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Norwegian Red, its characteristics and use in international crossbreeding

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Introduction

The dairy cattle industry worldwide is struggling to achieve the highest possible income from their cows. In many countries the Holstein-Friesian has been bred to produce extreme amounts of milk, but this intense breeding has had its consequence. By only focusing on the milk trait the non-production traits have been neglected. All over the world farmers are trying to get their high producers pregnant and at the same time keep them free of mastitis and other diseases. In addition to these problems, there is also a high occurrence of inbreeding in the Holstein population, leading to a depression in reproductive performance (Heins et al., 2006a). As a solution for these problems many trials have been initiated to find proper combinations for economic crossbreeding. By the use of crossbreeding the advantages from different dairy breeds can be combined and utilized. One of the breeds getting the most interest is the Norwegian Red Cattle (=Norsk Rødtfe, abbreviated NRF). This is a dual purpose cow which has been bred for health and reproduction for several decades together with milk and meat production (Hersleth, 2010b). The goal is to combine the superior milk production seen in Holstein with the more healthy and fertile Norwegian Red traits.

This work will first give a detailed description of the development of the Norwegian Red and its most important characteristics. Furthermore, the results from different international trails will be evaluated, as thorough research has been performed on both sides of the Atlantic. By comparing the results from the different nations a consensus of how the Norwegian Red and its crosses are performing outside Norway can be made. Own material of data from crossbreeding done on Hungarian farms with Holstein-Friesian and Norwegian Red will also be evaluated. These numbers are collected from the Hungarian National Database with the help of the Hungarian Holstein Association. Even if the current Hungarian results are only preliminary, they may be used for further investigation to find indication for crossbreeding both in Hungary and other countries of the same agricultural standard.

Development of the Norwegian Red

The cattle industry in Norway in the late 19th century was dominated by 8-10 local breeds that had their own geographical stronghold. Maintaining these old breeds alive also corresponded with the politics decided by the national government, so when farmers wanted to import Ayrshire to improve the dual milk and meat performance a lot of reluctance existed. In spite of this, Ayrshire from Scotland, some British Shorthorns and some Dutch Friesians were imported, together with the Ayrshire/Swedish Red from Sweden. The government had both patriotic reasons for their politic, as well as their Darwinistic way of thinking, that the animals that had developed in the different areas were the most suitable for their given environment. This way of thinking was not shared by those who wanted to import, who preferred a manmade cow for the future (Hersleth, 2010a).

During the 1920's many of the local breeds founded associations to stand up strong against the Ayrshire, but good meat production and higher milk yield gained more and more supporters. Especially in the eastern areas near the Swedish border, particularly in Hedmark County, they started to use imported Ayrshire/Swedish Red bulls. Christian Wriedt, who had been studying genetics in both the USA and in Europe, was hired as a genetics consultant for the government and thus one of the strongest driving forces behind the creation of the Norwegian Red. He was also one of the founders of Hornet Slettefe (Horned Plain Cattle) in 1923. He believed that only the top bulls should be used for breeding, and that the offspring should be investigated to get the most correct ranking of their breeding capacities. In 1935, after many years of arguing between the farmers in Hedmark County, they gathered and formed a breeding association for Hedmark cattle. The most fundamental thing with this establishment was their breeding goals. This is one of the main reasons why it is seen as the precursor for the Norwegian Red association. These goals: high lactation with fat percentage near 4%, meat producing animals at the size of Ayrshire, fast growers, good grazers and allowance of crossing were all kept in 1939 when the Hedmark cattle were united with the Hornet Slettfe. This new association then got a new name: Norwegian Red Cattle. In its early days these cattle had a negative reputation; it was said that it required a high amount of feed and that it was a low producer. In addition to this it was not considered positive, especially from the government, that they received Swedish help and expertise, and that they used numerous Swedish bulls for the breeding (Hersleth, 2010a).

An important side of Norwegian cattle breeding in the early days was a good exterior for exhibition. Initially, however, the fares were only open for the local breeds. The new breed was not accepted at exhibitions until the 1950’s, but when descent and yield started to play more important roles, they also started to exceed the other breeds. In 1959 at an exhibition in Oslo 32 Norwegian Red cows with a milk yield of 6400 kg and 4.4 % fat came way ahead of the other participants (Hersleth, 2010a).

Artificial insemination was introduced in 1942. In the early days mainly semen from Swedish bulls were used, since it was superior to the Norwegian at that time. The first Norwegian AI stations came in 1949; Stensby Semen facility. In 1952 they started with progeny testing, mainly for milk yield and fat. Four years later they also took exterior, udder quality and lactation speed into the calculation. In 1958 they started with young bull progeny testing in Vestfold County. Since fares and exhibitions became less important, the looks of the animals became less weighted in the breeding. More and more focus was put on the total merit index of the animals. Selecting the best bulls gave good progress for the breed (Hersleth, 2010a).

In the 1950’s there were still conflicts among the other Norwegian breeds and the Norwegian Red. The competition was hard and many of the associations suffered from bad economy. In 1959 the key associations had established AI stations, but the Norwegian Red was the most successful, consisting of 25 % of the Norwegian cattle population. As the supporters of population genetics were getting more and more numerous, the supporters of the different breeds also realized that they would be stronger together. One by one they united and in 1968 all the major breeds were integrated into the Norwegian Red population. The transit was swift since many of the other breeds had already started to use Norwegian Red semen with their cows. The union of the six major cattle breeds gave a total population of half a million animals, altogether 98 % of the Norwegian cattle population. The creation of the union was not always easy and some of the polled breeds had to see this trait being neglected since the association didn’t consider this an economic trait. Half of this population was now registered in the National Dairy Herd Recording System and this proportion only increased in the following years. The introduction of frozen sperm, the large population and the national database were three major factors for effective breeding (Hersleth, 2010b).

