special breeding values for organic breeding would also cost about EUR 30,000 per year (G. De Jong, 2007, NRS, personal communication.). Other matters, such as the selection of ET-free bulls, also take extra time. It is estimated that around 300 organic holdings use AI (Nauta *et al*., 2009, see Chapter 5), making the average cost of special breeding value estimation EUR 100 per farm per year. Costs could be reduced by expanding the market with more organic holdings abroad and/or with conventional holdings that have a similar breeding goal as organic (see section 6.3: Selecting suitable breeding stock).

For example, in setting up a closed bio-chain breeding programme with 25 bulls, testing would cost 25 x 30,000 = EUR 750,000 . This is certainly too high a price for 300 organic farms. The waiting time, several years in which bulls have to be kept in quarantine to prevent disease transmission, is particularly expensive. A so-called "cold" system, as used for the breeding program for MRIJ, or the 'young bull' system used for Guernsey cattle (Bichard, 2002), offers good prospects. In this system, bulls are culled after a certain quantity of semen has been frozen. There is no expensive waiting period. In the Netherlands, freezing 1000 doses of EU certified semen from one bull costs currently EUR 2,600 (KI-DeToekomst., 2008). The cost of using 25 bulls per year in the 'cold' system in the Netherlands would be EUR 65,000. The costs per dairy cow depend strongly on the number of participating farms (see also section 6.3: Selecting suitable breeding stock).

With breeding based on natural mating, breeding farms can generate extra income by selling breeding bulls for breeding or meat, particularly if they use a dual-purpose breed. The extra income can cover the costs of this type of breeding. (Nauta, 2005). The actual cost of rearing and housing the bulls depends very much on individual farm circumstances. With sufficient roughage and existing housing that is appropriate for bulls the costs are low, and the bulls can provide extra income.

Holdings which buy in bulls, only need to buy one young bull per year, at an estimated cost of EUR 1,200, depending on age and current slaughter value. If the housing costs are low, for example where the bulls is kept with the herd, the costs will be very limited compared with buying semen of breeding bulls (currently EUR 5 to 50 per bull) and artificial insemination (average cost EUR 15).

The returns must also be expressed in terms of genetic progress. It is difficult to say, however, which breeding option will give highest return. Many factors are involved (see section 6.3: Selecting suitable breeding stock) and simulations of different options are needed to answer this question. To give an idea of the range of possibilities for genetic gain in milk yield, Rendel and Robertson (1950) calculated that a farm with 100 milking cows and a closed breeding system can achieve 1% genetic progress in milk production per year, while the progress rate of a hypothetical AI-based breeding programme with 20,000 animals would be 1.8%. Dekkers (1992) reports that 2-3% genetic progress may be achieved in large populations, depending on programme characteristics such as progeny group size and the number of bulls being tested. Generally, however, the genetic progress rate for milk production rarely exceeds 1.5% per year (Brascamp, 1973).

It is not yet clear how the various costs and benefits stand in relation to social costs and benefits. For example, Boogaard *et al*. (2008) found that that the public expects there to be a bull on the farm. It is not known, however, whether having a bull on the farm would improve the sector's image and whether this translates into profit.

6.4 General conclusions with regard to the further development of breeding in organic dairy farming

The studies performed for this doctorate research are all part of a roadmap for a system of breeding in organic dairy farming that dovetails with the needs and preferences of the organic dairy sector, civil society organisations, consumers and other stakeholders. The general vision of dairy farmers and civil society is clear: breeding should be based on the principle of naturalness and should preferably take place within the organic chain, separately from the conventional sector (Nauta *et al*., 2005a, se Chapter 2). Breeding should also produce stock that is well-suited to organic dairy production (Nauta *et al*., 2005a, see Chapter 2). The breeding values of animals supplied by conventional breeding are based on conventional production environments. The differences identified between organic and conventional milk production demonstrate, however, that the effect of G x E reduces the accuracy of breeding values for organic production environments and makes it more difficult for organic farmers to select suitable animals (Nauta *et al*., 2006a and b, see Chapters 3 and 4). The fact that organic farmers themselves initiated the search for a suitable cow type and a suitable breeding system (Nauta *et al*., 2009, see Chapter 5) emphasises the importance of this issue for organic farming practice.

The issue of breeding for the organic dairy sector has many dimensions and many stakeholders (farmers, breeders, researchers, advisers and policymakers), both within and outside the organic sector, who all have a say with regard to the choices to be made. The various considerations (see section 6.3) illustrate the complexity of this issue in both breeding-technology and social terms. It is only when stakeholders join forces that the process towards a more appropriate breeding for organic dairy production can start to move forward. Restricting the use of conventional breeding would effectively mean the rejection – wholesale or in part – of a system with a long and successful history, and throw organic dairy breeding back on its own resources. This could cause difficulties, as organic dairy populations are relatively small compared to the conventional populations and the results the people were accustomed to achieving in the conventional breeding system would no longer be feasible. The existing system threatens to become dysfunctional, because it no longer satisfies the requirements.

These types of situation demand so called 'system innovations' at multiple levels which will create new, sustainable systems (Rotmans, 2005). System innovations are comprehensive changes that alter longstanding, firmly rooted patterns of thinking and acting (Grin and Van Staveren, 2007). Organic breeding demands a change in thinking from stakeholders (farmers, researchers, advisers and policymakers) as well as changes in breeding practices, the details of which need to be worked out. Comprehensive system innovations are rarely straightforward and require a considerable investment of time and energy.

