

# Quantifying the value of genetically specific organic lines within dairy breeding

PhD progress report  
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## Introduction

In animal breeding, breeding goals are defined to give relative importance to certain traits, usually based on economic weights (Groen et al., 1997). In Denmark, Finland, and Sweden, the Nordic Total Merit index (NTM), based on common economic weights, is used as the breeding selection tool in dairy production (Kargo et al., 2014). Breeding goals are defined for specific production systems and circumstances. To develop a breeding goal that farmers want to use, it is important to take the objectives of farmers into account. Setting up a breeding goal that does not correspond to the preferences of farmers will make little sense (Nielsen et al., 2014). These preferences can be defined by using farmer choice experiments, for example using conjoint analysis (Tano et al., 2003), a partial profile design (Nielsen and Amer, 2007; Martin-Collado et al., 2015), or pairwise rankings using preference-based tools like 1000Minds (Byrne et al., 2012). Several studies have shown heterogeneity in farmers' preferences for breeding goal traits (Duguma et al., 2011; Ragkos and Abas, 2015), and this may be linked to different cattle production systems (Sy et al., 1997; Ouma et al., 2007). If farmer preferences are heterogeneous, due to differences in production system, or in farm or farmer characteristics, it might be necessary to create multiple breeding goals within a population (Nielsen and Amer, 2007).

Two production systems that are expected to influence farmer preferences for trait improvements are organic and conventional dairy farming systems. Organic farming is associated with stronger regulations in terms of feed, outdoor access, and use of antibiotics and anthelmintics compared to conventional farming. A lower use of concentrate feed causes lower milk production levels in most organic dairy systems (Bennedsgaard et al., 2003; Rosati and Aumaitre, 2004), but the price for organic dairy products is higher than that of conventional dairy products. In Denmark, organic farming is widely applied, and 10% of dairy farms are certified organic (Landbrug and Fødevarer, 2014). A previous study has shown that Swedish organic farmers place more emphasis on resistance to mastitis, parasites and diseases, whereas conventional farmers emphasize a higher milk production (Ahlman et al., 2014). Production level and farmer characteristics like gender and age were found to affect trait improvement preferences for some traits, and production system (organic or conventional) had the largest effect on farmer preferences (Ahlman et al., 2014). Thus the difference between organic and conventional farming might have an effect on farmer preferences.

At present, organic and conventional dairy farming differs in management practices, but breeding practices are the same and farmers select their animals from the same population. When different traits are found more or less important in organic or conventional dairy farming, in terms of economic weights or farmer preferences, it might be beneficial to create separate breeding goals. The potential for multiple breeding goals has not been studied yet under Danish conditions. The reason for this is that the correlation between organic and conventional breeding goals within Denmark is assumed to be above 0.80, the so called break-even point. In populations of less than a million cows it has been shown to cause loss of genetic gain when breeding towards two different goals (Banos and Smith, 1991; Mulder and Bijma, 2006). Therefore the creation of multiple breeding goals in a small population has been considered a disadvantage. However, the use of genomic information in dairy cattle breeding may have changed the break-even point so that multiple breeding goals are advantageous even for correlations between breeding goals higher than 0.80. Therefore the effect of having a genetically specific organic line needs to be quantified.

## Aim of project

The overall aim of the project is to quantify the value of genetically specific organic lines within dairy breeding. In the first part of the project the specific aim is to study farmers' preferences for improvements in breeding goal traits by means of an online preference survey, for the three main dairy breeds in Denmark (Paper I: Slagboom et al. (2016) and Paper II: Slagboom et al. (2017)). In the second part, the specific aim is to investigate genetic gain in different organic and conventional breeding goals by genetic simulation with the stochastic simulation program ADAM (Pedersen et al., 2009) (Paper III). In the third part, the aim is to investigate different structures of the breeding population when simulating organic and conventional breeding goals in ADAM (Paper IV).

### Part 1

#### Farmers' preferences for breeding goal traits

##### Material and methods

###### *Farmer Preference Study*

A breed-specific survey was established to characterize preferences of dairy farmers for improvements in ten traits in Holstein, Danish Red (DR) and Danish Jersey (DJ) cattle. All traits, except for feed efficiency, are included in the current NTM, but some traits are composite traits of multiple (indicator) traits. The preference survey used the online software 1000Minds (1000Minds Ltd., Dunedin, New Zealand), which applies the PAPRIKA method to minimize the number of questions (Hansen and Ombler, 2009). The farmers choose from two alternatives, formulated in such a way that either the first trait is improved and the second remains at the same level as in the farmer's herd today, or vice versa (Figure 1). Farmers could also choose for the option 'they are equal'. The improvements of the two traits represented equal monetary value, based on economic weights calculated for an organic system in Denmark. The underlying monetary value was unknown to the farmer, since trait improvements were expressed in phenotypic units (kg milk, % pregnancy rate, etc. [see Table 1]). Preferences were ranked accordingly. The same survey was sent to organic and conventional dairy farmers so as to be able to compare the results. The correlation between the economic weights for an organic system and for a conventional system was almost unity (Slagboom, 2015).

Furthermore, farmers were asked to answer a general questionnaire about their herd, concerning herd characteristics such as herd size, average milk yield and housing system. In addition, data from the past year were extracted from the Danish Cattle Database for all farmers that finished the survey (Bundgaard and Høj, 2000). All recorded herd characteristics are described in Table 2, together with the average response for all items for Holstein farmers.

In April 2015, all Danish organic farmers with registered addresses in the cattle database, regardless of which breed they used, (n=357) were contacted by ordinary mail to access the web based survey. Farmers who had not answered yet, or had only partially completed the survey were later sent an e-mail or contacted by phone or both. In August 2015, almost all (n≈3000) conventional farmers were contacted by e-mail to access the survey, and a random sample of these farmers were later also contacted by phone, to minimize bias. The results of the survey for the organic dairy farmers were not published before the

survey for the conventional dairy farmers was finished. The general questionnaire was linked to the preference survey based on the herd number that farmers filled in. Not all farmers filled in both the general questionnaire and the preference survey, and some herd numbers did not match between the two. All farmers that completed the preference survey were included in the analysis.

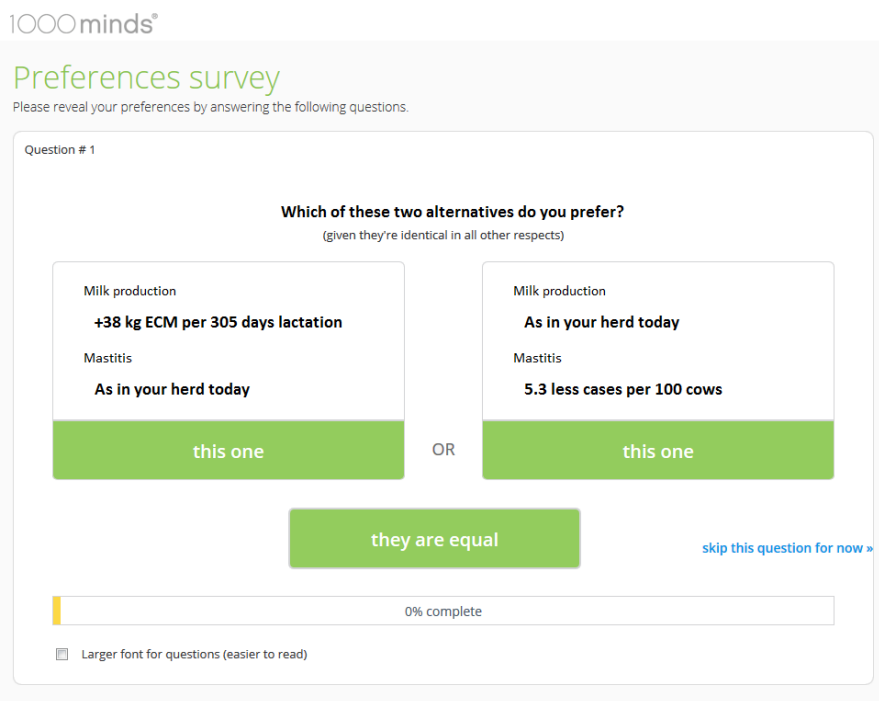


Figure 1: Example of a question in the preference survey in 1000minds.

Table 1. Breeding goal trait improvements included in the breed-specific preference surveys

Trait	Description	Improvement presented in the survey			
		Holstein	DR	DJ	
Cow fertility	Pregnancy rate in cows	+39	+10	+8	Pregnancies per 100 inseminations
Heifer fertility	Pregnancy rate in heifers	+11	+11	+13	Pregnancies per 100 inseminations
Calving difficulty	A difficult calving	-8.2	-8.6	-8.5	Cases per 100 cow-years <sup>1</sup>
Calf mortality	Death within 15 months after birth	-12	-64	-23	Dead heifers and heifer calves per 100 cow-years <sup>1</sup>
Cow mortality	Mortality and involuntary culling	-1.8	-1.8	-1.7	Cases per 100 cow-years <sup>1</sup>
Hoof and leg diseases	Hoof and leg diseases	-13.5	-13.9	-17.9	Cases per 100 cow-years <sup>1</sup>
Mastitis	Clinical mastitis	-5.3	-5.0	-5.1	Cases per 100 cow-years <sup>1</sup>
Other diseases	Reproductive, digestive and metabolic diseases	-10.1	-10.9	-8.6	Cases per 100 cow-years <sup>1</sup>
Milk production	305 day ECM <sup>2</sup> yield	+38	+35	+33	kg ECM <sup>2</sup> per 305 days of lactation
Feed efficiency	ECM <sup>2</sup> yield per feed unit	+0.01	+0.01	+0.01	kg ECM <sup>2</sup> per feed unit

<sup>1</sup>The number of cow-years equals the number of feeding days per year (for all the cows in a herd) divided by 365.

<sup>2</sup>Energy Corrected Milk. Test-day yield of ECM (kg) was calculated as  $[\text{kg of milk} \times (383 \times \text{fat \%} + 242 \times \text{protein \%} + 780.8)]/3,140$ .