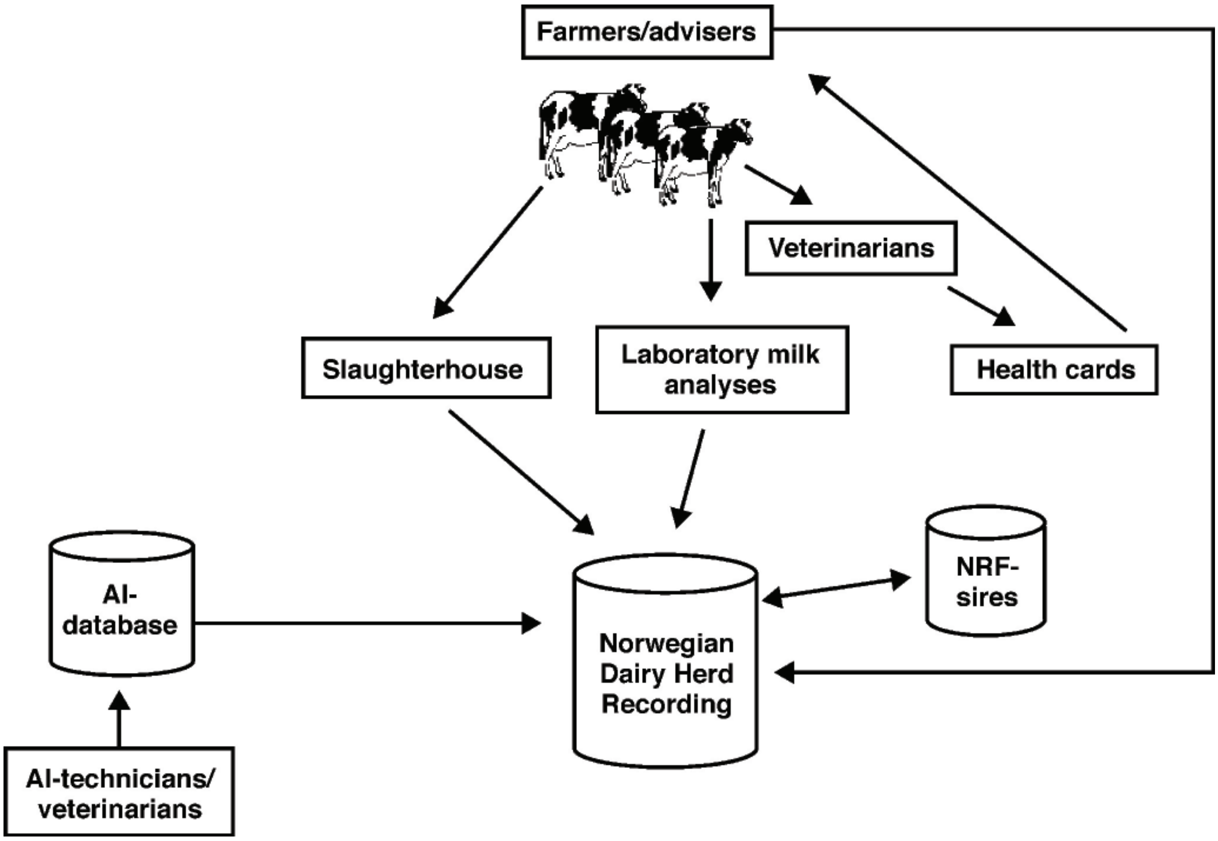


Figure 1: Data flow in the Norwegian Dairy Herd Recording (Ranberg et al. 2003)

When frozen sperm was introduced in 1965 it didn't take long before the Norwegian Red started to be exported. When the Faroe Islands needed frozen sperm and the Danes were not able to provide them, they had to turn to Norway. Although they were certainly not the largest marketplace, this was a good start (Hersleth, 2010b).

Hedmark County had been an important area for the development of the breed, but when the eastern parts of the country turned more to cereal grain production, many of the cattle herds were sold to other parts of the country in the west, south and north. This improved the spreading and gave quality herds in all regions. A Nordic agreement, between Sweden, Finland and Norway, in 1967 led to more cooperation, making semen from the best bulls from the different nations available for everyone to use. In the 1970's some farmers wanted to try Holstein-Friesian and to avoid a split in the population, semen from 17 bulls was imported. They originated from USA, Canada and the United Kingdom. Their offspring were tested, as was the rest of the young. From these the British came out worst, while some of the American bulls are direct ancestors to some of the elite bulls currently being used (Hersleth, 2010b).

In 1971 the bulls were started to be selected on basis of the fertility of their daughters, and in 1978 also from their daughters' health. These two traits have been essential when developing the breed as it is today. Each cow also got their own health card, and together with the veterinarians the association managed to document the occurrence of mastitis and take this into account for further breeding. The 1970's were very positive for the breed. Frozen semen got fixed transport routes nationwide and the curve was pointing upward for the breed. The progress continued in the 1980's with a peak in semen sale in 1985. By this time the Norwegian Red was also listed as a breed abroad and export of both animals and semen had started. Positive feedback, e.g. from the USA, gave motivation to expand this business. Unfortunately for the Norwegian Red there was little understanding abroad for the selection based on health and fertility, since these were said to be of low heritability. Comments were also made on the neglected looks (Hersleth, 2010b).

During the 1980's the selection for milk production was reduced and mastitis was increased. This gave positive results in the population, and this genetic progress also gained some international acceptance. The same changes were done in Sweden and Finland, but here they were less radical. In 1990 a polled bull managed to become an elite bull and as the interest for polledness was emerging, he became very widely used. Ten of his sons later achieved elite status. Polledness was reintroduced in the population as farmers found it an economical trait again. The Norwegian cattle population had started to decline in the 1990's, and this consequently led to a decrease in the national sale of semen. More focus was put on exporting semen, embryos and livestock and after the turn of the millennium great results have been achieved in trials abroad. Especially in crossbreeding trials with Holstein-Friesian, with results from several countries like Ireland and United States, has the Norwegian Red gotten positive feedback. Important traits for the Norwegian Red have been fertility, health and easy calving; since these often have been neglected in the Holstein-Friesian breeding, crossbreeding has been rewarding (Hersleth, 2010b).

Geno

The Norwegian Red Association changed their name in 1999 to Geno, which is Latin for "*I breed*". The development and breeding of the Norwegian Red cow is administered and run by Geno. It is a cooperation owned by 13,000 Norwegian cattle farmers, and through elected representatives from the different geographical areas the farmers also participate in important decisions regarding both breeding goals and the organisations future. The average Norwegian Red cow produced 7,057 kg of milk in 2009, with a mean fat percentage of 4.22% and a protein yield of 3.37%. The total population now consists of only slightly more than 200,000 cows. The current number shows that 98 % of the animals and 96 % of the herds are included into the National Dairy Herd recording System. This system is also used by TINE, the national dairy cooperation and Nortura, the national slaughterhouse cooperation, both of which are also owned by the farmers (TINE, 2009). As the population in Norway is decreasing, it is essential that Geno helps farmers to find the optimal bulls for their cows, which improves the breed every year and avoids inbreeding. If a farmer has a very good cow that gives birth to a bull calf after being breed with a top bull, this calf might be selected as a potential elite bull. Each year the best 330 Norwegian Red bull calves are shipped in from all over Norway to Geno's main facility at Stange in Hedmark. Later 130 of these are selected as test sires and each will have 250-300 daughters, whose qualities are tested. It is important that the number of the daughters is this high, since some of the main traits they look for, such as health and fertility, are of low heritability. From these 130 the top 10-12 will be selected as elite sires. This selection is based both on their total merit index, but also on their average relation to the population to avoid risk of inbreeding. 90 % of calves are born with the use of AI, and from these 40 % are from test sires, while the remaining 60 % are from the elite bulls. Each farmer is obliged to use a minimum of 40 % young test sires for proper evaluation. The farmers will then report back to Geno by logging on to the National Dairy Herd Recording System and give them feedback on the cow's production, fertility and health traits. The progenies are tested for 40 different traits, which are weighted differently according to their importance, to give the total merit index. These indexes are then published in a catalogue which is sent back to the farmers. In addition to this, Geno also exports Norwegian Red semen to more than 20 countries worldwide. There are about 250 people employed in Geno, and they have a yearly turnover of 30 mill Euros. In addition to the cattle industry, Geno also does research for artificial insemination in the fish industry (GENO Global, 2010a).

Breeding goals

The goal for the Norwegian cattle breeders was an animal that was high - and fast lactating, that gave a fat percentage close to 4 %, fast growing, a good grazer and in addition suitable for meat production. Furthermore, the exterior had a more important role in the early days. These breeding goals were established in the early days, but in 1963 they introduced a total merit index, in which the different traits were weighted against one another. These traits can be separated into four main groups; milk, growth rate, utility traits, and health and fertility. In the 1960's the main focus was milk but ,as seen in table 1 and figure 1, its share in the total merit index decreased before stabilizing in the early 1990's, increasing again slightly in recent years. Growth rate and utility traits have been fairly stabile both with a small peak in the mid-90's. The most important utility traits were udder, body condition, temper and milking speed (Hersleth, 2010b). Health and fertility traits have had a major importance in the Norwegian cattle breeding. It was introduced in the 1970's, and in the 80's it had already developed into significant traits for the breed. For the last decade it has had more than 40% of the weight of the breeding goals.