Breeding for organic production is not a new issue – people have been thinking about it for a long time (Nauta *et al*., 2001). System innovations are often based on a joined learning path for all stakeholders. In the dairy sector, a learning path can be differentiated at three levels: 'micro level', in which farmers create scope for experimentation, 'meso level', in which the sector strives to bring change, and 'macro level', or the playing field of civil society (Geels en Kemp, 2000; Roep and Wiskerke, 2007). These three levels can also be distinguished in the development of organic breeding. Below, this theory is used to sketch a roadmap for breeding in the organic dairy sector.

A process of joined learning and innovation

System innovations in the dairy sector take place at three levels: the individual farm, the sector and society. The interaction between these levels is particularly important in order to realise change (Roep, 2000). Each level has its own learning process and, when followed together, they may jointly result in sustainable, self-driven innovation. Good connection and interaction between the learning paths are key to system innovation (Roep and Wiskerke, 2007). The final outcome of a system innovation, that is, the features of the new system, is often unknown (Rotmans, 2005; Grin and Van Staveren, 2007). Actors each have their own capacities and motives (Alrøe and Noe, 2008), however, they have to follow a joined learning path that will ultimately reveal possible solutions. Innovations may take place with a specific goal in mind, or not (Grin and Van Staveren, 2007). The goal for organic breeding, for instance, could be breeding based on natural mating, which dovetails closest with organic agricultural principles. From a system-innovation point of view, it might be advisable, while maintaining this ultimate goal, to explore several if not all of the available options, as banning certain technologies might one day result in a process blockade or 'lock-in'. For example, if genomic selection were banned and later found to have high value for promoting genetic diversity in on-farm breeding based on natural mating, the ban would effectively pose an obstacle to the realisation of the organic objectives of diversity and naturalness through breeding. In other words, a 'lock-in' narrows the available choices and may lead to process collapse if it limits diversity – a key condition for innovation thrives – too severely (Rotmans, 2005). Interestingly, Verhoog *et al*. (2003) also concluded that it was important initially to keep as many options open as possible, in the interests of development. Precipitate decisions on restricting the use of conventional breeding would frustrate the development process. Also Alrøe and Noe, (2008) describe such a development. Both, however, emphasise that farmers and the sector should work towards a common goal, in this case, breeding based on natural processes.

It is important to initiate and maintain a joined learning process at all three levels. A survey of stakeholders' visions on breeding kicked off the learning process (Nauta *et al*., 2001 and 2005). Researchers, farmers and others in the sectors, and civil society organisations and consumers started thinking about the issue. After the survey and the resulting stakeholder discussions, experiments were carried out at various levels in a number of countries. More and more farmers started using their own bulls and/or practising natural mating (Nauta *et al*., 2009; Spengler and Metz, 2007), while researchers in several countries started examining the breeding-related concerns (Nauta *et al*., 2006a, 2006b, see Chapter 3 and 4; Nauta, 2008; Bapts, 2001 and 2007; Schmidko, 2007) and shared their findings at scientific congresses and meetings (Hovi and Baars, 2001; Nauta *et al*., 2006c and 2006d; Nauta and Roep, 2007; Simianer, 2007; Nauta and Roep, 2008). Recently, an international organisation for organic breeding, The European Consortium of Organic Animal Breeding (Eco-AB), was established with the goal to support the development of organic animal breeding (Eco-AB, 2008). There have also been several initiatives to support farmers, such as the selection of ET-free breeding bulls (Nauta en Langhout, 2004), a course on family breeding (Nauta and Schimmel, 2003), and support for on-farm breeding in various countries (NSbdK, 2006, Bapst, 2003; Spengler and Metz, 2007; Postler, 1998).

These activities together form the stakeholder arena at meso level (Grin and Van Staveren, 2007). In this arena, stakeholders work on the development of a suitable breeding system for organic agriculture. This level is characterised by a complex degree of organisation – an interweaving of strategic, organisational, technical, social, financial and practical considerations and interests – and strong resistance to change must be anticipated (Grin and Van Staveren, 2007). In addition, the organic sector itself is still in development – farmers themselves are trying out different management strategies which has made the sector hugely diverse (Nauta *et al*., 2009). Breeding is not merely about applying reproduction techniques and selecting animals based on calculated breeding values. There are as many opinions as there are stakeholders – including consumers – about what constitutes good breeding practice and what are the characteristics of a good milking cow. This means that both breeding-technology and institutional issues need to be addressed on the path towards breeding based on organic farming principles, and effective interaction between the two is crucial. Breeding is, after all, an established practice embedded in beliefs, rules and regimes, with their associated structures and interests. Introducing change within an existing system and achieving a comprehensive transition requires the time, input and support of a broad coalition (Grin and Van Staveren, 2007; Rotmans, 2005). This type of innovation is a multi-level, multi-dimensional and multi-stakeholder process.

Often, the pace of development is faster at micro level (Grin and Van Staveren, 2007, Roep and Wiskerke, 2007). As entrepreneurs, farmers have a fair degree of autonomy; there is little to stand in their way if they decide to carry out breeding based on natural mating (Van der Ploeg, 2000). This decision does not require major institutional reform. After some minor changes on the farm, farmers are ready to start using bulls, learning as they go along how the desired genetic results might be achieved (Nauta and Schimmel, 2003). Progress at this operational level takes place gradually through knowledge sharing among farmers and between researchers, consultants and farmers (Kroma, 2006). In view of the enormous diversity in organic farms, on-farm breeding often requires a tailor-made approach (Nauta *et al*., 2009, see Chapter 5).