Table 2. Description of recorded herd characteristics, possible response and average response for all farmers that inseminate some or all of their cows with Holstein semen (mean  $\pm$  SE)

Item	Possible response	Average response <sup>1</sup>
Herd characteristics from survey		
Organic	Yes or no	26.8 <sup>2</sup> $\pm$ 2.2
Herd size	Number of cow-years <sup>3</sup>	197 $\pm$ 10
ECM <sup>4</sup>	Average yield in kg per cow-year <sup>3</sup> for the dairy	10,111 $\pm$ 68
Systematic crossbreeding with dairy breeds	Yes or no	13.9 <sup>2</sup> $\pm$ 1.9
Inseminated with Jersey cattle	Yes or no	8.6 <sup>2</sup> $\pm$ 1.5
Inseminated with Danish Red cattle	Yes or no	27.6 <sup>2</sup> $\pm$ 2.4
Seasonal calving	Yes or no	2.0 <sup>2</sup> $\pm$ 0.8
Activity meter for estrus detection in cows	Yes or no	54.6 <sup>2</sup> $\pm$ 2.7
Activity meter for estrus detection in heifers	Yes or no	47.1 <sup>2</sup> $\pm$ 2.7
Housing system	Cubicles, deep straw or tie stall	88% Cubicles 5% Deep straw 8% Tie stall
Herd characteristics from cattle database		
Number of cow-years <sup>3</sup>	Number of cow-years <sup>3</sup> per farm	185 $\pm$ 7
Number of heifers	Number of heifers per farm	150 $\pm$ 5
Yearly milk yield per cow	In kg per year, measured with milk recording system	10,462 $\pm$ 70
Yearly protein yield per cow	In kg per year, measured with milk recording system	354 $\pm$ 3
Yearly fat yield per cow	In kg per year, measured with milk recording system	421 $\pm$ 3
Age	Average age of cows in years	4.91 $\pm$ 0.04
Productive lifespan	Number of years that each cow produces milk, from first calving to death	2.71 $\pm$ 0.02
Cell count	Cell count x1000 per mL	199 $\pm$ 3
Hoof and leg diseases	Average number of cases per cow-year <sup>3</sup>	0.16 $\pm$ 0.02

Metabolic diseases	Average number of cases per cow-year <sup>3</sup>	0.13 ± 0.01
Reproduction diseases	Average number of cases per cow-year <sup>3</sup>	0.17 ± 0.01
Udder diseases	Average number of cases per cow-year <sup>3</sup>	0.27 ± 0.01
Other diseases	Average number of cases per cow-year <sup>3</sup> , only diseases that are not otherwise specified <sup>5</sup>	0.05 ± 0.01
Stillborn calves	Percentage of calves with a birth defect, that are stillborn or die within 24 hours	6.08 ± 0.32
Dead calves	Percentage of calves that die 1-180 days after birth	5.06 ± 0.23
Dead cows	Percentage of cows that die on the farm or need an emergency culling	3.56 ± 0.25
Insemination rate, cows	Percentage of inseminations with regards to the no of cows that could be in heat	46.9 ± 0.8
Insemination rate, heifers	Percentage of inseminations with regards to the no of heifers that could be in heat	44.5 ± 1.2
Conception rate, cows	Percentage of inseminations that result in conception for cows	42.4 ± 0.6
Conception rate, heifers	Percentage of inseminations that result in conception for heifers	52.8 ± 1.1
Pregnancy rate, cows	Conception rate * insemination rate, cows	0.20 ± 0.00
Pregnancy rate, heifers	Conception rate * insemination rate, heifers	0.25 ± 0.01
Carcass conformation, cows	EUROP scale converted to a numerical scale (1:worst to 15: best)	2.45 ± 0.03
Carcass weight, cows	In kg	295 ± 1

<sup>1</sup>The number of respondents ranged from 314 to 396 per herd characteristic.

<sup>2</sup>Percentage of the farmers that answered 'yes' compared to all farmers that answered this question.

<sup>3</sup>The number of cow-years equals the number of feeding days per year (for all the cows in a herd) divided by 365.

<sup>4</sup>Energy Corrected Milk. Test-day yield of ECM (kg) was calculated as  $[\text{kg of milk} \times (383 \times \text{fat \%} + 242 \times \text{protein \%} + 780.8)]/3,140$ .

<sup>5</sup>NB: The herd characteristic 'Other diseases' is not the same as the trait 'Other diseases', which is presented to farmers in the survey. This is because metabolic diseases and reproduction diseases are a part of the trait 'Other diseases' and not of the herd characteristic 'Other diseases' (because these are recorded separately).

### *Statistical Analysis*

The part-worth utilities were translated into trait ranks by 1000Minds, where the most preferred trait had rank 1 and the least preferred trait had rank 10. These trait ranks were used to produce descriptive statistics of the survey outcome, per breed.

To analyze differences in mean trait ranks, a Friedman test was performed (Friedman, 1937). This accounts for the dependency and non-normality in the data by using a two factor unreplicated design, in which each farmer (the first factor) ranks each trait (the second factor). A significant result ( $P < 0.05$ ) of the

Friedman test meant that at least one of the trait means was different from the other traits, and subsequently a post-hoc test due to Nemenyi to test pairwise differences was performed (Sachs, 2013). Both tests were done by means of the Pairwise Multiple Comparison of Mean Ranks Package in R statistical software (Pohlert, 2015).

A principal component (PC) analysis was conducted in R (Husson et al., 2010). The results did not suggest that a dimension reduction would be appropriate. It was therefore decided to perform a Ward's hierarchical CA on the unreduced data. The optimum number of clusters was based on the gain of within group inertia criterion. All characteristics of the clusters, from the general questionnaire and the data from the cattle database, were tested for homogeneity across clusters using a Kruskal-Wallis test. A significant result ( $P < 0.05$ ) of the Kruskal-Wallis test for a characteristic meant that at least one of the cluster means differed from the others. Subsequently Dunn's post hoc test for pairwise differences (Dunn, 1964) was performed. The test was adjusted using the Holm method which controls the family-wise error rate (Holm, 1979).

These analyses were first performed per breed, and also separately for data from organic and conventional farmers with Holstein cattle. Descriptive statistics were also produced separately for organic and conventional farmers, and differences between the two production systems were analyzed with a Kruskal-Wallis test.

## Results

The response rate for the preference survey was 48% for organic farmers and 13% for conventional farmers for the three major dairy breeds in Denmark.

### *Preferences for Trait Improvements for All Farmers with Holstein Cattle*

The survey for farmers that inseminate some or all of their cows with Holstein semen was answered by 396 farmers (290 conventional and 106 organic). The ranks for all ten traits and the differences between these trait ranks are shown in Figure 2. The highest rank was given to an improvement in cow fertility ( $4.29 \pm 0.13$  [mean  $\pm$  SE]), followed by improvements in hoof and leg diseases, mastitis and milk production, and the lowest rank was given to improvements in calving difficulty (7.27). The remaining traits were all ranked intermediately and their mean ranks did not significantly differ from each other. Standard deviations for trait ranks ranged from 2.43 to 3.09.

*Different Farmer Clusters.* We found four clusters by means of a CA. These clusters are described and classified according to the most and least preferred trait improvements in the cluster compared to other clusters and compared to trait ranks for all farmers together (Figure 3). All mean trait ranks differed ( $P < 0.05$ ) according to a Kruskal-Wallis test, implying that at least one of the clusters had a different mean. Farmers in the first cluster, 'Health and Fertility', gave the most preference to improvements in traits related to diseases and fertility. Especially hoof and leg diseases and other diseases were ranked much higher compared to their overall ranks. Farmers in this group gave the least preference to production traits such as milk production and feed efficiency.

Farmers in the second cluster, 'Production and Udder Health', were mostly oriented towards improving production traits and mastitis. Improvements in fertility traits were the least preferred.



Farmers in the third cluster, 'Survival', placed the most emphasis on calf and cow mortality. Compared to all farmers together, these farmers gave a much higher rank to calving difficulty. Other diseases and production traits were the least preferred by these farmers.

Farmers in the fourth cluster, 'Fertility and Production', gave the highest ranks to fertility and production traits. Calving difficulty, other diseases and hoof and leg diseases were ranked the lowest compared to all farmers together. These farmers gave the highest rank of all farmers to cow and heifer fertility and to milk production.

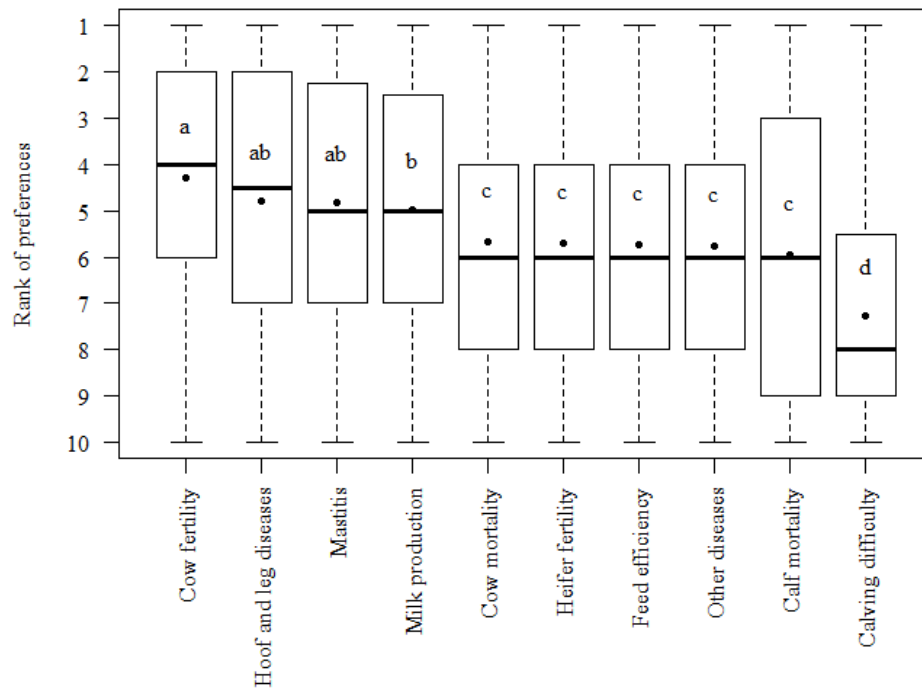


Figure 2: Boxplot of trait ranks for the ten traits evaluated by the survey. Means with different letters differ ( $P < 0.05$ ) according to a post-hoc test due to Nemenyi.

*Associations to Production System.* We found a difference in the proportion of organic farmers between clusters (Table 3). Farmer clusters that are more production-based, clusters 'Production and Udder Health' and 'Fertility and Production', had the highest percentage of organic farmers, whereas the survival- and health-based clusters had a higher percentage of conventional farmers. When comparing mean trait ranks between conventional and organic farmers, we found that calf mortality and milk production were ranked higher by organic farmers ( $P < 0.001$  and  $P = 0.02$  respectively) and calving difficulty, cow mortality and hoof and leg diseases were ranked lower by organic farmers compared to conventional farmers ( $P = 0.03$ ,  $P < 0.01$  and  $P < 0.01$ ) according to a Kruskal-Wallis test. A large number of herd characteristics differed between organic and conventional farmers (Table 4). Average yields, Energy Corrected Milk (ECM), disease incidences and the percentage of dead cows were lower in organic herds, and the percentage of dead calves was higher compared to conventional herds, as well as the average age of the cows and their productive lifespan.