During the progeny testing the sires are tested for traits they are not necessarily showing themselves. Their daughters are tested, and since many of the traits have low heritability they need a large number of daughters for secure evaluation (GENO 2009). The combinations of traits are making the investigation more difficult. When the breeding goal include both production traits and functional non-production traits calculation of the effect will be much more difficult and failure to do this will decrease the selection index by 15-25 %. The Scandinavian programs combine production, reproduction and health traits as the basic principle of selection, and this has been supported by studies and research results worldwide (Philipsson et al., 1994). The different traits have different economic values. The ten main traits are: milk, meat, mastitis resistance, fertility, calving difficulties, stillbirth, other diseases, udder, temperament and legs were calculated on 3,259 Norwegian dairy farms between 1999 and 2003. Out of the ten traits it was estimated that seven of them had a positive economic value. Only calving difficulties, stillbirth and other diseases did not result in profit. While these traits could be lowered without loss, others might be increased. The largest profit was found in milk, then udder, meat, mastitis resistance and temperament. This proves that the Scandinavian way of breeding with a several breeding goals may be quite profitable for the farms (Steine et al., 2008).

Changes in Breeding Goals 1963-2009

	1963	1974	1978	1982	1990	1994	1997	2000	2001	2003	2007	2009
Milk	68	60	50	40	19	19	21	23	23	24	24	28
Growth rate	10	10	10	10	11	11	12	9	9	9	9	6
Utility traits	22	26	25,6	20	36,6	38,4	29	28	28	27	27	25
Health and fertility	0	4	14,4	30	33,4	31,6	38	40	40	40	40	41

Table 1: Changes in Breeding Goals 1963-2009 (GENO, 2008).

The table and graph (figure 1) show the development in breeding goals for almost half a century. These breeding goals differ from what has been common in the dairy industry. Other Scandinavian countries started similar programs in the following years, and in more recent years other countries have changed their breeding strategy to put more focus on the health and fertility traits, similar to the Norwegians. An example for this is the American Lifetime Net Merit Index where in 2010 the weight for the non-milk production traits was more than 60 % compared to ten years earlier when it was under 40 % (Rogers, 2010).

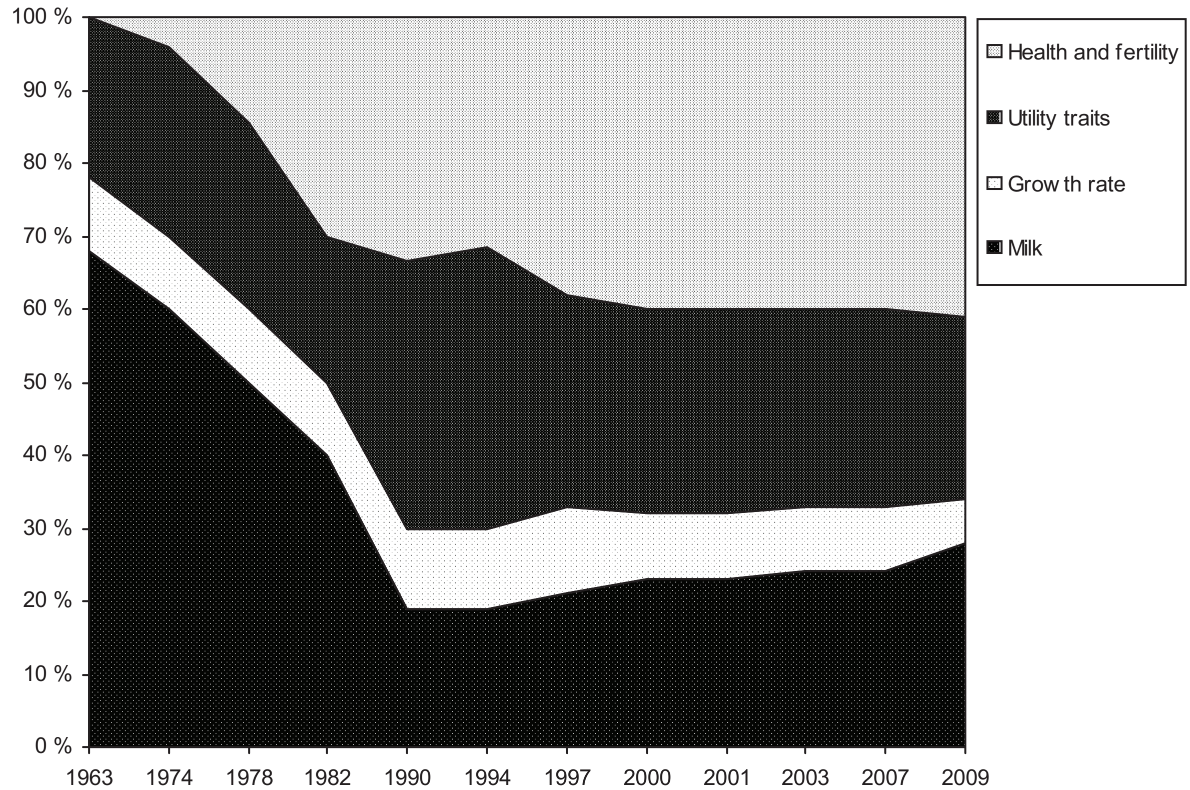


Figure 2: Changes in Breeding Goals 1963-2009 (GENO, 2008).

The main Characteristics of the Norwegian Red

Traits	Relative weight (March 2009)	Old relative weight
Milk production (Protein, fat, and milk yield)	28	24
Mastitis (Frequency of clinical mastitis in 1st, 2nd and 3rd lactation)	21	22
Fertility (Female fertility for heifers and first-lactating cows)	18	15
Udder conformation (Foreteat placement, supernumerary teats, udder balance, teat attachment, fore and rear udder attachment, udder support, and teat length)	15	15
Leg conformation (Rear leg, side and rear view, foot angle and hoof quality)	6	6
Growth rate (Carcass value, young bull)	6	9
Temperament (Behavior of cows when milked)	2	4
Diseases other than mastitis (Milk fever, ketosis, and retained placenta)	2	3
Milk ability (Milking speed)	1	0
Calving difficulty (Maternal)	0,5	1
Stillbirth (Paternal and maternal)	0,5	1

Table 2: Current breeding traits (GENO, 2009)

Milk production (Weighted 28 %)

The main character for the Norwegian Red's and any dairy cow is its milk production. The farmers type all the information he receives from the dairy regarding the individual animal's milk yield, protein, fat and somatic cell count in to the National Dairy Herd Recording System. The best Norwegian Red cows may produce more than 16,000 kg of milk annually and the best herds have an average of more than 10,000 kg. The nationwide average production of a Norwegian dairy cow exceeded the 7,000 kg mark (7,057 kg) for the first time in 2009, the fat content increased from 4.19 % in 2008 to 4.22 % in 2009 while the protein yield decreased slightly from 3.39 % to 3.37 % (TINE, 2009). Protein yield had an annual increase of 0.63 kg/year from 1979 and onwards (Heringstad et al., 2005). These numbers are corrected for 305 days of milking. Included in the evaluation of the milk production breeding value are kg protein, kg fat, kg milk, protein percentage, fat percentage and somatic cell count. They are calculated and corrected for which lactation and what stage of lactation they are in. The milk index contains kg protein, weighted 1.0, kg milk which is weighted -0.1 and kg fat, which is weighted 0.1 (Geno, 2009). Breeding for milk production has negative effect on the female fertility. The traits are almost like antagonists (Kadarmideen et al., 2000). It is said that 10 %

improvement in fertility and health consequently reduces the milk yield by 12-13 % (Lindhé and Philipsson 1998). Since the Norwegian Red has been breed for both fertility and milk there has been a stabile level of non-returning animals in first lactating cows, while the milk yield has been increased, however, there has also been an undesirable increase in the interval from first calving until first insemination (Andersen-Ranberg et al., 2005).