System innovation at macro level concerns the overriding objectives of organic agriculture, such as working in sustainable systems and maintaining and promoting biodiversity. The latter goal ties in with broader biodiversity objectives at national and international level, as laid down in, for instance, the Convention on Biodiversity (MinLNV, 2008) and thus runs parallel to more comprehensive change processes (transitions). By giving more publicity to its own role in biodiversity preservation, the organic sector could exploit the strong international focus on preserving biodiversity (Tak, 2007).

So many different activities being conducted at different levels by different actors in different countries give the overriding impression of fragmentation. The lack of interaction and the failure to connect learning processes restricts the joined learning capacity (Roep, 2000). Many breeding-related activities in organic agriculture are carried out independently of each other [in isolation], so that little is learned from each other. For instance, debates on organic breeding were conducted in various countries (Nauta *et al*., 2001, Simianer, 2007; Bapst, 2003), but little information was exchanged between the initiators. Another example is the ecological breeding value estimation method developed in Germany, Switzerland and Austria (Postler, 1999), which so far is not available outside these countries. Among farmers, too, little information has been shared about on-farm experiments with own bulls and/or selecting breeding animals. A joined learning process thus requires regional, national and international networks which connect stakeholders at all levels. Only then can innovations at the various levels mutually reinforce each other (Rotmans, 2005). In this way, new innovations at farm level, such as using land races or breeding with own bulls, can become 'seeds of transition' (Wiskerke and Van der Ploeg, 2004) which challenge actors at higher levels to find a way to cultivate these innovations and processes effectively.

Knowledge gaps

The generation and dissemination of knowledge among stakeholders is a precondition for innovation and good decision-making (Kemp *et al*., 2007; Rotmans, 2005). Several knowledge gaps remain with regard to breeding in organic agriculture. This doctorate research comprised a first survey of visions on breeding among organic dairy farmers and relevant civil society organisations (Nauta *et al*., 2005a, see Chapter 2; Nauta, 2008) and an investigation of the genotype by environment interaction between conventional and organic dairy production (Nauta *et al*., 2006a and b). In addition, various researchers have described practices in organic breeding and farmers have started experimenting with different breeding methods. Yet there is still insufficient knowledge about, for instance:

- the effect of G x E between conventional and organic agriculture in and between countries;
- the possibilities offered by different breeding programmes – calculations need to be made for an accurate comparison of programmes;
- the cow types required for the various types of farm;
- bull housing and management;
- society's perceptions with regard to breeding in organic agriculture, i.e. the sector's public image in this area;
- the social costs and benefits of a more natural breeding system.

In addition to shortcomings in knowledge development, existing knowledge is not disseminated or used effectively. This has severely restricted the sector's joined learning capacity. While there have been many projects involving alternative breeding systems, conducted by researchers as well as organic dairy farmers, both independently and in small networks, little has been done with the results and, in particular, little has been learned. This problem is not unique to the Netherlands. There have been similar initiatives in Germany, Denmark, the UK and Switzerland, but so far there has been little collaboration between the various groups and/or countries concerned (see previous section). The result is fragmented knowledge acquisition and dissemination. In order to reach international agreement on breeding in organic agriculture, an innovation process should also be started at international level.

Embedding innovation and keeping course

A true transition towards a sustainable system will only be achieved by embedding innovations and an ongoing review of the joined learning process (Grin and Van Staveren, 2007; Roep and Wiskerke, 2007). How can system innovations concerning breeding in organic agriculture be embedded in farming practice, thus leading to sustainable breeding for the organic sector? In other words, who will lead the way? In which practises will breeding be embedded and how will the course be determined? Perhaps breeding in organic farming could be taken up by existing institutional structures, but it is also possible that new actors, individuals, organisations or companies are required.

In a system innovation, pilot projects are often carried out to test whether certain practices are sustainable and how they might be improved (Grin en van Staveren, 2007). The ET-free bull chart was the outcome of a small pilot project which revealed that conventional breeding still offers a reasonable number of ET-free bulls (Nauta and Langhout, 2004). Some organisations still publish lists of ET-free bulls today (Anon., 2008c). In Switzerland, too, research into demand for ET-free bulls and bulls suited to organic production conditions resulted in a special bull chart that is still maintained today (Bapst and Spengler, 2003). In Germany, Switzerland and Austria, many organic farmers rely on breeding value estimates calculated especially for ecological dairy production (ÖGZ) (Postler, 2008). Discussions about organic breeding and the increased availability of information about breeding based on natural mating are causing more and more farmers to decide to use natural mating (Nauta *et al*., 2009). But more pilot projects need to be conducted if there is to be a common approach to breeding. These might examine the feasibility of, for instance, AI bulls selected especially for the organic sector or investigate the conversion to kin breeding (Nauta *et al*, 2005). New breeding networks or learning communities could bring together farmers/breeders, researchers, consultants and policymakers, so that they could discuss and explore the various options and resolve problems together. The results of pilot projects also need to be reviewed, so that the course can be changed if necessary. Ongoing support for this process could result in breeding that is increasingly suited to organic dairy production and that is firmly embedded in the organic sector.

Closing remarks

A process of technical and institutional renewal with regard to organic breeding has come into motion. System innovation is required at all levels. In particular, the interaction between these levels will facilitate a joined learning process, resulting in innovation aimed at breeding based on organic principles and practices. In this process of system innovation, it is important to keep as many options open as possible.

The difficulty is, however, that the organic sector is bound to regulations concerning production methods and that it must foster its public image. Certain restrictions might strengthen the sector's image and the market for organic products in general. In view of the application of new technologies in conventional programmes, such as sexed semen and marker and genomic selection, it may be strategic to develop a definition of organic breeding. Until now, the organic sector has neither adopted a formal standpoint on these technologies nor developed regulations in this regard. It is necessary that such action is taken.