*Associations to Herd Characteristics.* We found some herd characteristics that differed significantly between clusters (Table 3). Farmers in the cluster oriented towards improving survival traits had a higher

percentage of dead cows in their herds compared to the other clusters ( $P < 0.001$ ). These herds also had a higher cell count. Herds from farmers that gave the highest rank to cow and heifer fertility, in the cluster 'Fertility and Production', had the lowest conception rate. Farmers in the cluster 'Health and Fertility' ranked hoof and leg diseases the highest and had the highest incidence of hoof and leg diseases. This cluster also had the highest incidence of udder diseases, but the difference between clusters was not significant ( $P = 0.07$ ). The production based clusters had the lowest yearly ECM yield and yearly protein yield, and the overall Kruskal-Wallis test showed this tendency ( $P = 0.05$  and  $P = 0.09$  respectively). However, pairwise differences between clusters were not significant.

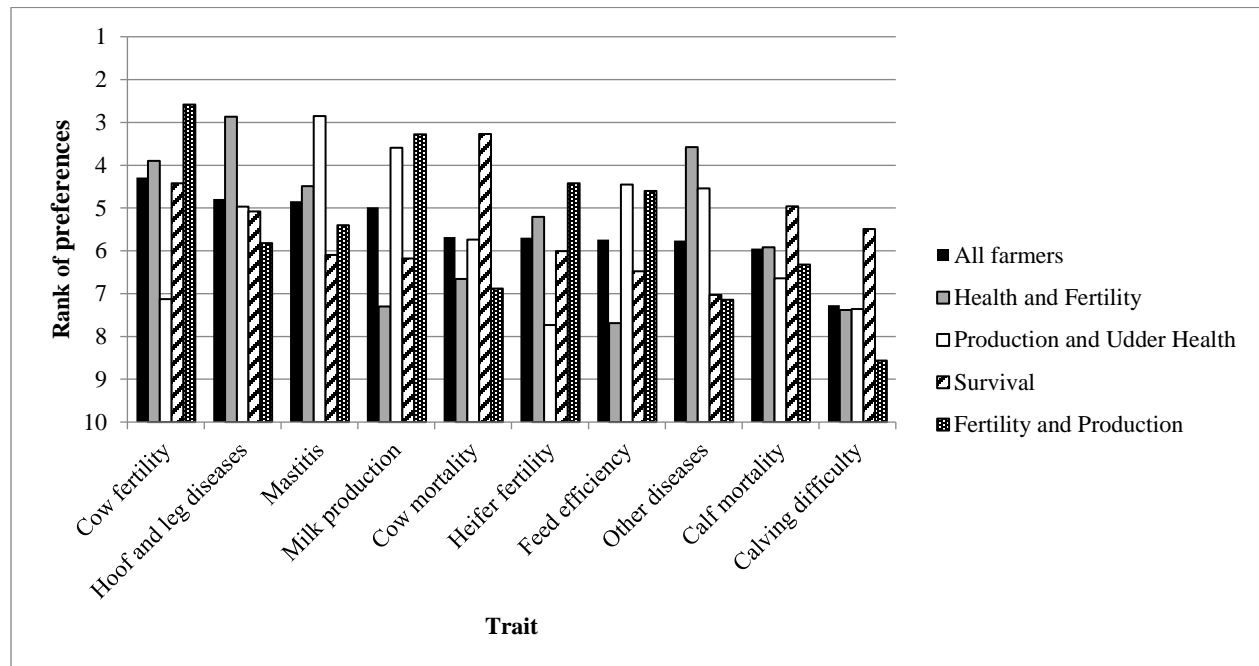


Figure 3: Mean trait ranks for all Holstein farmers together and per cluster of Holstein farmers. The number of farmers in the cluster 'Health and Fertility' is 89, in the cluster 'Production and Udder Health' the number of farmers is 83, in the cluster 'Survival' the number of farmers is 100 and in the cluster 'Fertility and Production' the number of farmers is 124.

#### Conventional Farmers with Holstein Cattle

When analyzing conventional farmers that inseminate with Holstein semen ( $n = 290$ ) separately, the trait ranks were very similar to the trait ranks for all farmers together. We found three clusters by means of a CA. All mean trait ranks differed ( $P < 0.05$ ) according to a Kruskal-Wallis test. The mean ranks of trait improvements are shown in Figure 4 for all conventional farmers and per conventional cluster. The first cluster we found for the separate analysis of the conventional farmers, 'Health', consisted of farmers that ranked all disease traits the highest, but unlike the cluster 'Health and Fertility' from the CA for all farmers together, these farmers did not rank fertility traits very high. The second and third cluster of conventional farmers contained farmers that ranked traits in the same way as the clusters 'Survival' and 'Fertility and Production', from the analysis of all farmers together.

When comparing herd characteristics, we found differences between clusters (Table 5). As in the overall analysis, the cluster 'Survival' again contained herds which had a higher percentage of dead cows.

Table 3. Trait ranks (1 = highest rank, 10 = lowest ranks), and herd characteristics per cluster of Holstein farmers (mean  $\pm$  SE). Only herd characteristics with a difference between clusters ( $p < 0.10$ ) are shown.

Item	Cluster				P-value <sup>1</sup>
	Health and Fertility	Production and Udder Health	Survival	Fertility and Production	
Number of farmers	89	83	100	124	
Trait ranks <sup>2</sup>					
Cow fertility	3.90 <sup>a</sup>	7.13 <sup>b</sup>	4.42 <sup>a</sup>	2.58 <sup>c</sup>	<0.001
Heifer fertility	5.21 <sup>a</sup>	7.73 <sup>b</sup>	6.01 <sup>c</sup>	4.42 <sup>d</sup>	<0.001
Calving difficulty	7.38 <sup>a</sup>	7.36 <sup>a</sup>	5.49 <sup>b</sup>	8.56 <sup>c</sup>	<0.001
Calf mortality	5.92 <sup>ab</sup>	6.64 <sup>a</sup>	4.96 <sup>b</sup>	6.32 <sup>a</sup>	<0.01
Cow mortality	6.66 <sup>a</sup>	5.74 <sup>b</sup>	3.27 <sup>c</sup>	6.88 <sup>a</sup>	<0.001
Hoof and leg diseases	2.87 <sup>a</sup>	4.97 <sup>b</sup>	5.08 <sup>b</sup>	5.82 <sup>b</sup>	<0.001
Mastitis	4.49 <sup>a</sup>	2.85 <sup>b</sup>	6.10 <sup>c</sup>	5.40 <sup>c</sup>	<0.001
Other diseases	3.58 <sup>a</sup>	4.54 <sup>b</sup>	7.03 <sup>c</sup>	7.14 <sup>c</sup>	<0.001
Milk production	7.30 <sup>a</sup>	3.59 <sup>b</sup>	6.18 <sup>c</sup>	3.28 <sup>b</sup>	<0.001
Feed efficiency	7.69 <sup>a</sup>	4.45 <sup>b</sup>	6.48 <sup>c</sup>	4.60 <sup>b</sup>	<0.001
Herd characteristics <sup>3</sup>					
Organic <sup>4</sup>	19.1 <sup>a</sup> $\pm$ 4.2	27.7 <sup>ab</sup> $\pm$ 4.9	19.0 <sup>a</sup> $\pm$ 3.9	37.9 <sup>b</sup> $\pm$ 4.4	<0.01
ECM <sup>5</sup>	10,389 <sup>a,6</sup> $\pm$ 119	9,879 <sup>a</sup> $\pm$ 159	10,132 <sup>a</sup> $\pm$ 135	10,043 <sup>a</sup> $\pm$ 126	0.05
Yearly protein yield	363 <sup>a,6</sup> $\pm$ 5	348 <sup>a</sup> $\pm$ 6	352 <sup>a</sup> $\pm$ 5	353 <sup>a</sup> $\pm$ 5	0.09
Cell count	185 <sup>a</sup> $\pm$ 7	203 <sup>ab</sup> $\pm$ 6	208 <sup>b</sup> $\pm$ 5	198 <sup>ab</sup> $\pm$ 5	0.01
Hoof and leg diseases	0.21 <sup>a</sup> $\pm$ 0.04	0.14 <sup>ab</sup> $\pm$ 0.03	0.16 <sup>ab</sup> $\pm$ 0.03	0.15 <sup>b</sup> $\pm$ 0.03	0.01
Udder diseases	0.31 <sup>a,6</sup> $\pm$ 0.02	0.26 <sup>a</sup> $\pm$ 0.02	0.27 <sup>a</sup> $\pm$ 0.02	0.24 <sup>a</sup> $\pm$ 0.02	0.07
Dead cows	3.01 <sup>a</sup> $\pm$ 0.51	2.76 <sup>a</sup> $\pm$ 0.52	5.68 <sup>b</sup> $\pm$ 0.51	2.72 <sup>a</sup> $\pm$ 0.42	<0.001
Conception rate, cows	42.9 <sup>ab</sup> $\pm$ 1.2	43.4 <sup>a</sup> $\pm$ 1.5	43.6 <sup>ab</sup> $\pm$ 1.0	40.4 <sup>b</sup> $\pm$ 1.2	0.04
Pregnancy rate, heifers	0.29 <sup>a</sup> $\pm$ 0.02	0.23 <sup>ab</sup> $\pm$ 0.02	0.24 <sup>ab</sup> $\pm$ 0.01	0.23 <sup>b</sup> $\pm$ 0.01	0.04

<sup>a-d</sup>Means within a row with different superscripts differ ( $P < 0.05$ ) according to Dunn's test for multiple comparisons.

<sup>1</sup>Result of Kruskal-Wallis test with null-hypothesis 'all cluster means are equal'.

<sup>2</sup>Standard errors of trait ranks are in the range of 0.14 – 0.35.

<sup>3</sup>Description and average response per herd characteristic can be found in Table 2.

<sup>4</sup>Percentage of organic farmers among the survey respondents.

<sup>5</sup>Energy Corrected Milk. Test-day yield of ECM (kg) was calculated as  $[\text{kg of milk} \times (383 \times \text{fat \%} + 242 \times \text{protein \%} + 780.8)]/3,140$ .

<sup>6</sup>Due to an adjustment of p-values to correct for the Family-wise error rate, it may occur that pairwise differences cannot be found by Dunn's test, even though the Kruskal-Wallis test shows that at least one of the cluster means is different ( $P < 0.05$ ).