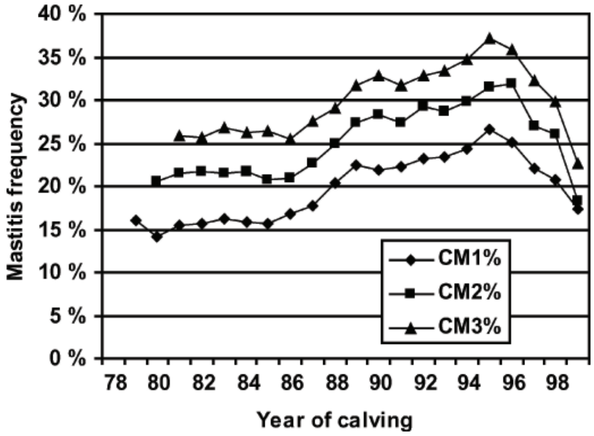
Mastitis (Weighted 21 %)

Mastitis was included into the breeding value in 1978, but in Norway and worldwide, it's still the disease causing the most economical losses in the dairy industry (Hersleth, 2-2010). 45 % of veterinarian treatments of dairy cattle are due to clinical mastitis (Heringstad et al., 2002). Every treatment is registered into the National Dairy Herd Recording System and this information is then used for the evaluation of the sires. Due to the low heritability, a young bull needs a minimum of 300 daughters for the evaluation of this trait. Since the introduction of breeding for low occurrence of mastitis its importance has increased (table 1). In the 1980's it constituted almost one third of the breeding index and tendencies show even higher emphasis in the last decade. While the weight on milk was lowered, the health traits were doubled (from 14.4 % to 30 %). Records of 1.6 millions daughters of 2,411 Norwegian Red sires taken from 1978 until 1998 showed a presence of 6.6 % clinical mastitis. In the early period, from 1978 to 1990, the daughters had a decrease of -0.02 % each year, but from 1990 until 1998 there has been a yearly change of -0.27 % (Heringstad et al., 2003).

Interval	Lactation	Days from calving	Cumulative freq.[1], %	Mastitis culling rate[2], %
1	1	-30 to 0	3.9	
2		1 to 30	8.8	0
3		31 to 120	5.0	3.6
4		121 to 300	7.0	10.3
5	2	-30 to 0	3.3	
6		1 to 30	9.9	33.5
7		31 to 120	9.3	35.2
8		121 to 300	9.8	40.6
9	3	-30 to 0	3.8	
10		1 to 30	13.0	60.5
11		31 to 120	11.2	61.9
12		121 to 300	11.1	65.6

Table 3: Mastitis frequency and cumulative culling rate (Heringstad et al. 2003).
[1]Percentage of cows with at least one case of clinical mastitis during the interval.
[2]Percentage of cows that were culled before the start of the interval.

These records also reveal the unfavourable negative correlation between increasing milk yield and reduced resistance to mastitis. Other breeds and nationalities have started to experiment with health traits as breeding goals in recent years and since the Norwegian Red has records all the way back to 1978 it is one of the few populations with this kind of documentation. Results show that it is possible to have positive genetic improvement, despite unfavourable genetic correlation between the traits and low heritability (Heringstad et al., 1999). A connection between early mastitis prior to the first lactation and mastitis later has also been seen (Heringstad et al., 2004).



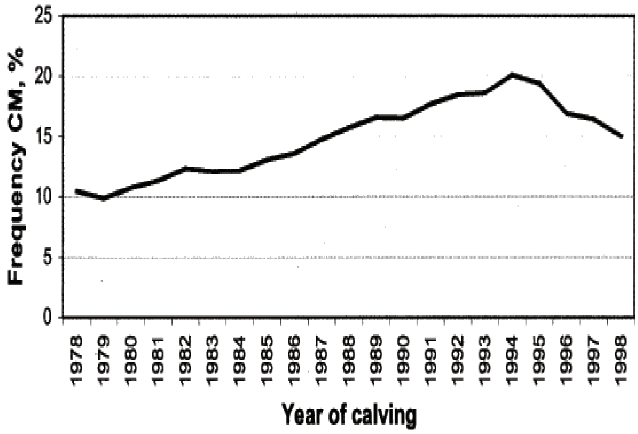


Figure 3 (left): Mastitis frequency in 1st, 2nd, and 3rd lactation (Heringstad et al. 2004).
Figure 4 (right): Occurence from -15 day until +120 day after birth (Heringstad et al. 2003).

372,227 daughters of 2,411 sires were tested for the presence of mastitis in the following intervals: 30 days prior to - and until birth, the first 30 days after birth, from the 31st until the 120th day and from the 121st to 300th day. The presence of mastitis was highest in the first period; 0.09 and lowest in the last; 0.05, with an overall average occurrence of 0.07. During the observance of three lactations, it was seen that in the first period of both the first and third lactation it was highest and lowest in the last interval of third lactation. The culling rate due to clinical mastitis after the first lactation was 33.5 % and 60.5 % after the second lactation (Heringstad et al., 2004). Clinical mastitis also influences the length from calving until conception in first lactation. This may be an underestimated connection, but research shows that there is a genetic correlation of 0.21 between the two traits (Heringstad et al., 2006). British Holsteins have shown similar tendencies; high mastitis being genetically associated with reduced fertility. The presence of mastitis is much higher here, ranging from 0.21 to 0.41 (Kadarmideen et al., 2000). Years of persistent breeding has reduced the occurrence of mastitis, while the interval from calving until conception has remained level. Seeing that the milk production has increased in the same period, with negative correlations for fertility traits, this is a positive result. Documentation of this is always difficult, seeing that animals that suffer from either are more prone to be culled early. Selection for mastitis will also have beneficial effects on other health traits and it is suggested that there might be some general disease resistance factor which improves protection against ketosis, milk fever and retained placenta, among others (Heringstad et al., 2007).