Restrictions can also boost innovation. The introduction of advanced reproduction technologies in plant breeding forced organic plant breeders to think about where they stood and [deliberate addition] they eventually decided against using these technologies. This culminated in Commission Regulation (EC) 1452/2003 concerning the organic propagation of seeds (EU, 2003). The new regulation has had a positive effect on the continued development of organic plant breeding (Lammerts Van Bueren *et al*., 2002 and 2003a and 2003b). Making choices might also pay for animal breeding. The results presented in this thesis, when considered as a whole, suggest that organic dairy breeding might do well to set out its own course, taking natural mating as its starting point. Around a core group of breeding farms using natural mating, an AI system could be set up for practical reasons. It would be fairly easy to justify AI used in this context to society at large. It would, on the other hand, be more difficult to explain the use of conventional breeding, in view of the wide scale application of unnatural production technologies. The so-called young bull system, which achieves similar genetic progress at a much lower cost (Bichard, 2002) certainly deserves serious consideration.

Finally, it is important to rein in the tendency to seek a uniform solution for breeding in the organic sector. For commercial reasons, conventional breeding often focuses on one breeding goal with high market potential. Organic agriculture, however, attaches special value to biological, social and cultural diversity (IFOAM, 2002). The larger the group of farmers that is working to optimise their production systems – for which suitable animals, including breeding bulls, are needed – the better agro-biodiversity is ensured. In this, it is advisable to choose solutions developed within the organic sector and seek to optimise their potential.

As I have argued in this discussion, organic dairy farmers need cows that perform well in extensive production environments and on a roughage diet. There is a growing debate on whether and to what extent organic farming can go into conventional methods (Alrøe and Noe, 2008). The use of conventional breeding animals with a high production potential tends to result in a more conventional interpretation of organic production and management, i.e. the purchase of concentrates so that cows get the calories they need. While this is sound management from the viewpoint of animal welfare, this type of cow does stand in the way of the development of an organic system that is tied to the land and local resources. Selecting breeding bulls that originate from an extensive organic environment may accelerate the development of organic agriculture.

This thesis focused on breeding for organic dairy production, but the issues raised here apply equally to other animal production sectors (Nauta *et al*., 2001 and 2003). In principle, the conclusions and recommendations resulting from this research apply to the breeding of organic pigs, goats and poultry. These sectors, too, lack breeding systems that dovetail with organic production environments.

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Summary

Organic farming has a long history in Europe. Until the late1980s, organic farming in the Netherlands was largely equivalent to bio-dynamic farming. Organic production started to take off in the early 1990s. The European Union laid down organic standards in order to give consumers assurance of the integrity of organic products. Since then, organic agricultural production has continued to grow steadily.

Organic farming systems differ from conventional systems in many aspects. In general, the functional integrity of production prevails over resource sufficiency in organic farming, while it is the other way around on conventional farms. Organic production is more strongly tied to local resources, either farm-based or area-based.

Organic farming is still developing to achieve all its goals. One aspect requiring more organic development is breeding. Only incidental steps have been taken towards organic breeding. When the majority of the dairy farmers switched over to organic production at the end of the 90s, most milked Holstein cows and experienced a significant decline in milk yield. Moreover, many cows on organic farms developed health and fertility problems and the question arose as to what type of cow would be suitable for the extensive production environments in organic agriculture, given the differences with conventional farming.

At the same time, questions arose about the use of modern and artificial reproduction techniques which are used in conventional breeding programmes, of which most organic farmers use breeding bulls. Legislation concerning animal selection and breeding technologies in organic farming is limited and vague. It provides that “animals should be able to adapt to the local environment” and “local breeds are preferred”. As for breeding technologies, the direct use of AI is allowed but ET is not. Through the use of AI breeding bulls from conventional breeding, however, organic agriculture uses breeding technologies like ET indirectly. The artificiality of these techniques conflicts with the principle of naturalness in organic agriculture. Furthermore, they contribute to loss of genetic variation in dairy cow populations and so hamper the pursuit of biodiversity in agriculture. The debate about a suitable cow type and the use of conventional reproduction techniques formed the basis for this doctorate research.

Before statements could be made about these questions, several studies were carried out, starting with an investigation into organic dairy farmers’ and other stakeholders’ visions on breeding. (see Chapter 2). Organic dairy farmers indicated that they want a breeding system which is in keeping with the principles of organic agriculture, based primarily on the conviction that breeding should be part of a closed (milk production) chain. They also indicated that cows from conventional stock did not perform well on their farms: these cows persistently gave too much milk in relation to the amount of feed they could take in, which led to health and fertility problems. To bring breeding

more into line with organic principles, 95% of the 50 participating farmers were keen to use bulls that were not produced by embryo transplantation (ET). Around 50% of farmers wanted to work towards a breeding programme based entirely on organic stock. The other half, however, wanted to retain the option of selecting bulls from the entire range, including the conventional sector, mainly because of the greater genetic variation this offers. Some respondents wanted breeding based on natural mating rather than artificial insemination (AI). Various civil society organisations agreed with this vision based on their conviction that the image of organic agriculture would be enhanced by a specific organic breeding system. They also thought that organic breeding should in due course be subject to national or international regulations and certification for organic production.