Table 4. Average herd characteristics for organic and conventional farmers that participated in the survey for Holstein cattle (n=106 and n=290, respectively). Only herd characteristics with a difference between the two production systems ( $p < 0.10$ ) are shown.

Herd characteristic <sup>1</sup>	Organic	Conventional	P-value <sup>2</sup>
ECM <sup>3</sup>	9,314 ± 118	10,419 ± 73	<0.001
Systematic crossbreeding with dairy breeds	23.2 ± 4.4	10.4 ± 1.9	<0.01
Inseminated with Danish Red cattle	37.1 ± 4.9	23.9 ± 2.7	0.01
Activity meter for estrus detection in cows	66.3 ± 4.9	50.2 ± 3.2	<0.01
Yearly milk yield per cow	9,736 ± 122	10,751 ± 78	<0.001
Yearly protein yield per cow	327 ± 4	365 ± 3	<0.001
Yearly fat yield per cow	392 ± 5	432 ± 3	<0.001
Age	5.09 ± 0.05	4.83 ± 0.05	<0.001
Productive lifespan	2.86 ± 0.04	2.65 ± 0.03	<0.001
Cell count	220 ± 6	191 ± 3	<0.001
Hoof and leg diseases	0.07 ± 0.02	0.20 ± 0.02	<0.001
Metabolic diseases	0.09 ± 0.01	0.14 ± 0.01	<0.001
Reproduction diseases	0.10 ± 0.01	0.20 ± 0.01	<0.001
Udder diseases	0.19 ± 0.01	0.30 ± 0.01	<0.001
Dead calves	5.98 ± 0.45	4.70 ± 0.26	<0.01
Dead cows	1.63 ± 0.36	4.32 ± 0.31	<0.001
Insemination rate, heifers	39.0 ± 2.4	46.5 ± 1.4	<0.01
Pregnancy rate, heifers	0.20 ± 0.02	0.26 ± 0.01	<0.01
Carcass conformation, cows	2.32 ± 0.04	2.50 ± 0.03	<0.01
Weight at slaughter, cows	289 ± 2	297 ± 2	<0.01

<sup>1</sup>Description and average response per herd characteristic can be found in Table 2.

<sup>2</sup>Result of Kruskal-Wallis test with null-hypothesis 'both means are equal'.

<sup>3</sup>Energy Corrected Milk. Test-day yield of ECM (kg) was calculated as  $[\text{kg of milk} \times (383 \times \text{fat \%} + 242 \times \text{protein \%} + 780.8)]/3,140$ .

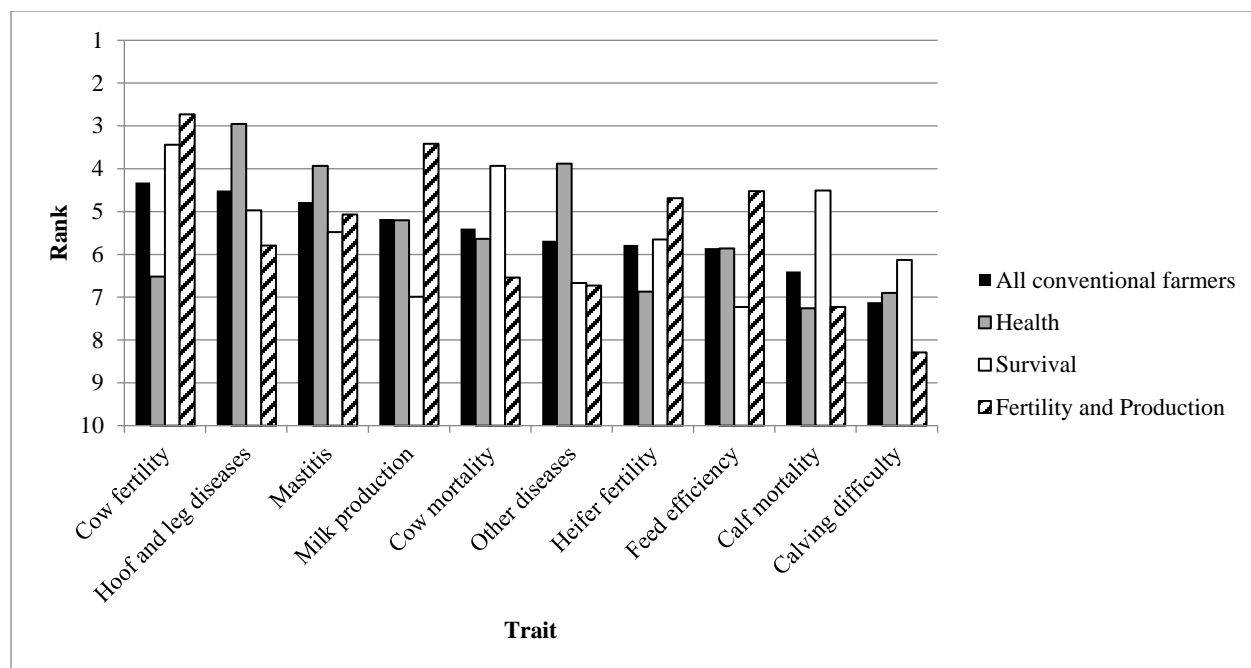


Figure 4: Mean trait ranks for conventional Holstein farmers together and per cluster of conventional farmers. The number of farmers in the cluster 'Health' is 105, in the cluster 'Survival' the number of farmers is 90 and in the cluster 'Fertility and Production' the number of farmers is 95.

Table 5. Average herd characteristics per cluster of conventional Holstein farmers. Only herd characteristics with a difference between clusters ( $p < 0.10$ ) are shown.

Item	Cluster			P-value <sup>1</sup>
	Health	Survival	Fertility and Production	
Number of farmers	105	90	95	
Herd characteristics <sup>2</sup>				
Yearly milk yield	10,831 <sup>a</sup> ± 111	10,508 <sup>a</sup> ± 164	10,913 <sup>a</sup> ± 128	0.04
Yearly protein yield	368 <sup>a</sup> ± 4	356 <sup>a</sup> ± 6	371 <sup>a</sup> ± 5	0.04
Yearly fat yield	436 <sup>a</sup> ± 4	423 <sup>a</sup> ± 6	436 <sup>a</sup> ± 5	0.04
Productive lifespan	2.70 <sup>a</sup> ± 0.05	2.69 <sup>a</sup> ± 0.05	2.55 <sup>a</sup> ± 0.05	0.05
Dead cows	3.68 <sup>a</sup> ± 0.50	6.16 <sup>b</sup> ± 0.53	3.13 <sup>a</sup> ± 0.51	<0.001

<sup>a-b</sup>Means within a row with different superscripts differ ( $P < 0.05$ ) according to Dunn's test for multiple comparisons.

<sup>1</sup>Result of Kruskal-Wallis test with null-hypothesis 'all cluster means are equal'.

<sup>2</sup>Description and average response per herd characteristic can be found in Table 2.

### Organic Farmers with Holstein Cattle

Organic farmers ( $n=106$ ) mostly preferred improvements in cow fertility (rank  $4.21 \pm 0.26$ ), followed by milk production and calf mortality, and improvements in calving difficulty were the least preferred (rank

7.69). Organic farmers ranked improvements in production traits (milk production and feed efficiency) higher compared to all farmers together.

We found three clusters based on organic farmers' preferences for trait improvements (Figure 5). All mean trait ranks differed ( $P < 0.05$ ), but we did not identify any difference in herd characteristics between the clusters. The first cluster of organic farmers, 'Robustness', contained farmers that were mostly oriented towards improving mortality and disease traits. Production traits were ranked very low by these farmers. The second and third clusters of organic farmers that we found were similar to the clusters 'Production and Udder Health' and 'Fertility and Production' from the results of the CA for all farmers together.

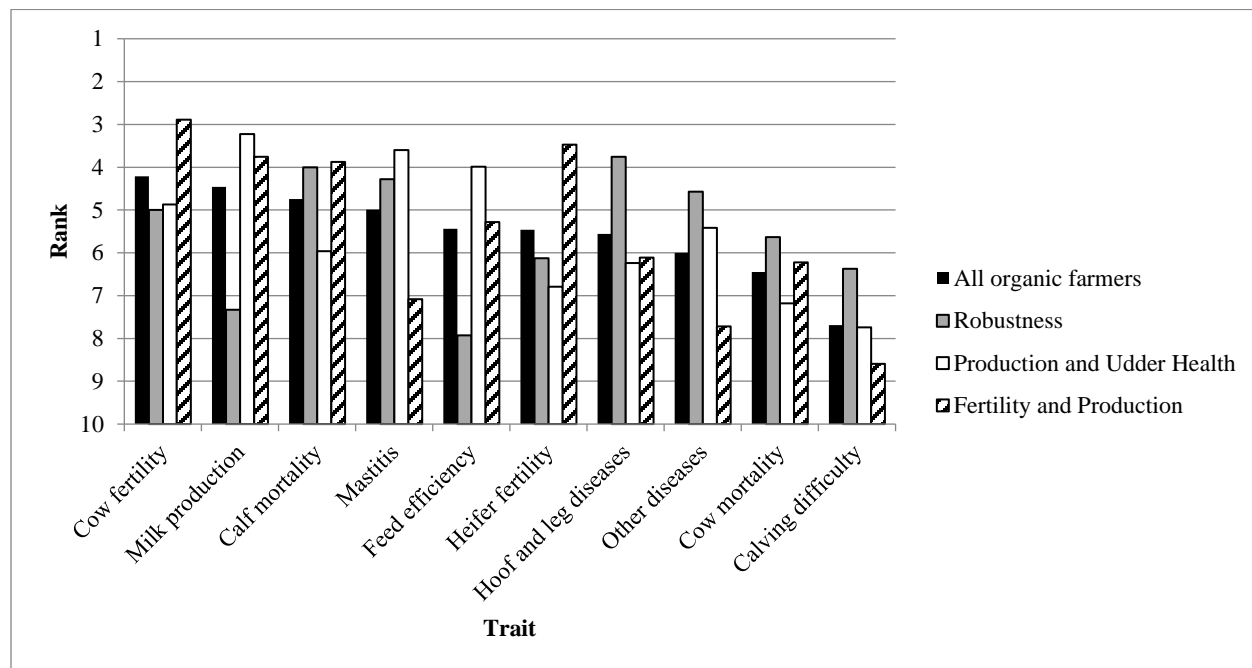


Figure 5: Mean trait ranks for organic Holstein farmers together and per cluster of organic farmers. The number of farmers in the cluster 'Robustness' is 27, in the cluster 'Production and Udder Health' the number of farmers is 42 and in the cluster 'Fertility and Production' the number of farmers is 37.