Fertility (Weighted 18 %)

The importance of good fertility is being emphasised more and more in modern cattle breeding. The economic importance is shown by comparing two herds of the same production level, where one has a fertility of 45 % while the other has one of 60 %; the latter will have a 10 % higher overall income (Boichard, 1990). It is a complex trait with a minimum of two important components; interval trait and success trait. Both the abilities of the bull and the cow are evaluated. The bulls are examined for willingness to mount, ability to cover, sufficient semen production and high sperm quality. Even if bull fertility is currently not included in the overall breeding goal, the bulls have to show good results or they will be removed from the testing facility. For cows the most important traits are the 56 days non-return rate after first insemination, the interval from calving until first insemination, the number of inseminations needed, the ability to show oestrus signs and the calving interval. The sires are then evaluated via their daughters' performance, with the fertility of the heifers weighing 2/3 and the first lactating cows' fertility constituting the final 1/3. The numbers are then corrected according to herds, age of dam when inseminated, double insemination and month of insemination. The possibility for early detection is an advantage since there is a large correlation between heifer fertility and fertility in lactations. A high correlation of 0.51 between non-return after 56 days in the first lactation and the interval between calving and first insemination can also be seen. By changing one, you largely affect the other as well (Andersen-Ranberg et al., 2005). Fertility was introduced as an important trait early in the 1970's and it has steadily gained increasing importance and now weighs 0.18 of the total merit index. By using the national records of 1.632,961 daughters from 2,945 sires, the 56 days non returning rate in virgin heifers was investigated and a heritability of 1.2-1.4 % was found when using six different models. Due to this low heritability, a minimum of 260 daughters are needed for proper progeny testing (Geno 2008). The 56 days non-returning rate is a relevant measure of fertility, however it depends on reports from inseminations and mating in order to be evaluated properly. The genetic change for the 56 days non-returning rate from 1979 until 2000 was 0.04 %, yearly. In 1979 the 56 days non-returning rate was 72.5 %, while after two decades of consistent breeding, it increased to 76 % in 1999 (Ranberg et al., 2003).

Reproduction problems are highly significant in the dairy industry. Long calving intervals, increase numbers of inseminations, higher veterinarian costs, higher culling rates and increased replacement costs are only some of the drawbacks that the long term selection with only high milk production as a breeding goal has. The negative correlation has led to a genetic deterioration of the female fertility (Roxström et al., 2001). By studying insemination reports from 1985 until 2005, an increase in 60 days non-return rate from 68.1 % to 72.7 % can be seen, while the number of services needed decreased from 1.8 to 1.6. The average calving interval remained steady at 12.4 and 12.6 months the entire period, while the interval between calving and first insemination increased from 79-102 days in 1990 to 86-108 days in 2005. When looking at animals culled due to poor fertility, the percentage has been stabile between 4.5 % and 6 % for the entire period. Internationally oestrus cycle control has been used to compensate for the increasing calving to first service and conception interval, decreasing pregnancy interval and increasing number of inseminations, which is often a consequence of poor oestrus detection in large herds. The age of first insemination was 15.6 months in 1991, while in 2001 and 2005 it was 16.2 months. The overall pregnancy rate of the Norwegian Red after the first insemination is 60.7 %. For heifers the average was 68.8 %, in first lactating cows it was 56.0 % and for later lactations 58.7 %. Fertility of animals in the first lactation is normally lower compared to the other periods, mainly due to the negative energy balance when the animal is not able to compensate the energy loss due to milking with a sufficient feed uptake. Programs are offered by both veterinarians and agricultural advisors to improve the herd management, nutrition and reproduction of the farms (Refsdal, 2007). The mean calving interval is currently 376 days with 95 open days. The calving to first insemination interval is 79.5 days, while the interval from calving to the last insemination is 98 days (Garmo et al., 2010). There has been a change in calving to first insemination of only 0.11 days/year (Andersen-Ranberg et al., 2005).

In addition to the programs being offered to farmers there are further factors improving the overall fertility. Eradication of Bovine Viral Diarrhoea, which started in late 1992, might have been a contributing factor. When the program started 11.3 % of herds, of altogether 2.950 herds, were restricted, but in 2005 there was only one herd remaining with restrictions (National Vet Institute, 2006). Other important reasons may be the generally low milk production seen in the Norwegian Red compared to the high producing Holstein-Friesian. The Norwegian climate is also known to cause less summer depression than in warmer countries on the continent, while fertility does decrease slightly during the winter. More emphasis on nutrition has also been a contributing factor (Refsdal 2007).

Udder conformations (Weighted 15 %)

The heifers selected for progeny testing have their udders examined by the national dairy cooperation TINE, together with evaluation of the rest of the body. They are selected on the basis of sire, calving date and geographic spread. For the udder to properly develop, the judgement should be performed a minimum of thirty days after calving. This will also give more even references for comparison (GENO, 2009). Recently, the bulls are also marked as suitable or unsuitable for Voluntary Milking Systems depending on the udder traits. In addition to making milking simpler, good udder conformation has a beneficial effect on the somatic cell count with a genetic correlation of 0.22-0.30 (Monardes et al., 1990). The average increase of the udder index for sires from 1986 until 2006 has been 0.68, annually (GENO, 2010).

Characteristics	Heritability	% Weight
Distance between tip of teats	0.38	10
Distance between front teats	0.37	25
Supernummerary teats	0.19	10
Udder balance	0.07	5
Teat attachment	0.06	5
Foreudder attachment	0.06	10
Rearudder attachment	0.06	10
Udder support	0.06	15
Length of teats	0.21	10

Table 4: Udder Conformation Characteristics (Geno, 2009).

Leg conformation (Weighted 6 %)

In Norway nearly 88 % of dairy cattle are kept in tie stalls, but new regulation will force all dairy farmers to convert to free stall housing by 2024. From 2006 following, the farmers have had to install soft flooring, normally rubber mattresses, and for many this decreased the natural wear of hooves. Once or twice annually, normally in spring and autumn, the hooves are trimmed by professional craftsmen. The hoof is very important in good dairy cattle. 90 % of lamenesses in dairy cattle are caused by claw disorders (Murray et al., 1996). When examining 57 free stall herds, with 1547 cows and 403 heifers, for lameness a prevalence of 1.6 % was found in hind legs and only 0.3 % in the front limbs. The most common lesions in the hind limb were: 39.6 % heel horn lesions, 20 % haemorrhages of sole, 13.6 % haemorrhages of the white line, 9.4 % white line fissures, 6.7 % dermatitis and 3.0 % sole ulcer. From the environment both dermatitis and horn lesions can be acquired (Sogstad et al., 2005).

Characteristics	**Heritability**	**% Weight**
Hock Angle	0.09	30
Bone Positioning Hind	0.06	20
Carpus/Tarsus Joints	0.08	30
Twisted Hooves	0.02	20

Table 5: Leg Conformation Characteristics (GENO, 2009).

A similar testing procedure was used for the evaluation of the udder. A number of heifers are selected each year to be tested within the first month after calving. Stage of lactation, time of calving, age at calving, herd keeping and sire are only some of the traits that are evaluated (GENO, 2009). The average increase of breeding index for leg conformation between 1987 and 2006 has been 0.42 yearly (GENO, 2010).

Growth rate (Weighted 6 %)

Unlike most dairy breeds worldwide the Norwegian Red is a dual purpose cattle breed. The income from meat production is an important part of the revenues. Slaughter weight, carcass grading and fat grouping of the bulls are evaluated at the slaughterhouses. They are normally slaughtered between the 40th and 121st week of age and at this time they should be between 50 and 500 kg, occasionally even heavier. The bulls have a daily weight gain of approximately 1.4 kilo/day until slaughter. Slaughter data has been collected since 1988. After 1996 the classification grading was changed to the EUROP system. Only the fathers are evaluated and the findings are calculated according to age at slaughter, year and month of slaughter and herd environment. The heritability of slaughter weight is 0.39; carcass grading is 0.19, while 0.17 is the heritability for fat groups. In the combined meat index the slaughter weight is graded 60 %, while carcass and fat gradings are each 20 %. The yearly breeding goal is a decrease by one day from birth to slaughter, obviously within natural limits, while a mild improvement of carcass grouping is also expected. No genetic progress for fat grouping is expected (GENO, 2009).