Some years after the vision survey, organic dairy farmers were asked to fill in a questionnaire about their breeding aims in relation to their farm management and the choices they made in the selection of breeding animals (see Chapter 5). This study showed that many farmers were already experimenting with breeds and crosses in a quest for the most suitable type of cow for their farm. Despite differences in farm management, organic farmers had more or less the same breeding aim. Compared with the conventional breeding aim, with a fifty-fifty spread over production and functional traits, the organic dairy farmers give a weighting of 68% to functional traits

It is remarkable that organic dairy farmers are now pursuing this breeding aim through the selection of different breeds and crosses. In the mid 2000s, 30% of organic dairy farmers were crossing their Holstein cows with different native and foreign breeds. The study did not, however, demonstrate any relationship between the farm management system and the breed or cross used, which indicates that although farmers demand suitable animals, they do not know what type of cow this would be. This may be due in part to a lack of useful information about how different breeds and cross breeds function under different farming regimes. On the other hand, organic farmers may have started using different breeds for other reasons, such as their more individual approach to farm management, their greater readiness to experiment and their preference for certain breeds in the interests of preserving agro-biodiversity, cultural or historic values or of raising the profile of their organic production methods. A remarkable finding was that a growing number of organic farmers intend to use bulls for natural mating for reasons such as the desire for a natural and organic breeding system.

An important issue in the discussion about the need for a separate breeding programme for organic was the importance of the effect of genotype-environment interaction (G x E) between organic and conventional dairy production. To analyse this effect, data on the milk production and fertility of dairy cows on conventional and organic dairy farms were collected and analysed for differences and G x E between conventional and organic milk production (see Chapters 3 and 4). There proved to be significant differences in levels of milk production, percentage of protein in the milk, milk cell count and fertility between Holstein heifers on the two types of holding (see Chapter 3).

The effect of G x E can be measured by estimating the genetic correlation between the breeding values of related animals which produce in different environments. A genetic correlation

of 0.80 was found for milk production and 0.78 for protein production between the breeding values for milk production traits, estimated on the basis of data from conventional and organic production environments in the Netherlands. Such a correlation indicates that G x E has a fairly large impact on the production traits of dairy cows in conventional and organic agriculture. This effect is probably due to the lower uptake of energy by cows in organic agriculture, due to both a lower energy content in organic fodder and a smaller proportion of concentrate. However, tighter regulations for organic feed are expected to lead to decreased concentrate use and a increase of the effect of G x E.
Based on the results of the different studies, three distinct options can be formulated for the future of organic breeding , ranked in order of naturalness:

(1) use of adapted conventional breeding (ET-free and suitable bulls);
(2) a separate breeding programme within a closed organic chain (bio-chain breeding programme);
(3) breeding based on natural mating.

The three options all have their advantages and disadvantages for the organic dairy farmer in relation to naturalness, technical breeding issues, societal concerns, image and costs and benefits (see Chapter 6). Breeding based on natural mating is closest to the natural process of reproduction. Without AI, however, every farm would have to use a bull for natural mating, which is thought to be impracticable. Most organic dairy farmers regard AI as indispensable. With regard to the use of adapted conventional breeding, organic farmers have a preference for bulls which have not themselves been produced by ET. Yet most of these breeding bulls are from elite breeding programmes which make extensive use of ET if not in this, then in previous generations, which limits the use of these breeding programmes.

Techniques such as AI and ET are often linked to loss of genetic diversity, which would not be in line with the organic principles. In a bio-chain breeding programme, sound agreements would have to be made to prevent too great a loss of genetic diversity. Nowadays, marker and genome selection and the use of sexed semen are strongly promoted in conventional breeding systems. Cloning and cisgenesis may, in time, also be incorporated in international breeding programmes. These technologies raise several concerns in the organic sector. Introducing even more advanced technologies into breeding, which reduce the degree of naturalness even more, goes against the grain for many organic farmers and will probably make it impossible for organic agriculture to use of such breeding programmes any longer.

A separate organic breeding programme based entirely on animals that are bred on organic farms does have advantages for a closed organic production chain. However, conventional, world wide breeding programmes make use of large animal populations, which facilitates faster genetic progress. The greater degree of variation in a large, open, worldwide dairy population allows for a larger selection intensity, which leads to a larger selection result in the next generation. The magnitude of G x E between conventional and organic dairy production also has a role to play.

Information on G x E is, however, still limited. The genetic correlation between breeding values estimated for conventional and organic dairy production in the Netherlands was calculated to be 0.80 (see Chapter 4). Opinions differ however, as to whether an effect of this magnitude warrants a separate breeding programme addressing specific production conditions.

A bio-chain breeding programme would be more feasible and less costly with a considerably larger organic population. This might require an international approach based on populations from several countries. Additionally, costs could be reduced through a 'cold' AI breeding system and more natural mating.

The image of organic farming and issues of ownership may play a role in decisions on which breeding option is desired. However, the public and consumers have little knowledge about current breeding practices. As for ownership of organic cattle breeding, there are several possibilities. As yet, however, there is little information about the genetic and financial feasibility of the various possibilities.

The description of strengths and weaknesses of each of the three different options illustrates the complexity of the breeding issue in both breeding-technology and social terms. Restricting the use of conventional breeding would effectively mean the rejection of a system with a long and successful history, and throw organic dairy breeding back on its own resources. The existing system threatens to become dysfunctional, because it no longer satisfies the requirements. These types of situation demand so called 'system innovations' at multiple levels which will create new, sustainable systems.

It is only when stakeholders join forces that the process towards a more appropriate breeding in organic dairy production can start to move forward. System innovations in the dairy sector take place at three levels: the individual farm, the sector and society. It is important to initiate and maintain a joined learning process at all three levels.