#### Farmers with Danish Red cattle

The DR-survey was filled in by 87 Danish dairy farmers; 29 organic and 58 conventional farmers. These farmers gave the highest preference to improvements in mastitis (average rank of  $4.38 \pm 0.29$  [mean  $\pm$  SE]), followed by improvements in milk production. The lowest preference was given to calving difficulty ( $7.49 \pm 0.26$ ). Significant differences were found between a number of trait ranks (Figure 6), although the level of variability in preferences meant that at the whole surveyed population level, significant differences couldn't be established for the majority of traits. By means of a cluster analysis, farmers with DR cows were divided into three different clusters, which were named according to the trait improvements that were the most preferred per cluster: Robustness, Production and Health, and Fertility and Production (Figure 7). All mean trait ranks differed between clusters ( $P < 0.05$ ) according to a Kruskal-Wallis test, implying that at least one of the clusters had a different mean. We found herd characteristics that significantly ( $P < 0.05$ ) differed between clusters (Table 6). The most substantial differences were found between the cluster 'Robustness' and the cluster 'Fertility and Production'.

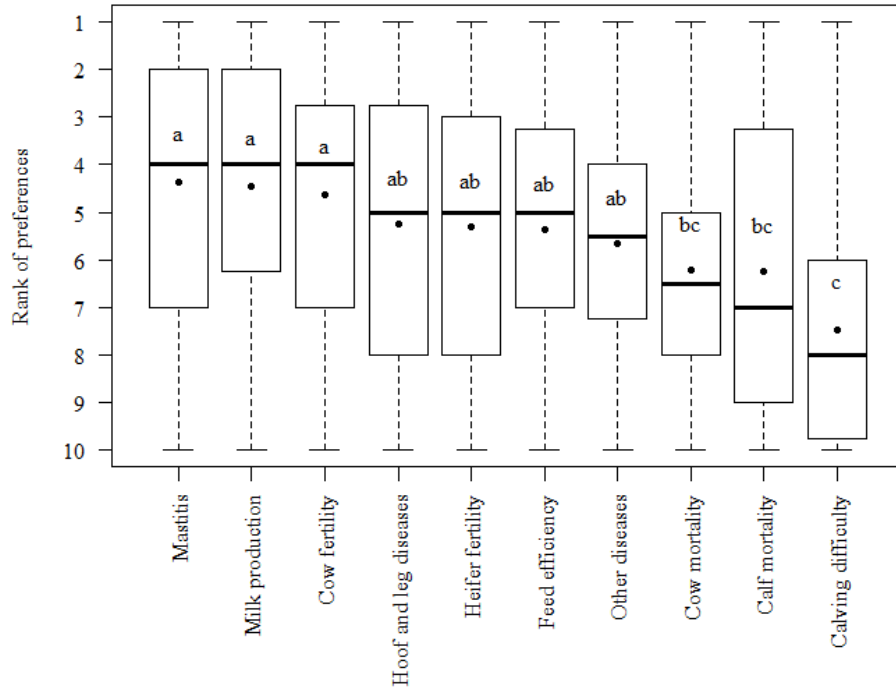


Figure 6: Boxplot of trait ranks for the ten traits evaluated by the survey for farmers with Danish Red cows. Means with different letters differ ( $P < 0.05$ ) according to a post-hoc test due to Nemenyi.

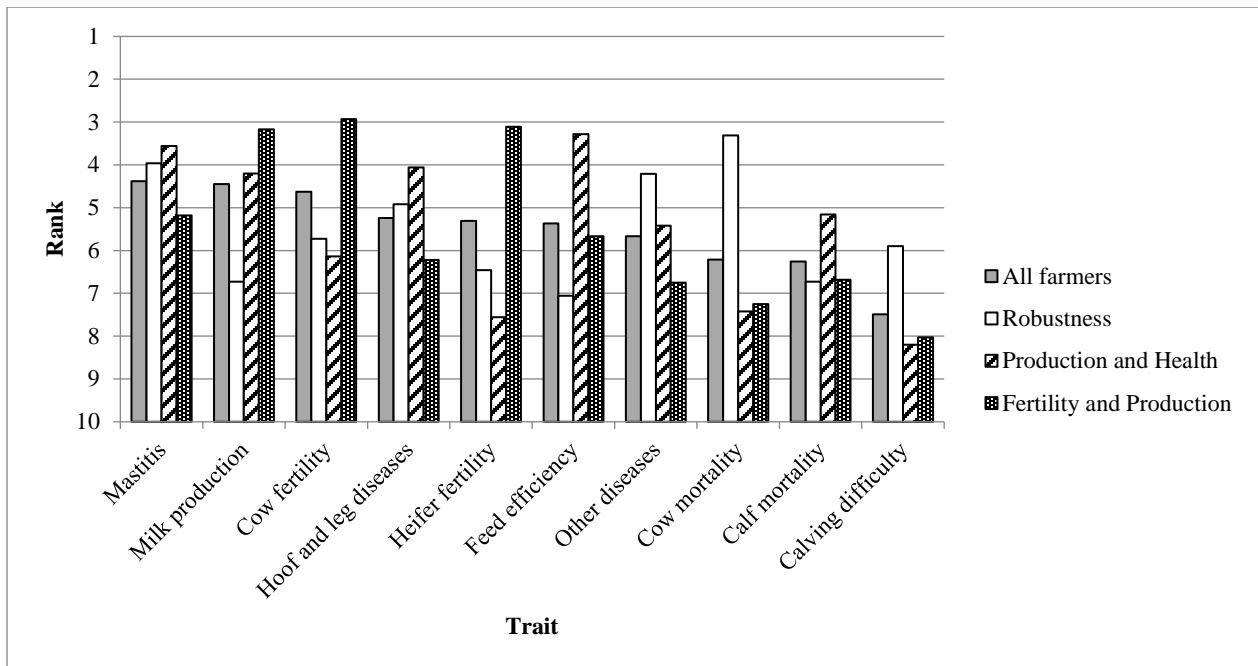


Figure 7: Mean trait ranks for all farmers who answered the survey for Danish Red cows, and per cluster of these farmers.

Table 6. Average herd characteristics for all farmers who answered the survey for Danish Red cows, and per cluster of these farmers. Only herd characteristics with a difference between clusters ( $p < 0.10$ ) are shown.

	All farmers	Cluster			P-value <sup>1</sup>
		Robustness	Production and Health	Fertility and Production	
Number of farmers	87	24	25	38	
Herd characteristics					
Crossbreeding <sup>2</sup>	16.0 ± 4.3	33.3 <sup>a</sup> ± 11.4	16.7 <sup>ab</sup> ± 7.8	6.1 <sup>b</sup> ± 4.2	0.04
ECM <sup>3</sup>	9,167 ± 160	9,723 <sup>a</sup> ± 197	9,322 <sup>ab</sup> ± 328	8,733 <sup>b</sup> ± 238	0.01
Herd size <sup>4</sup>	137 ± 9	153 <sup>a</sup> ± 23	156 <sup>a</sup> ± 14	113 <sup>a</sup> ± 11	0.05
Organic <sup>5</sup>	33.3 ± 5.1	16.7 <sup>a</sup> ± 7.8	24.0 <sup>ab</sup> ± 8.7	50.0 <sup>b</sup> ± 8.2	0.01
Udder disorders <sup>6</sup>	0.23 ± 0.02	0.27 <sup>a</sup> ± 0.04	0.25 <sup>a</sup> ± 0.03	0.19 <sup>a</sup> ± 0.03	0.08
Yearly fat yield <sup>7</sup>	391 ± 6	404 <sup>a</sup> ± 12	402 <sup>a</sup> ± 12	375 <sup>a</sup> ± 9	0.04
Yearly milk yield <sup>7</sup>	9,562 ± 158	9,885 <sup>a</sup> ± 293	9,864 <sup>a</sup> ± 305	9,142 <sup>a</sup> ± 226	0.04
Yearly protein yield <sup>7</sup>	323 ± 6	335 <sup>a</sup> ± 10	334 <sup>ab</sup> ± 11	307 <sup>b</sup> ± 8	0.03

<sup>a-b</sup>Means within a row with different superscripts differ ( $P < 0.05$ ) according to Dunn's test for multiple comparisons. Due to an adjustment of p-values to correct for the Family-wise error rate, it may occur that pairwise differences cannot be found by Dunn's test, even though the Kruskal-Wallis test shows that at least one of the cluster means is different.

<sup>1</sup>Result of Kruskal-Wallis test with null-hypothesis 'all cluster means are equal'.

<sup>2</sup>The percentage of farmers that answered that they used systematic crossbreeding with dairy breeds in the general questionnaire.

<sup>3</sup>Energy corrected milk, filled in by farmers in the general questionnaire. Test-day yield of ECM (kg) was calculated as  $[\text{kg of milk} \times (383 \times \text{fat \%} + 242 \times \text{protein \%} + 780.8)]/3,140$ .

<sup>4</sup>In number of cow-years and filled in by farmers about their own herd in the general questionnaire.

<sup>5</sup>Percentage of respondents that filled in the survey for organic farmers.

<sup>6</sup>Average number of cases per cow-year, extracted from the cattle database.

<sup>7</sup>In kg per year, measured with milk recording system and extracted from the cattle database.

#### *Farmers with Danish Jersey cattle*

The DJ-survey was filled in by 76 farmers; 27 organic and 49 conventional farmers. Farmers with DJ cows ranked mastitis the highest ( $4.29 \pm 0.33$ ) and calving difficulty the lowest ( $7.85 \pm 0.31$ ). Only the rank of calving difficulty significantly differed from the other trait ranks ( $P < 0.05$ ). The DJ farmers were also divided into three clusters and named according to the trait improvements that were the most preferred per cluster (Figure 8). All mean trait ranks differed between clusters ( $P < 0.05$ ) according to a Kruskal-Wallis test, except for the mean ranks of calving difficulty and mastitis.

The percentage of dead cows and the prevalence of udder disorders differed significantly between clusters (Table 7). In addition, the cluster 'Survival' had the highest prevalence of udder diseases, and these farmers ranked mastitis higher than the other clusters, but the difference in the rank of mastitis between clusters was not significant ( $P = 0.53$ ).