Temperament (Weighted 2 %)

Temperament was included in the total merit index in 1978 and has since been weighted between 2 and 4 %. Between 1978 and 1989 the heifer's reaction to the milking process, as well as reactions to a stranger arriving and - performing the heifer examination were the basis of the temperament evaluation. From 1989 until 2001 only the remarks taken by the official heifer measurer were reported back to GENO, but from 2000 the information from the farmer at milking were reported and included. All heifers from AI bulls are graded, 1) especially friendly and calm, 2) average or 3) uneasy and aggressive. Since 1988 the scoring of nearly 25 % of heifers after the first calving have been classified as calm with generally less than 10 % uneasy, while the remaining 65 % have been classified as average. Previously, the animals were evaluated on behalf of their daughters, compared to the yearly mean, but since 2000 ancestors and relatives are also included in the evaluation and are compared to a continuous scale with the BLUP-index (GENO 2009).

Diseases other than mastitis (Weighted 2 %)

The individual health card for each animal has been the basis of disease documentation in the Norwegian dairy industry since the mid-1970s; it has made it possible to get an overview of the occurrence of diseases. Since 1978 the information has been forwarded to the National Dairy Herd Recording System by the farmers. With this information the breeders could select those animals which were less prone to diseases for further breeding. This would then increase the animal welfare, reduce economic losses for the farmer and increase food safety due to reduced use of antibiotics. Resistance against diseases cannot be measured directly so the animals are only examined by the occurrence, or non-occurence, of a certain disease. A large number of daughters are needed for a proper progeny testing of this trait. The heritability is less than 0.05, but due to the interference of the environment and herd management it is a difficult trait to evaluate. Time is also an important factor, since some diseases are seasonal or connected to the period around calving. For young sires the age of their daughters doesn't allow evaluation of the frequency in later lactation, even if this information would be beneficial to know for the breeding value (GENO 2009).

By controlling 372.227 daughters of 2411 sires, ketosis was found to have a heritability of 0.15, milk fever around 0.11, with increasing occurrence in higher lactations, and a 0.08 heritability for retained placentas. A positive correlation between mastitis resistance and decreased occurrence of other diseases was also discovered. The highest correlation was between ketosis and mastitis (0.26), while milk fever or ketosis had the lowest correlation with retained placenta (Heringstad et al., 2007). It is known that the milk production, including the protein yield, may be reduced when breeding for non-production traits like health. By investigating 2.7 million animals, classified as high producers and low producers, it was seen that there was a negative correlation between health traits and high milk production, while those considered as low producers had a decreased tendency for diseases like clinical mastitis, ketosis and retained placenta. When selecting for mastitis resistency they saw that the occurrence of ketosis and retained placenta also decreased. During a period of five bovine generations they noted a distance between the high producers and low producers; high producers had 10 % higher occurrence of clinical mastitis, 1.5 % more ketosis, while the occurrence of retained placentas was 0.5 % higher in the high producing herds (Heringstad et al., 2007).

	High Milk Prod.	**Low Milk Prod.**	**High Protein Yield**	**Low Protein Yield**	**All groups**
Cows with health data	1,369	1,016	1,429	1,302	2,719,353
Mean CM frequency,[1] %	17.5	12.8	14.1	10.6	13.5
Mean KET frequency,[1] %	11.5	9.2	2.4	2.5	7.0
Mean RP frequency,[1] %	2.6	2.4	2.6	2.2	2.2
Cows with PY305 data	1,209	854	1,249	1,130	2,283,059
Mean PY305, kg	214	188	222	206	202

Table 6: Summary for clinical mastitis (CM), ketosis (KET), retained placenta (RP), and 305-d protein yield (PY305) (Heringstad et al. 2007).

[1]Absence or presence of each of the 3 diseases was scored as 0 or 1, respectively, based on veterinary treatments within the interval of 15 d before - to 120 d after the first calving for CM and KET, and within the first 5 d for RP.

Since the middle of the 1980's the occurrence of ketosis has gradually decreased. Prior to this it was a considerable problem for Norwegian dairy farmers. Breeding for more healthy animals also helped reduce the problem and in 1994 most of the interest was transferred to the mastitis part of the health trait. In 1997 the frequency of ketosis was so low that the index was renamed "other diseases" and also included milk fever and retained placenta (GENO, 2009). Ketosis is the reason for 9 % of all veterinary treatments, 8 % is due to milk fever, while retained placentas account for 5 % of the treatments (Heringstad et al., 2005).

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	First lactation	Second lactation	Third lactation
Number of Cows	372,227	247,692	147,051
Mean CM frequency,[1] (%)	15.8	19.8	24.2
Mean MF frequency, (%)	0.1	1.9	7.9
Mean KET frequency, (%)	7.5	13.0	17.2
Mean RP frequency, (%)	2.6	3.4	4.3

Table 7: Mean frequency of clinical mastitis (CM), milk fever (MF), ketosis (KET), and retained placenta (RP) by lactation (Heringstad et al. 2007)

[1]Percentage of cows with at least one case of CM in the period from 15 d prior to calving to 120 d after calving.

Milk ability (Weighted 1 %)

While milking speed has been integrated into the breeding value since the early 1960's, breeding against leakage was added in 1979. Except for a period during the 1970's, when the weight was near 4 %, it has been close to 14 % for both the characteristics. After the organisation decided in 1997 that the balance between the two antagonising traits was sufficient in the Norwegian Red population they were reintroduced into the total index merit in March 2009. As a precursor to the current reporting system, in 1955 the heifers were tested for milk speed by weighing the amount of milked within the first two minutes. Until 1989 it was integrated in the heifer investigation and performed by the inspectors. Furthermore, leakage was reported by the farmer. The procedures were changed after 1989 and now the farmers do the entire evaluation. By doing this the association was able to include a higher number of daughters in the progeny testing, and the number was increased from 80 to 180 for each sire in order to achieve a better result. The milking was graded as 1) Quick, 2) Medium or 3) Slow. Since 1990 the share of quick-milking heifers has steadily been decreasing from 30 % until nearly 20 %, while the fraction of slow-milking heifers has been around 12-15 % in the same period. The group of medium-fast milking heifers has increased, in correlation with the other groups decreasing, from 55 % to more than 65 %. The leakage has been evaluated in a similar scale, with 1) None 2) Some or 3) Clearly. Four out of five heifers are placed in the none-group, while about 15 % show some signs of leakage. The last 5 % are without doubt leaking. These numbers have been quite stabile during the last two decades (GENO, 2009). A study was done on the basis of milk speed and leakage data from 330,000 first lactating cows between 2000 and 2008 and compared it to the occurrence of mastitis. They found that milking speed has a heritability of 0.18, while leakage is 0.10. The genetic correlation between milking speed and leakage is 0.80. No real connection was discovered between these traits and mastitis in the period stretching 30 days both prior to and after calving, while there was a certain connection between mastitis after the 30th day until the 300th day, with 0.17 for leakage and 0.21 for milking speed (Heringstad - Sivertsen, 2010).

Calving difficulty (Weighted 0.5 %)

Even if the weight for calving difficulties was cut in half to 0.5 % in 2009, it has been an important part of the breeding value since 1978. Until 1989 calving difficulties were only reported on the progeny heifers of the tested bulls, but after 1989 it was obligatory for all heifers in the population. Since then the farmer has had to characterize the calving with four alternatives: 1) No difficulties, 2) Slight difficulties, 3) Major difficulties and 4) Unknown. If the sex was not reported they estimated that 50 % of the first group, 63.5 % of the second and 68.3 % of the third group were bull calves (GENO, 2009).