In recent years, many different activities have been conducted at different levels by different actors in different countries. However, they give the overriding impression of fragmentation and a lack of interaction between different levels and actors. A joined learning process is required between regional, national and international networks which connect stakeholders at all levels. Only then can innovations at the various levels mutually reinforce each other. Ongoing support for this process could result in breeding that is increasingly suited to organic dairy production and that is firmly embedded in the organic sector.

Finally, in order to facilitate this development, it is important that clear lines are drawn for animal breeding based on organic principles. This could have a beneficial knock-on effect on the sector's development in general. In seeking to develop organic breeding, it is important to maintain a broad view rather than focusing on a uniform, "one size fits all" solution, as the latter approach is in conflict with the development of robust systems.

Samenvatting

Biologische landbouw heeft een lange geschiedenis in Europa. Tot de late jaren '80 bestond biologische landbouw voornamelijk uit biologisch-dynamische bedrijven. In de jaren '90 zijn grote aantallen gangbare melkveehouders omgeschakeld naar biologische melkveehouderij. De Europese Unie publiceerde regelgeving voor biologische productie waarmee de consument duidelijkheid kreeg over de gecontroleerde kwaliteit van de biologische producten. Nadien is de biologische productie gestaag gestegen.

Biologische productie verschilt op veel gebieden van de gangbare productiemethoden. In h*et al*gemeen is de biologische productie voornamelijk gestoeld op functionele integriteit in plaats van het optimaal omzetten van grondstoffen in humane voedingstoffen. In de gangbare landbouw is het omgekeerde de praktijk. Daarbij is biologische productie meer grondgebonden op bedrijfsniveau en/of op regionaal niveau.

Biologische landbouw ontwikkelt nog steeds richting haar doelen. Fokkerij verdient in deze ontwikkeling meer aandacht. Tot nu toe zijn alleen nog maar een aantal kleine incidentele stappen gezet richting biologische fokkerij. De meeste van de huidige biologische melkveehouders (80%) zijn eind jaren '90 omgeschakeld naar biologische productie. De meeste van deze veehouders bleven koeien melken van het Holstein Friesian ras en maakten met deze koeien een duidelijke daling in melkproductie mee. De koeien kregen tevens problemen met de vruchtbaarheid en gezondheid en hierdoor rezen vragen over wat gegeven de van de gangbare landbouw afwijkende bedrijfsvoering, een geschikt koetype zou zijn voor de biologische landbouw.

Tegelijk rezen ook vragen over moderne voortplantingstechnieken die worden gebruikt in de gangbare fokprogramma's en via het inzetten van de KI-fokstieren uit deze fokprogramma's ook direct en indirect in de biologische landbouw worden gebruikt. De regelgeving voor biologische productie is voor de fokkerij beperkt en vaag. KI wordt toegestaan maar embryotransplantatie niet. Echter, door het gebruik van stieren die uit ET komen gebruikt de biologische landbouw deze techniek indirect. Het onnatuurlijke karakter van zulke technieken strookt niet met de uitgangspunten van de biologische landbouw. Verder kunnen deze technieken ook bijdragen aan het verlies van genetische variatie. Dit laatste past ook niet bij het streven naar biodiversiteit in de biologische landbouw. Het vraagstuk omtrent het koetype dat past bij de biologische melkveehouderij en het gebruik van de moderne voortplantingstechnieken vormden de basis voor dit proefschrift.

Om tot uitspraken over bovenstaande vragen te kunnen doen, zijn er meerdere onderzoeken uitgevoerd, te beginnen met een onderzoek naar de visie van de biologische melkveehouders en een aantal maatschappelijke organisaties op fokkerij (zie Hoofdstuk 2). De veehouders gaven aan een fokkerij te wensen die in overeenstemming is met de uitgangspunten van de biologische landbouw. Als belangrijkste reden voeren zij aan dat de ook fokkerij deel moet zijn van een gesloten melkproductie keten. Verder gaven zij te kennen dat koeien uit het gangbare aanbod niet voldeden op hun bedrijf. Deze dieren bleven teveel melk produceren in verhouding tot de hoeveelheid voer die kon worden opgenomen en dat gaf problemen met de gezondheid en vruchtbaarheid.

Om de fokkerij meer in overeenstemming te brengen met de uitgangspunten van de biologische landbouw was 95% van de 50 deelnemende veehouders graag bereid om stieren te gebruiken die niet uit embryotransplantatie (ET) zijn voortgekomen. Ongeveer de helft van de veehouders wilde toewerken naar een fokprogramma dat geheel binnen de biologische keten wordt uitgevoerd. De andere helft wenste echter de beschikking te houden over het gehele aanbod van stieren, dus ook uit de gangbare sector, vooral vanwege de grotere genetische variatie die dan voorhanden is. Enkele deelnemers wensten een op natuurlijke dekking gebaseerde fokkerij i.p.v. kunstmatige inseminatie (KI). Verschillende maatschappelijke organisaties sloten zich aan bij deze visie omdat het imago van de biologische landbouw gediend is met een specifiek biologische fokkerij. Op termijn zou ook de fokkerij onderworpen moeten zijn aan officiële (internationale) regulering en certificering voor biologische productie.