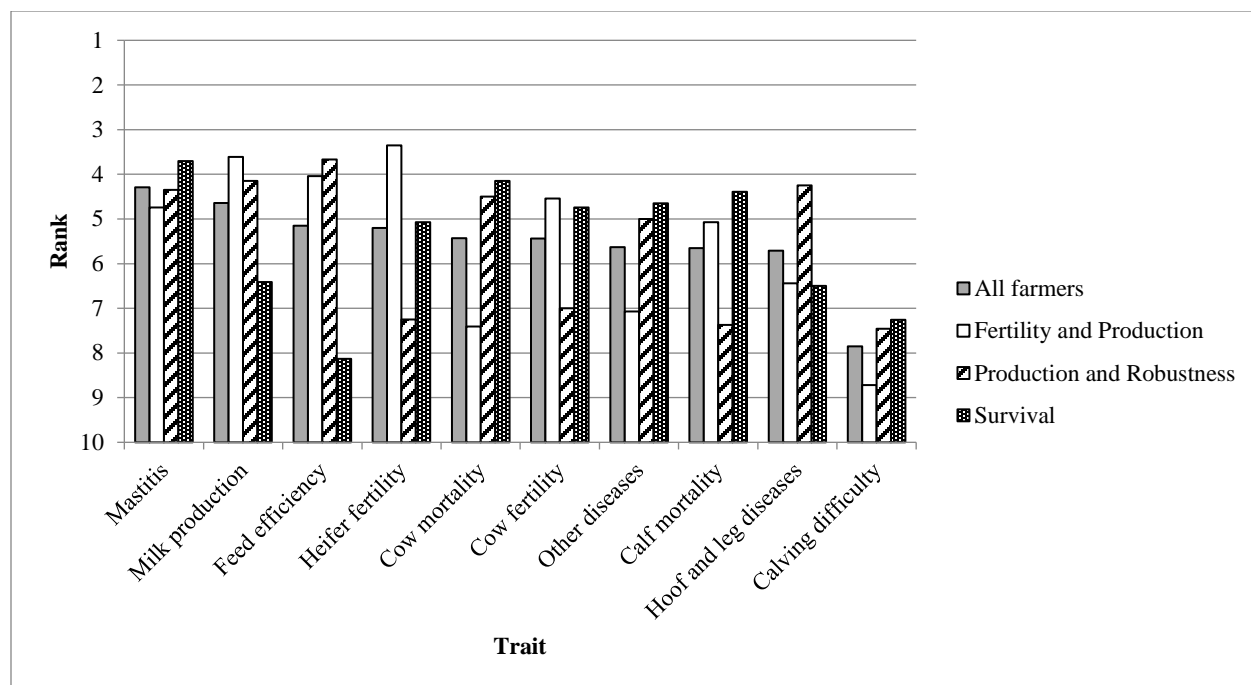


Figure 8. Mean trait ranks for all farmers who answered the survey for Danish Jersey cows, and per cluster of these farmers.

Table 7. Average herd characteristics for all farmers who answered the survey for Danish Jersey cows, and per cluster of these farmers. Only herd characteristics with a difference between clusters ( $p < 0.10$ ) are shown.

	All farmers	Cluster			P-value <sup>1</sup>
		Fertility and Production	Production and Robustness	Survival	
Number of farmers	76	27	26	23	
Herd characteristics					
Dead cows <sup>2</sup>	3.77 ± 0.62	1.67 <sup>a</sup> ± 0.78	4.40 <sup>a</sup> ± 1.01	5.50 <sup>a</sup> ± 1.35	0.04
Udder disorders <sup>3</sup>	0.26 ± 0.03	0.18 <sup>a</sup> ± 0.04	0.27 <sup>ab</sup> ± 0.04	0.33 <sup>b</sup> ± 0.05	0.03

<sup>a-b</sup>Means within a row with different superscripts differ ( $P < 0.05$ ) according to Dunn's test for multiple comparisons. Due to an adjustment of p-values to correct for the Family-wise error rate, it may occur that pairwise differences cannot be found by Dunn's test, even though the Kruskal-Wallis test shows that at least one of the cluster means is different.

<sup>1</sup>Result of Kruskal-Wallis test with null-hypothesis 'all cluster means are equal'.

<sup>2</sup>Percentage of dead cows on average per herd, extracted from the cattle database.

<sup>3</sup>Average number of cases per cow-year, extracted from the cattle database.

## Discussion

This study characterized preferences of Danish dairy farmers for improvements in breeding goal traits and associated these preferences with herd characteristics and production system (organic or conventional), for the three main breeds in Denmark.

### *Farmers with Holstein cattle*

The clusters found for Holstein farmers differed in ranks of traits, and the proportion of organic and conventional farmers also differed. When performing the analysis on the combined data from organic and conventional farmers with Holstein cattle, we found that farmer clusters that are more production-based had a higher percentage of organic farmers. Organic farmers also ranked milk production higher than conventional farmers. When performing the analysis for organic farmers separately, we found two production-based clusters, whereas the analysis for conventional farmers found only one production-based cluster. The reason for this might be that the average milk yield is lower in organic herds compared to conventional herds and that the price for organic milk is higher. On the other hand, disease incidences are lower in organic herds and therefore they might also rank those traits lower, simply because they are less of a problem in their herd. If the need for improving disease traits is lower, a farmer can easily choose for improving milk yield, since this can directly improve farmer income. In contrast, Ahlman et al. (2014) found that Swedish organic farmers tended to value milk production lower and health traits higher compared to conventional farmers. However, the design of our survey was completely different from their survey. Where we used pairwise rankings based on economic values of traits, they used a number of different techniques including giving custom weights on the five most preferred traits by the farmers. The farmer was thus able to see the consequences of his or her preference on genetic gain in the individual traits, which was not possible in our design. Thus the difference in the answers given in Sweden and Denmark may to a large extent relate to the time perspective, meaning that the farmer preferences given in our result have a shorter time horizon than the answers in the Swedish survey, as they knew some (but not all) of the long term consequences before answering the questionnaire. On the other hand, our survey was based on economic weights derived from a simulation study based on an average organic farm in Denmark and thus choices of farmers might be more realistic. Also, the high number of respondents for our survey, especially for organic farmers, gives a reliable estimate of farmers' preferences. Thus, production system can be linked to farmers' preferences and organic farmers rank production traits higher compared to conventional farmers.

Besides production system, some other herd characteristics were also found to differ significantly between clusters. In this study, a large number of herd characteristics were recorded and compared between clusters. Some of these were clearly different between clusters. The herd characteristics that differed significantly between clusters indicated that farmers rank those traits higher that are related to problems they have in their herd. The clearest example of this is that farmers that rank mortality traits the highest had the highest percentage of dead cows in their herds. Another example is that farmers that gave the highest rank to cow and heifer fertility had the lowest conception rate in their herds. When we compared organic farmers with conventional farmers, instead of comparing the clusters of farmers that we found with the CA, we also found that farmers want to improve traits that are more problematic in their herds. Since many herd characteristics differed between organic and conventional farmers, production system can be seen as a predictor of certain herd characteristics, like yields and disease incidences (Table 4). This suggests that production system is more an indicator of certain herd characteristics which are related to farmers' preferences, rather than the production system being an indicator of preferences directly. Martin-Collado et al. (2015) found that the farm and farmer characteristics measured in their study did not differ between clusters, except for farmer age. Therefore,

they suggested that farmers' preferences for trait improvements are intrinsic to farmers. The results from this study suggest that farmers choose to improve those traits that they have a problem with in their herd. In this study, heterogeneity was found to exist in farmer preferences. This corroborates the findings of previous studies (Duguma et al., 2011; Ragkos and Abas, 2015). By means of a CA, distinct clusters were found, which differed in the ranking of all ten traits surveyed, showing the diversity of the clusters. We decided to use all 10 PCs for the CA, because the results did not show that a reduced number of PCs would explain a sufficient proportion of the variability. Thus, we analyzed all the variability in the farmers' preferences. We found farmers that were more production-focused and more functionality-focused. But rather than finding one group of farmers being either production or functionality-focused, farmers distinguished between different functional traits, thereby ranking groups of health-related traits, survival traits and fertility traits in roughly the same way. Mastitis was a special case that sometimes seemed more linked to production traits than to functional traits. This could be because farmers have to discard the milk when a cow is being treated for mastitis. Martin-Collado et al. (2015) studied Australian farmers' preferences for traits improvements and found comparable results. They performed a CA of the first 5 PCs, which accounted for only 55.5% of the variability. The clusters they found contained farmers that were either production-focused, functionality-focused or type-focused. Thus, farmers' preferences for breeding goal traits are not homogeneous, but groups of farmers with different preference profiles can be identified.

#### *Farmers with Danish Red cattle*

Heterogeneity was also found in the results for farmers with Danish Red cattle. The different farmer clusters clearly preferred improvements in different traits. The most substantial differences were found between the cluster 'Robustness' and the cluster 'Fertility and Production'. Farmers in the first cluster gave milk production the lowest rank of all three clusters, whereas farmers in the last cluster gave milk production the highest rank of all. Interestingly, herds in the first cluster had the highest average yield (energy corrected milk, yearly milk, fat and protein yield) and herds in the last cluster the lowest average yield, suggesting that farmers want to improve yield in their herd because it is lower than on average for all farmers (Table 6). The last cluster also had the highest percentage of organic farmers amongst the respondents (50%), which suggests that organic farmers are more inclined to prefer improvements in milk production than conventional farmers. This corroborates the findings for Holstein farmers. The increased preference for improving milk production might be caused by the higher price of organic milk, and the lower yield in organic herds compared to conventional herds ( $P < 0.001$ ; data not shown). It may be noted that organic farmers had significantly less hoof and leg, metabolic, reproduction, and udder disorders, and dead cows in their herd than conventional farmers ( $P$ -values range between  $< 0.001$  and  $0.02$ ; data not shown). This could mean that improving health traits is not regarded as important because it is a lesser problem in organic herds. This gives room for increasing milk yield, and therefore increasing farmers' incomes. This suggests that the preference for improving milk production is mostly influenced by whether or not the farm is organic and the current milk yield in the herd, based on the data collected in this study. Another herd characteristic that significantly differed between the cluster 'Robustness' and the cluster 'Fertility and Production' is the percentage of farmers that use systematic crossbreeding with other dairy breeds. The cluster 'Robustness', with the highest average yield, had the highest percentage of crossbreeding. Thus some of the farmers answering in this cluster may be farmers having Holstein, Jersey

or crossbred cows, but using DR sires in their crossbreeding program. In this cluster 53% of the farmers used insemination with Holstein, whereas in the other two clusters around 30% of the farmers indicated to use Holstein semen (non-significant difference,  $P=0.18$ ). This might explain why the average milk yield is higher in the cluster 'Robustness', since on average Holsteins have a higher milk yield than DR. We also found that farmers in the cluster 'Production and Health' had a higher preference for improving mastitis than farmers in the cluster 'Fertility and Production'. The herds in the cluster 'Production and Health' also had the highest average prevalence of udder disorders, together with herds in the cluster 'Robustness', although the difference between clusters was not significant ( $P=0.08$ ). To conclude, a link can be found between farmers' preferences and certain herd characteristics, indicating that farmers using DR semen want to improve traits that are possibly problematic in the herd.