The occurrence of calving difficulties is generally higher in heifers, as they are not fully developed and unfortunately unsuitable, larger bulls could have been used. The percentage of heifers with slight difficulties has increased from 4 % in 1990 to more than 7 % in 2006. For the same period the percentage in later calvings has remained steady around 2-3 %. The amounts of difficult calvings have also been quite stabile; 2-3 % in heifers and 1 % in later calvings. On an overall basis the remaining 95 % of calvings are reported as easy calving (Heringstad et al., 2007). Calf sizes, 1) small, 2) medium, 3) large or 4) unknown have also been reported since 1999, together with malformations. These are not directly used in the breeding program as required characteristics, but serves as an indication for bulls which are not suitable for heifers (GENO 2009).

The calving difficulties may be due to direct heritability as a result of the calf's size and viability, or of maternal origin, i.e the dam's birth canal and ability to nourish the calf during pregnancy. The heritability of the direct causes of calving difficulties is 0.13 and derives from both parental animals. Heritability of maternal causes is 0.09 and is inherited from only the maternal parents. There is also a strong correlation of 0.79 between both stillbirths and direct calving difficulties, as well as a correlation of 0.62 between stillbirths and the maternal calving difficulties, This will result in favourable results in both when breeding for either (Heringstad et al., 2007). Since the calving abilities are of low heritability a large amount of daughters are needed for a proper evaluation.

Stillbirth (Weighted 0.5 %)

Stillbirth is a binary trait and the overall percentage in heifers is around 3 %, while in later calvings it decreases to 1.5 % (Heringstad et al., 2007). There are three alternatives too the calves' survival: 1) Abortion or death more than 20 days prior to expect calving date. These are not used in the breeding value calculation. 2) Stillbirth, when the calves were dead at birth, or within first 24 hours post-parturient. These could be used in the total index calculation, but since the gender was often not reported, it is predicted that 65.4 % of these were bull calves. Lastly, 3) Dead, including calves which died shortly after the first 24 hours. Due to uncertainty around the time of birth it may sometimes be rather random, whether the calf is given either of the last two codes. For this matter they are often used together in the statistics. The statistics between 1972 and 2006 show that the number of dead calves, in the first calving have been increasing slightly from 5 % until 5.5 %. The number of aborted calves has remained steady with 0.5 %, composing almost 10 % of the overall dead calves. Stillbirths have been responsible for the slight increase of overall dead calves, ranging from 3 % in 1972, to nearly 3.5 % in 2006. The number of dead calves after 24 hours has been level at 1 % during the entire period. For the second calving the percentage is lower; less than 4 % dead calves in 1972, with a slight decrease to 3.5 % in 2006. Abortion was close to 1 % the entire period, while dropping close to 0.8-0.9 % after the turn of the millennium. The percentage of stillbirths is fairly level around 2 % during the entire period, while the percentage of dead calves in the last category also decreased from about 1 % in 1972 to 0.7-0.8 % in 2006. For the third calving the numbers were quite identical to the second calving (GENO, 2009). On an international level the number of stillbirths are increasing. From 1992 to 2002 the percentage increased in Danish Holstein from 7 % to 9 % (Hansen et al, 2004). In Sweden there has also been an increase among the Holstein in the last decades and more than 10 % of calves born by heifers are stillborn or die within short period. This is approximately twice the amount found in the Swedish Red (Steinbock et al., 2003). In Dutch heifers 12.2 % of the calves were stillborn in 1999 (Harbers et al., 2000), while stillbirth in American heifers increased from 9.5 % to 13.2 % between 1985 and 1996 (Meyer et al., 2001).

Polledness

During the construction of the current Norwegian Red many of the local Norwegian breeds were used. Some of these were polled, but this trait was not regarded as an economical trait back in the late 1960's, however when a polled bull managed to become an elite bull in the early 1990's, the popularity was so high that polledness was reintroduced as an important trait (Hersleth, 2010b). With the current breeding the degree of polled animals was 15 % in 2003 (Pryce et al., 2003). The sons of polled bulls are systematically selected which has led to more and more animals that are naturally polled. Among the young sires tested for the first time in March 2010 more than 60 % of these carried the polledness gene (Sehested, 2010). It is estimated that within the next 20-25 years the entire Norwegian Red population will be polled (GENO, 2008).

Colour

The combinations of colours are mainly white markings on red cows, but also white markings on black cows, or red or black markings on white animals. Even if the breed is called Norwegian Red there are several black or white animals in the population. This originates from both the mixing of the old local breeds, as well as from crossing with imported black coloured breeds like Holstein-Friesian later on (GENO, 2006).

Development of the characteristics

Characteristics	**Average index change yearly since 1987**	**Units**	**Expected difference between offspring after bulls with 110 and 100 index.**
Kg protein	1.0375	Kg Protein/Lactation	+ 9.50
Protein %	0.4776	Protein - %	+ 0.08
Fat %	0.4613	Fat - %	+ 0.15
Meat	0.3867	Slaughterweight, kg	+ 0.60
Carcass grouping	0.1447	1=P-, 15=E+	+ 0.28
Fat grouping	- 0.0943	1=5+, 15=1	+ 0.30
Fertility	0.3277	% non-return at 56 days	+ 3.20
Mastitis	0.4188	% daughters without mastitis	+ 4.40
Other Diseases	0.1155	% daughters without other diseases	+ 2.90
Milking Speed	- 0.0044	% quick daughters	+ 9.20
Leakage	0.0978	% daughters without appearant leakage	+ 2.90
Temperment	0.2704	% daughters with good temperament	+ 4.70
Calving Difficulties, Maternal	0.1170	% daughters without calving difficulties	+ 5.10
Calving Difficulties, Calf	0.0572	% calvings without difficulties	+ 5.20
Stillbirth, Cow	0.1049	% daughters without stillbirth	+ 2.30
Stillbirth, Calf	0.0448	% calvings without stillbirth	+ 1.60

Table 8: Development of Characteristics 1987-2010 (GENO, 2010).

Crossbreeding

In the dairy industry, as elsewhere in animal keeping, there are two main methods of crossbreeding. The first are populations of different breeds continuously crossed systematically for generations. This method is used by GENO Global together with Semex Alliance internationally in a program called Twoplus™. The second is a limited introduction of some new genes into a population. An example for the latter is when Norway imported some American Holstein-Friesian bulls in the 1970's. In both cases you may encounter the heterosis effect. This is when the offspring achieve an ability that exceeds the mean of the parent. It may be defined as an opposite of inbreeding depression. For production traits a heterosis of 2-3 % or more may be experienced, while with non-production traits concerning reproduction and health, one may encounter hybrid vigour of near 10 %, e.g. for fertility (Lang-Ree, 2010).

To compensate for the many years of uniform breeding of many dairy breeds, especially the Holstein-Friesian, crossbreeding with breeds like Norwegian Red which have emphasized health and reproduction traits for more than three decades is becoming more and more common. The trends show an increase both in fertility and mastitis resistance, in addition to important production traits like milk protein content.