Enige jaren na het onderzoek naar de visie op fokkerij, werden de veehouders via een enquête gevraagd naar hun fokdoelen in relatie tot hun bedrijfsmanagement en keuze voor fokdieren (zie Hoofdstuk 5). Dit onderzoek leverde een beeld op van veel veehouders die al experimenterend met rassen en kruisingen op zoek waren naar een geschikt type koe voor hun bedrijf. Het fokdoel van de biologische melkveehouders was over h*et al*gemeen gelijk voor alle biologische melkveehouders, ongeacht hun verschillen in bedrijfsvoering. Ten opzichte van het gangbare fokdoel met een fifty-fifty verdeling over productie en functionele kenmerken, leggen de biologische melkveehouders 68% gewicht op functionele kenmerken. Opmerkelijk was hoe de biologische veehouders dit fokdoel met de keuze voor verschillende rassen en kruisingen proberen te bereiken. Rond 2005 bleken 30% van de biologische melkveehouders hun Holsteinkoeien te kruisen met verschillende rassen uit binnen en buitenland. Uit het onderzoek blijkt echter geen relatie tussen de bedrijfsvoering en het ras of kruising dat werd gebruikt, hetgeen aangeeft dat de veehouders op zoek zijn naar geschikte dieren maar dat het voor hen niet duidelijk is welk type dier geschikt is voor hun bedrijfsvoering. Een reden hiervoor is wellicht het gebrek aan goede informatie over het functioneren van de verschillende de rassen onder verschillende bedrijfsregimes. Daarnaast zijn er ook andere mogelijke oorzaken aan te wijzen die voor deze veranderingen. Zo hebben biologische boeren een meer eigenzinnige aanpak van hun bedrijf, experimenteren ze meer en hebben ze een voorkeur voor bepaalde rassen vanwege het in standhouden van biodiversiteit, culturele en historische waarden of om hun biologische productiewijze zichtbaar te maken. Opmerkelijk was dat een groeiend aantal veehouders ging fokken met natuurlijk dekkende stieren, bijvoorbeeld een natuurlijke en biologische fokkerij na te streven.

Een belangrijk onderwerp in de discussie over het kunnen selecteren van de juiste fokdieren voor de biologische productie was het effect van genotype-milieu interactie (G x E) tussen biologische en gangbare productiemilieus. Om dit effect te analyseren zijn verschillen en het effect van G x E geanalyseerd tussen gangbare en biologische melkproductie van Holsteinvaarzen (zie Hoofdstuk 3 en 4). Er bleken significante niveauverschillen te bestaan voor melkproductie, eiwitpercentage in de melk, melkcelgetal en vruchtbaarheid tussen Holsteinvaarzen op beide bedrijfstypen (zie Hoofdstuk 3). Het effect van G x E kan worden gemeten door de genetische correlatie te schatten tussen de fokwaarden van verwante dieren die produceren in verschillende milieus. Tussen de fokwaarden van melkproductiekenmerken die werden geschat op basis van gegevens uit het gangbare en biologische productiemilieu, werd een genetische correlatie van 0.80 gevonden voor melkproductie en 0.78 voor eiwitproductie (zie Hoofdstuk 4). Een dergelijke correlatie geeft aan dat er een tamelijk groot effect bestaat van G x E tussen productiekenmerken van melkkoeien in de gangbare en biologische landbouw in Nederland. Dit effect wordt waarschijnlijk veroorzaakt door een lagere opname van energie door de dieren in de biologische landbouw, zowel door een lagere energie-inhoud in het biologisch ruwvoer als ook door een lagere krachtvoergift. Het onderzoek betreft echter wel een momentopname. Door verscherping van de regelgeving op dit terrein is te verwachten dat het krachtvoergebruik op biologische bedrijven zal afnemen en het effect van G x E zal toenemen.

Op basis van de resultaten van de verschillende studies zijn drie onderling duidelijk af te bakenen opties voor een toekomstige biologische fokkerij te formuleren. Gerangschikt naar een steeds natuurlijker aanpak zijn dit:

(1) Gebruik van een aangepaste gangbare fokkerij
(2) Een afzonderlijk fokprogramma binnen een gesloten biologische keten (bio-ketenfokprogramma)
(3) Fokkerij gebaseerd op natuurlijke dekking

Elke optie kent zo zijn eigen overwegingen en afweging van voor en nadelen in relatie tot de natuurlijkheid, foktechnische mogelijkheden, het imago, en kosten en baten van de fokkerij (zie Hoofdstuk 6). Fokkerij op basis van natuurlijke dekking is het meest natuurlijk. Zonder KI zou echter elke veehouder met een stier moeten werken, wat praktisch onhaalbaar lijkt. De meeste biologische veehouders zien KI dan ook als onmisbaar. Echter, zij wensen KI stieren te gebruiken die niet uit ET voort zijn gekomen. KI-stieren uit de gangbare fokprogramma's zijn echter voor een groot deel uit ET voortgekomen, wat het gebruik van deze fokkerij zeer beperkt. Technieken als KI en ET worden vaak in verband gebracht met het verlies aan genetische variatie. Dit is ook een reden waarom deze technieken niet bij de biologische landbouw zouden passen. In een mogelijk bio-ketenfokprogramma zouden daarom bij het gebruik van KI duidelijke afspraken moeten worden gemaakt omtrent het voorkomen van het verlies van genetische variatie.

Tegenwoordig worden het seksen van sperma en genoomselectie sterk gepromoot vanuit de gangbare fokprogramma's. Tevens zouden klonen en cisgenese in internationale fokprogramma's hun intrede kunnen krijgen. Deze technieken roepen veel vragen op in de biologische sector. De introductie van meer technologie in de fokkerij is strijdig met het streven naar natuurlijkheid en stuit veel veehouders tegen de borst. Zulke technieken in de gangbare fokkerij kan het gebruik daarvan onmogelijk maken.