#### *Farmers with Danish Jersey cattle*

We found heterogeneity in the results for Danish Jersey. The three clusters that were found for DJ farmers differed significantly in mean trait ranks, except for the mean ranks of calving difficulty and mastitis. Some herd characteristics also significantly differed between clusters. Farmers in the cluster 'Fertility and Production' ranked reductions in cow mortality very low and their herds had the lowest percentage of dead cows compared to the herds in the other two clusters. On the other hand, farmers in the cluster 'Survival' ranked cow mortality very high and their herds had the highest percentage of dead cows. This suggests that farmers want to improve cow mortality if it is a larger problem in their herd than on average. For Holstein farmers, a clear link between the rank of cow mortality and the percentage of dead cows was also found. In addition, the cluster 'Survival' had the highest prevalence of udder diseases, and these farmers ranked mastitis higher than the other clusters, but the difference in the rank of mastitis between clusters was not significant ( $P=0.53$ ). Fewer significant differences were found between clusters of DJ farmers than between clusters of DR farmers, and this might be due to the smaller number of respondents for the DJ survey. However, the clear link that was found between the percentage of dead cows in a herd and the rank of cow mortality, together with the possible rank of mastitis and the prevalence of udder disorders, indicates that farmers with DJ cows also want to improve traits that might be problematic in their herds.

#### *Methods*

When using predefined improvements in traits, some bias in the results may occur. The improvements for traits in this study were based on economic weights simulated for an organic system in Denmark. Conventional farmers also answered the survey based on these economic weights, but since the correlation between economic weights calculated for a conventional system and for an organic system were almost unity, it is unlikely that a bias was created because of this. The trait improvements that were compared in the survey were all equal to 100 DKK in monetary values and therefore we believe the pairwise rankings provide a good representation of farmers' preferences. However, the use of trait improvements based on simulated economic weights might create a bias when the absolute value of one of the improvements is very high. The value of cow fertility was very high (+39 pregnancies per 100 inseminations). This may have caused a bias in farmers being more inclined to choose for cow fertility, and we also see that cow fertility was the most preferred trait for all farmers together. However, the mean rank of cow fertility did not significantly differ from that of hoof and leg diseases and mastitis (Figure 2).

The different farmer clusters also showed a great variation in the rank of cow fertility, and some farmers still gave a low preference to this trait (Table 3), despite the high improvement presented in the survey. Therefore, the potential bias created by using this method is unlikely to be very high.

The number of respondents in the survey was quite high, but nonetheless a potential bias might have been present. A number of farmers did fill in the general questionnaire, but did not proceed to the preference survey. Through personal communication with a group of farmers after the survey, some farmers said that the survey took too long to finish. This could be a reason for farmers not to fill in both the general questionnaire and the preference survey. A higher proportion of organic farmers were contacted by phone than conventional farmers, and therefore the proportion of organic respondents was higher, relative to the proportion of organic farmers in Denmark. This might have caused the trait ranks for all farmers to shift more towards organic farmers' preferences, rather than being a representative sample of the whole farmer population in Denmark. However, by analyzing the organic and conventional farmers separately, we have a good perspective on farmer preferences per production system. The survey was intended to be anonymous, but because the general questionnaire and the preference survey had to be linked somehow, we asked farmers to fill in their herd number. It was mentioned however, that the herd number would only be used to link the general questionnaire with the preference survey. Thus, we feel that the potential bias has been minimized.

### *Implications*

The results of this study can be used for the development of total merit indexes for different farmer types, either as customized indices or as indexes for different lines at population level. This can be done in different ways. The first is by using the weights based directly on farmer preferences of the different clusters, in monetary values. The used software, 1000Minds, also provides this type of data. The rank data that are used for the definition of farmer clusters are valuable for understanding farmer preferences, but this type of data cannot be used directly to calculate relative weightings of traits. The second method is by changing the assumptions in the model that derive economic weights so that these assumptions correspond to the phenotypic levels within each cluster. Irrespective of which method is chosen this will give an increased ownership of the breeding goal. Given the assumed short-term perspective of the answers from the survey, we suggest breeding goals derived from farmer preferences to be used as customized indices. For breeding goals intended to be used at population level the long-term effects on genetic gain for all traits involved must be known.

### *Conclusions*

This study shows that heterogeneity exists in farmers' preferences for trait improvements for Holstein, DR and DJ cattle. For all breeds, the results suggest that farmers choose to improve traits that are more problematic in their herds. Organic farmers with Holstein cattle prefer more improvements in production traits compared to conventional farmers.

## Part 2

### Simulating organic breeding goals with emphasis on organic principles, disease resistance and roughage consumption

#### Material and methods

Different breeding goal scenarios were developed and simulated for organic and conventional dairy production, to study the effect on genetic change for specific traits. The outcome of Part 1 was unexpected, in the sense that organic farmers actually preferred a breeding goal that was closer to the simulated breeding goal for a conventional system than to the simulated breeding goal for an organic system. In Part 2 we therefore aimed to develop an organic breeding goal that was based on the organic principles from IFOAM, and not on economic values of traits in an organic system. The unexpected results were also the reason for sending out an extra questionnaire to ask farmers, researchers and experts in the area of organic animal husbandry their opinion about what a breeding goal based on the organic principles should look like. We used the output of this questionnaire in the developing process. In addition to this breeding goal, we also simulated the breeding goals that had already been set up based on the preference survey of Part 1 and based on the economic weights that had been simulated in SimHerd prior to this PhD project.

#### *Genetic Parameters*

The traits that were included in the simulation were all traits from Part 1 (in Table 1) and two new traits: roughage consumption (dry matter intake in kg/day) and beef production (growth of bull and heifer calves in kg/year). These trait were chosen because they were thought to be of economic importance or of particular importance to set up an organic breeding goal based on organic principles.

Heritabilities and genetic variances for all traits were based on estimates used in Interbull evaluations for Holstein cattle (Interbull, 2008, 2010, 2012, 2015) and estimates found in literature (Hansen et al., 2002; Weller and Ezra, 2008; Laursen et al., 2009; Fuerst-Waltl and Sørensen, 2010; Vallimont et al., 2011; Heise et al., 2016; Li et al., 2016) (Table 8). Heritabilities were rounded to two decimals.

A genetic and a phenotypic correlation matrix were constructed using relevant reports from scientific literature. Residual correlations were calculated from the genetic and the phenotypic correlation matrix. All correlations were rounded to the nearest 0.05 points. Estimates from Danish studies or similar conditions for Holstein cows were preferred. Reliable correlations could not be found for all traits in literature and therefore some correlations were estimated using correlations between other traits, in combination with expert opinion and biological reasoning. Missing genetic correlations for feed efficiency were based on milk yield genetic correlations, multiplied by the genetic correlation between feed efficiency and milk yield (0.59). The same was done for heifer fertility, missing genetic correlations were based on cow fertility and the correlation between these two traits (0.89). In some cases, where phenotypic correlations were not available in the scientific literature, phenotypic correlations were based on genetic correlations.

#### *Scenarios*

The following scenarios were developed and simulated (corresponding economic weights in Table 9).

1. Conventional economic weights from simulations. Economic weights (EW) were simulated in SimHerd for a typical Danish conventional dairy farm (Kargo et al., 2015). Economic weights were not simulated for beef production and roughage consumption, thus these traits had an EW of 0 in this scenario.
2. Conventional breeding goal based on farmers' preference survey. A farmer preference study was carried out to study preferences of conventional farmers for breeding goal traits. A description of the survey can be found in Part 1 and Slagboom et al. (2016). The input of the survey was based on the economic weights simulated for an organic dairy farm (scenario 1). Economic weights were not simulated for beef production and roughage consumption, thus these traits had an EW of 0 in this scenario.
3. Organic economic weights from simulations. Economic weights were simulated in SimHerd for a typical Danish organic dairy farm (Kargo et al., 2015). Economic weights were not simulated for beef production and roughage consumption, thus these traits had an EW of 0 in this scenario.
4. Organic breeding goal based on farmers' preference survey. A farmer preference study was carried out to study preferences of organic farmers for breeding goal traits. A description of the survey can be found in Part 1 and Slagboom et al. (2016). The input of the survey was based on the economic weights simulated for an organic dairy farm (scenario 3). Economic weights were not simulated for beef production and roughage consumption, thus these traits had an EW of 0 in this scenario.
5. Organic breeding goal based on organic principles. A questionnaire was sent out to a number of farmers, researchers and experts in the area of organic animal husbandry from May 2016 until October 2016. The participant was presented with a short introduction into the project and with an official definition of each of the four organic principles (IFOAM). The participant was then asked whether each of the traits was not at all, somewhat or very much related to each of the four organic principles. The purpose of the questionnaire was not to get a general representative answer but to map experts' views and opinions on relationships between specific breeding traits and the principles of organic agriculture. An optimization program in R was developed to determine index weights for all traits that matched expected genetic gain for this breeding goal, i.e. expected genetic gain when breeding in agreement with the organic principles. A first set up of the organic breeding goal will be made in discussions with the whole project group and based on the output of the optimization program.
6. Organic breeding goal with extra emphasis on roughage consumption and conversion.
7. Organic breeding goal with extra emphasis on disease resistance.

### *Simulation*

With the matrices, heritabilities, genetic and phenotypic variances, the G and R matrix could be calculated for the input for the pseudo-genomic simulations, similar to the method used by Buch et al. (2012). The R matrix was not positive-definite, and thus it was banded. Economic weights were multiplied with genetic standard deviations to get the weight per genetic standard deviation unit for each trait in all scenarios. Reliabilities of traits were based on GEBV reliabilities on average from young bulls born in 2014 (NAV). Each scenario was simulated for 30 years, and replicated 20 times in the stochastic simulation program ADAM (Pedersen et al., 2009). ADAM simulates a population of animals and tracks genetic change in individual traits and the aggregate genotype.

Table 8. Genetic and phenotypic parameters<sup>1</sup> used in the simulation. Heritabilities are on the diagonal, genetic correlations above the diagonal and phenotypic correlations below the diagonal. Genetic standard deviations ( $\sigma_a$ ) are shown in a separate column<sup>2</sup>. (This is not the positive-definite matrix.)