Een fokkerij die is gebaseerd op dieren die op biologische bedrijven zijn gefokt geeft voordelen voor een geheel gesloten biologische productieketen. Echter, gangbare fokprogramma's maken gebruik van grote wereld wijde populaties waardoor snelle genetische vooruitgang mogelijk is. Door grote variatie binnen deze wereldwijde fokprogramma's kan immers de selectie-intensiteit toenemen wat het selectieresultaat verhoogt. Hierbij speelt echter het effect van G x E een rol maar er is nog te weinig informatie over dit effect. De genetische correlatie tussen biologische en gangbare melkproductie is geschat op 0.80 (zie Hoofdstuk 4). De meningen verschillen echter of een dergelijke correlatie genoeg is voor het opzetten van een apart biologisch fokprogramma. Een echt groot biologisch fokprogramma zou hiervoor ook meer mogelijkheden bieden en minder duur zijn. Hiervoor zou een internationale aanpak nodig zijn. Daarnaast zou een 'koud' systeem en meer gebruik van natuurlijke dekking de fokkerij ook minder duur maken.

Het imago van de sector en het eigenaarschap van een biologische fokkerij spelen mogelijk ook een rol bij de keuze voor een bepaalde aanpak van de fokkerij. Voor verschillende partijen zijn er mogelijkheden om de fokkerij in de biologische landbouw op te pakken. Er is echter nog weinig informatie over de financiële en genetische haalbaarheid van de mogelijkheden.

De beschrijving van voor en nadelen van de verschillende opties illustreren de complexiteit van het vraagstuk, zowel foktechnisch als ook sociaal. Een restrictie van het gebruik van de gangbare fokkerij betekent dat een systeem met een lange succesvolle geschiedenis verliest zijn functionaliteit, waardoor de biologische landbouw op eigen kracht verder moet. Het bestaande systeem werkt niet meer omdat het niet meer voldoet aan de verwachtingen. In een dergelijke situatie is een zogenaamde 'systeeminnovatie' nodig op verschillende niveaus die tot een duurzaam nieuw systeem moet leiden. Voor een ontwikkeling richting een duurzaam foksysteem is het nodig dat verschillende partijen gezamenlijk optrekken. In de melkveehouderij vinden systeeminnovatie plaats op drie verschillende niveaus: op bedrijfsniveau, in de sector en op maatschappelijk niveau. In de afgelopen jaren zijn veel verschillende activiteiten georganiseerd op verschillende niveaus en door verschillende partijen in verschillende landen. Tussen deze activiteiten is weinig interactie en uitwisseling van kennis geweest. Voor een duurzame ontwikkeling is een gezamenlijk leerproces nodig m*et al*le partijen op verschillende niveaus en in verschillende landen. Dit proces moet constant worden gefaciliteerd om tot een passend foksysteem te komen dat goed geborgd is in de biologische sector.

Voor deze ontwikkeling is het belangrijk dat er duidelijke lijnen worden uitgezet die zijn gebaseerd op de uitgangspunten van de biologische landbouw. De ontwikkeling van een biologische fokkerij kan zo een positief effect hebben op de ontwikkeling van de biologische melkveehouderij als geheel. In de zoektocht naar een passend foksysteem is het ook belangrijk dat er niet gefocussed wordt op een uniforme oplossing omdat dit de ontwikkeling van een robuust systeem in de weg staat.

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Wytze Nauta

Curriculum vitae

Wytze Jan Nauta was born in March 1964 and grew up on a dairy farm in the northern Dutch province of Friesland. After completing his secondary education, he studied animal husbandry and breeding at the Higher Agricultural College in Leeuwarden, graduating in 1986. With farm succession not a viable option, Mr Nauta decided to pursue his interest in animal breeding at the Department of Animal Sciences at Wageningen University. While studying quantitative breeding, he also became deeply interested in developmental biology and genomics. Mr Nauta's first graduate project was a study into the genes that play a role in milk protein production. He carried out a second study at Colorado State University, concerning the *in vitro* production of bovine embryos. Mr Nauta graduated from Wageningen University in 1991 with three majors, Animal Breeding, Animal Husbandry and Biotechnology.

After graduation, Mr Nauta was hired by the Dutch Research Institute for Animal Husbandry and Animal Health to conduct a study into the feasibility of cloning in livestock production. Then, after a brief stay in Colorado, he set up a business for the commercial *in vitro* production of bovine embryos. He soon developed doubts about the sustainability of pursuing maximum milk yield, the primary focus of conventional production, in the light of increasing animal health and fertility problems. Unable to reconcile his views with his line of work, he sold the business.

Mr Nauta started working at Louis Bolk Institute in 1998, after a chance encounter with Ton Baars, then head of the livestock farming section, who was conducting research into breeding systems for the organic dairy sector. Mr Nauta's first project at the Institute, 'Partner Farming', was aimed at achieving closed mineral cycles in the organic chain. Funding then became available for the project 'A vision on animal breeding', a collaboration with Wageningen University's Animal Breeding and Genetics Group and Rural Sociology Group. This project led to follow-up funding for doctorate research into selective animal breeding and organic dairy production.

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Organic farmers lack a specific organic breeding system. Therefore they either have to keep a bull at the farm for natural service, or use bulls from conventional breeding programmes for artificial insemination. Given the aims of organic farming, this situation raises issues in relation to naturalness of breeding, suitability of animals, ecology, bio-diversity and socio-economics. This doctoral research examines whether organic dairy farming needs a distinct organic breeding programme, and how such a breeding programme could be developed.

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