Trait <sup>3</sup>	BP	CaM	CD	CoF	CoM	FE	HeF	HLD	MA	MP	OD	RC	$\sigma_a$
BP	0.33	0.00	0.10	-0.05	0.15	-0.25	-0.05	0.00	0.15	-0.45	-0.10	0.10	24.56
CaM	0.00	0.04	0.05	-0.05	0.15	0.00	-0.05	0.15	0.05	0.00	0.10	-0.05	0.07
CD	0.10	0.05	0.06	0.00	-0.40	0.15	0.00	0.00	0.00	0.25	0.10	0.05	0.21
CoF	0.00	-0.05	0.35	0.04	0.15	-0.55	0.90	-0.05	-0.30	-0.40	-0.30	0.15	0.09
CoM	0.05	0.15	0.00	0.00	0.07	-0.20	0.15	0.40	0.35	-0.30	0.40	-0.50	0.13
FE	-0.25	0.00	0.00	-0.15	-0.20	0.14	-0.10	0.15	0.20	0.60	0.05	0.10	0.08
HeF	0.00	-0.05	0.00	0.05	0.00	-0.10	0.01	-0.05	-0.25	-0.30	-0.25	0.25	0.04
HLD	0.00	0.15	0.00	0.00	0.40	0.15	0.00	0.01	0.45	0.25	0.20	0.05	0.03
MA	0.05	0.05	0.25	0.00	0.15	0.20	0.00	0.00	0.07	0.35	0.15	0.05	0.08
MP	-0.45	0.00	0.00	-0.15	-0.10	0.60	-0.15	0.00	0.05	0.44	0.05	0.55	2.73
OD	-0.10	0.10	0.00	0.00	0.40	0.05	0.00	0.00	0.00	0.05	0.02	0.05	0.05
RC	0.05	-0.05	0.05	0.00	-0.05	-0.30	0.00	0.05	0.05	0.30	0.05	0.46	1.20

<sup>1</sup>Used references: Bijma et al. (1998), Buch and Norberg (2008), Correlation between YSS and NTM-traits (N.D), Dematawewa and Berger (1998), Eaglen et al. (2013), Fuerst-Waltl and Sørensen (2010), Hansen et al. (2002), (Heise et al. (2016), Interbull (2008, 2010, 2012, 2015), Kadarmideen et al. (2000), Laursen et al. (2009), Li et al. (2016), Oltenacu et al. (1991), Spurlock et al. (2012), Søndergaard et al. (2002), Sørensen (1999), Team Avlsværdiurdering: Årsstatistik Avl (2013/14, 2014/15), Van Arendonk et al. (1991), Vallimont et al. (2011, 2013), VanRaden et al. (2004), Weller and Ezra (2008)

<sup>2</sup>Genetic standard deviations are in the unit of the traits described in Table 1. Milk production is an exception: the  $\sigma_a$  is per milking day, not per 305-d lactation.

<sup>3</sup>Traits: beef production (BP), calf mortality (CaM), calving difficulty (CD), cow fertility (CoF), cow mortality (CoM), feed efficiency (FE), heifer fertility (HeF), hoof and leg diseases (HLD), mastitis (MA), milk production (MP), other diseases (OD), roughage consumption (RC)

### Population

The simulated breeding population consisted of 20,000 cows distributed in 200 herds. These animals were distributed in the age classes 1-6 years for cows and 1-5 years for bulls. Every year the 2000 best heifer calves and the 2000 best bull calves were genotyped, whereby calves from reproductive technologies had priority. The 100 best (genotyped) bulls between 1 to 2 years old were selected for breeding. The 200 best (genotyped) heifers were selected for MOET and produced 10 progeny each from 5 different sires. The remaining cows produced one calf each every year. Unselected animals, bulls above 5 years and females above 6 were culled. Also 15% of all animals were randomly culled before selection decisions were made. Animals were selected based on a total merit index, including all 12 traits with different economic weights per scenario. The DMU package (Madsen and Jensen, 2013) was used to predict breeding values, using a single-step genomic BLUP. See Buch et al. (2012) for a more detailed description of this method.



Table 9. Economic weights per genetic standard deviation for the different scenarios. Economic weights for scenario 5-7 are not estimated yet.

Trait	Scenario			
	1	2	3	4
BP	0.00	0.00	0.00	0.00
CaM	-74.87	-50.21	-60.14	-68.44
CD	-264.64	-181.52	-254.07	-153.88
CoF	167.82	29.29	24.19	29.83
CoM	-836.75	-716.30	-704.07	-582.32
FE	559.52	665.26	705.60	706.44
HeF	32.44	34.56	36.27	36.60
HLD	-16.06	-24.46	-20.92	-20.66
MA	-81.06	-169.42	-150.63	-165.21
MP	1965.83	2306.53	2173.05	2596.09
OD	-28.52	-45.93	-47.26	-42.86
RC	0.00	0.00	0.00	0.00

#### Data Analysis

The output of the ADAM simulation will be analyzed using R.

#### Results

##### Questionnaire about Breeding Traits and the Organic Principles

The questionnaire was answered by 29 participants in total: 3 farmers, 15 international experts and researchers, 5 employees from breeding organizations and 6 employees from advisory groups for farmers. Participants could rate each trait as ‘not at all’, ‘somewhat’ or ‘very much’ related to each principle. In Table 10 the percentage of participants that rated each trait as ‘very much’ related to each principle are shown.

*Principle of Health.* The traits calf mortality, cow mortality, hoof and leg diseases, mastitis and other diseases were rated as ‘very much’ related to this principle by more than 80% of the participants. Cow fertility, heifer fertility and calving difficulty were rated as ‘very much’ related to this principle by 48-59% of the participants.

*Principle of Ecology.* The traits feed efficiency and roughage consumption were rated as ‘very much’ related to this principle by more than 59-66% of the participants. The remaining traits were given this same rating by 21-46% of the participants.

*Principle of Fairness.* The traits calf mortality and cow mortality were rated as ‘very much’ related to this principle by about 60% of the participants. The remaining traits were given the same rating by 21-45% of the participants.

*Principle of Care.* More than 50% of the participants answered that the following traits were very much related to this principle: calving difficulty, calf mortality, cow mortality, hoof and leg diseases, mastitis and other diseases. Cow and heifer fertility were given the same rating by 41-45% of the participants.

Table 10. Percentage of participants rating each trait as ‘very much’ related to each of the organic principles defined by the IFOAM.

Trait	Organic principle			
	Health	Ecology	Fairness	Care
Cow fertility	55%	46%	24%	45%
Heifer fertility	48%	41%	21%	41%
Calving difficulty	59%	21%	45%	59%
Calf mortality	83%	34%	59%	72%
Cow mortality	83%	34%	62%	69%
Hoof and leg diseases	97%	31%	45%	62%
Mastitis	93%	31%	45%	59%
Other diseases	86%	21%	41%	55%
Milk production	10%	28%	31%	21%
Feed efficiency	14%	59%	24%	28%
Roughage consumption	29%	66%	31%	34%

No other results have been generated and analyzed yet.

Part 3  
Effects of specific organic breeding lines

In the last part of the PhD project, the effect of creating specific organic breeding lines will be simulated. We focus on changing the structure of the breeding population for the simulations in ADAM. One conventional and one organic scenario from part 2 will be used. Selection will vary between selection within lines only or across organic and conventional breeding lines. It will also be studied whether it is beneficial for both the organic and the conventional production to have separate reference populations or to share a reference population. Another project within the SOBCows project will study genotype by environment interaction and the results of this project will be used in the simulation. Therefore the effects of varying the following four dimensions will be studied in the simulation: breeding goal (organic or conventional), selection (within or across lines), reference population (within or across lines) and GxE (existing or non-existing). We will look at genetic gain of the aggregate genotype and inbreeding, and the program Zplan will be used to calculate the costs of running separate breeding programs.

Other PhD elements

Courses

Title	ECTS	Period
✓ Biological Consequences of Selection (NOVA), DK	3	17 – 21 August 2015
✓ Genotype by environment interaction and uniformity (WUR), NL	1.5	19 – 23 October 2015
✓ Feed efficiency in Dairy Cattle (NOVA), NO	4	7 – 11 March 2016
✓ Introduction to the SAS Software for Statistical Analyses (SLU), SE	2	14 – 18 March 2016
✓ Introduction to Programming for Animal Sciences (AU), DK	5	29 March – 12 April 2016
✓ Advanced Use of Excel (SLU), SE	2	12 April – 10 May 2016
✓ Quantitative Genetics in Animal Breeding (NOVA), FI	3	15 – 19 August 2016
✓ Teaching in Higher Education (SLU), SE	4.5	5 October – 8 December 2016
✓ Environmental impact of animal production (SLU), SE	2	17 – 22 October 2016
- Scientific Visualization (AU), DK	3	2 April – 22 May 2017
<b>Total</b>	<b>30</b>	

Presentations, teaching and alike

Title	Period
✓ Oral presentation for representatives of VikingGenetics	3 December 2015
✓ OrganicDairyHealth project meeting, CH	22 – 23 February 2016
✓ Nordic workshop on Genetics and Genomics in cattle, DK – oral presentation	25 – 26 April 2016
✓ 67th Annual Meeting of the European Federation of Animal Science, UK – oral and poster presentation	29 August – 2 September 2016
✓ Teaching in course ‘Designing Breeding Programmes’ at SLU, SE	12 September 2016
✓ Teaching in course ‘Lantbrukets animalieproduktion’ at SLU, SE	19 September 2016
- Teaching in course ‘Genetics’ at AU, DK	23 January – 10 March 2017
- Co-supervising master thesis at SLU, SE	January – May 2017

- |   |                       |
|---|-----------------------|
| - OrganicDairyHealth project meeting, DK  | 12 – 13 June 2017     |
| - 26th Conference of the Nordic Association of Agricultural Scientists 'Organics for tomorrow's food systems', FI | 19 – 21 June 2017     |
| - 11th World Congress on Genetics Applied to Livestock Production 2018, NZ  | 11 – 16 February 2018 |

## Publications

- I. Organic dairy farmers put more emphasis on production traits than conventional farmers (2016) - *Published in Journal of Dairy Science, Volume 99, Issue 12*
- II. Herd characteristics influence farmers' preferences for trait improvements in Danish Red and Danish Jersey cows (2017) - *Published online in Acta Agriculturae Scandinavica, Section A – Animal Science*
- III. Simulating organic breeding goals with emphasis on organic principles, disease resistance and roughage consumption - *Planned for 2017*
- IV. Effects of specific organic breeding lines - *Planned for 2018*

## Research environment change

From 31 January until 12 November 2016 I stayed at Sveriges Lantbruksuniversitet, at the department of Animal Breeding and Genetics. During my stay, I worked together with Anna Wallenbeck, my supervisor from SLU, Lotta Rydhmer and other researchers. Through seminars I have shared my research there and I have gained knowledge on other research projects. I have followed various courses and taught in two courses at SLU.

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