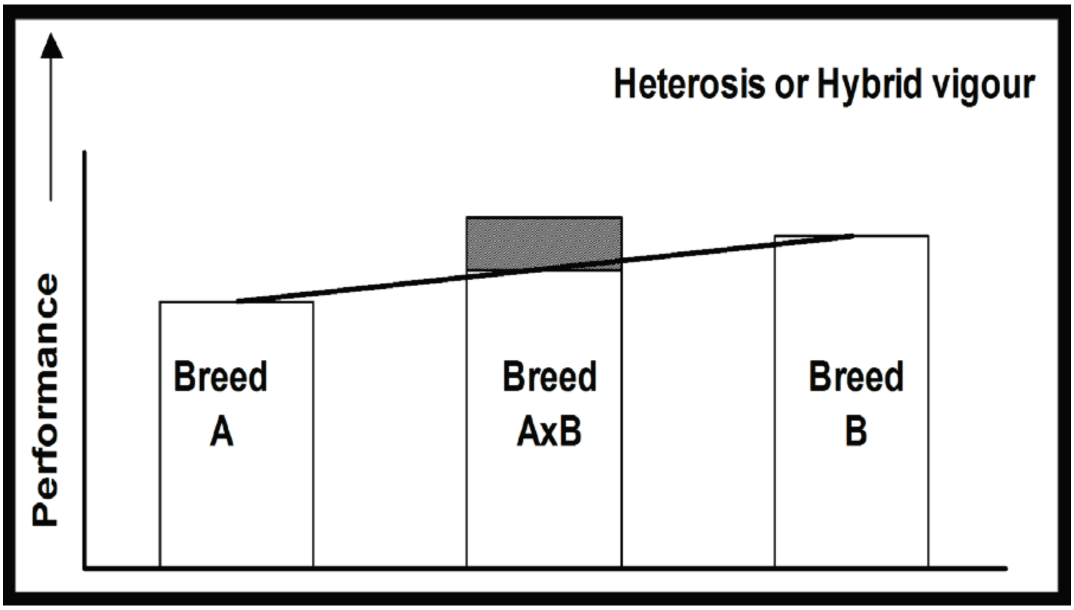

Figure 5: Heterosis (Begley, 2010).

For successful crossbreeding large purebred populations are a necessary basis. A minimum of two populations are neede, and it is important that they continue their individual genetic progress in addition to the crossing of the breeds. The breeds must furthermore complete each other to make the crossbreeding economical. The Holstein has superior milk production, in addition to good udder confirmation. After years of selective breeding the Norwegian Red has excellent reproductive and health traits. It also carries polled genes in its pool and this will also save both work and money for the farmers. Both are excellent breeds and a combination could result in an animal of high milk production, as well as good health and reproduction. Worldwide crossbreeding has been successfully used in commercial sheep, pig, chicken and beef cattle for several decades, so the possibilities for the dairy industry are being examined (Heins et al., 2006).

Twoplus

Geno Global and Semex Alliance have created a systematic crossbreeding program where the Holstein and Norwegian Red are crossed every second time with each other.

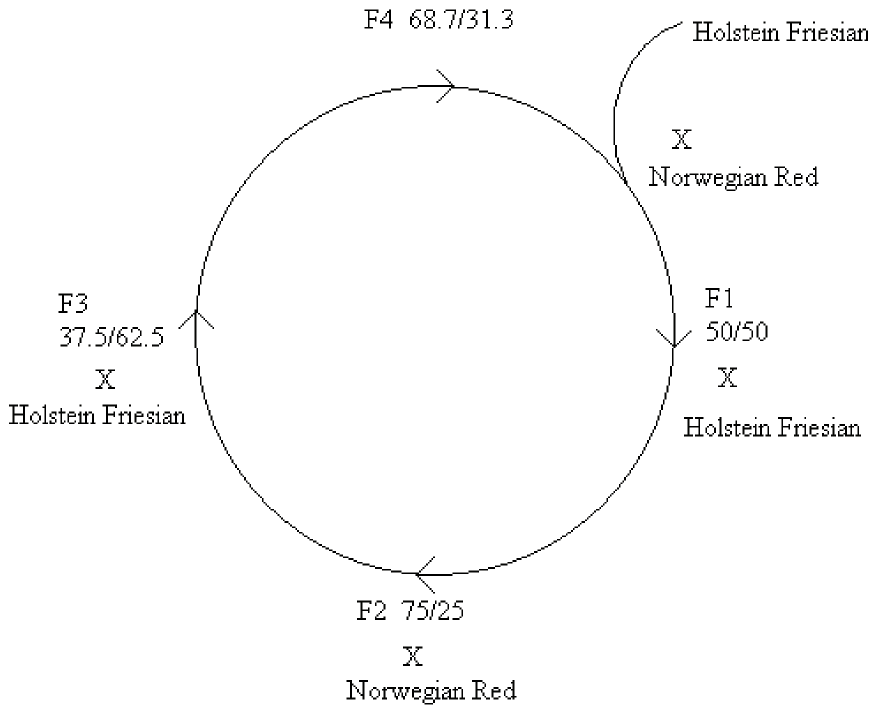

Figure 6: The Twoplus program (GENO Global, 2010c).

In the Twoplus breeding program there is no longer a full heterosis, but one may witness a 2/3 hybrid vigour in the first generations, nonetheless over time this may also decrease. Research done by Geno Genetics has shown that over 22 generations this would give a slightly better milk yield increase than in pure Holstein-Friesian, while for fertility, mastitis resistance and calf survival it would better than the Holstein-Friesian by 12-15 % (Hersleth, 2006).

International Trials

Ireland

In 1999 a trial was initiated at the Moorepark Research Centre in Ireland, for which they imported 30 young Norwegian Red calves. These were then compared with Holstein, Normand, Montbeliarde and Holstein hybrids. After three lactations the Norwegian Red displayed a lower milk yield than the Holstein and showed the lowest live weight, but had great reproductive performance, the longest herd life and also showed a good body condition score (Walsh et al., 2008). The Norwegian Red also had the lowest somatic cell count, indicating good udder health (Walsh et al., 2007).

	Holstein	Norwegian Red	Holstein x NR
Milk Yield (kg)	6,214	5,874	6,108
Fat (kg)	243	227	238
Fat (%)	3.91	3.86	3.90
Protein (kg)	214	202	211
Protein (%)	3.44	3.44	3.45
Somatic Cell Count (x1000)	202	190	195

Table 9: First trial - 3 years lactation (Begley, 2010).

This first test caused the Irish to be interested and they decided to start a second trial to see if future crossbreeding would be beneficial. In June 2004 a newer and bigger experiment was initiated. 400 Norwegian Red calves were imported and together with equal numbers of pure Holstein and crossbreeds of same age, they were evenly divided to 50 farms to be compared in equal and varied environments (Hersleth, 2006). These were then evaluated on several levels. By comparing udder health and immune response it was revealed that the Norwegian Red had superior udder health compared both the purebred Holstein and the crossbreed, but it also gave indications that crossbreeding would give beneficial results. This was revealed by immunizing 648 second lactating cows, of which 274 were pure Holstein, 207 pure Norwegian Red and 167 were crossbreeds, with egg white lysozyme. The antibody mediated immune response was then examined with ELISA. The Norwegian Red showed a greater primary response, among others a lower mean Somatic Cell Count within 30 days. The differences in secondary response and cell-mediated immune response were not that evident (Begley et al, 2009b). The Irish dairy industry is based on intensive calving during the spring, starting late February, and for the majority of the lactation the cows are kept on pastures to reduce the costs of feeding with concentrates (Lang-Ree, 2009). It is therefore important that the animals are able to become pregnant in the requested period. Due to the high feed costs the milk production in Ireland is not that intense. Fat content and especially protein are very important milk traits. In the second trial the results showed little differences in the breeds in the milk production. The Norwegian Red had a lower nadir for protein content, and during the lactation it had lower lactose while the udder health were superior (Begley, 2010).

	Holstein	**Norwegian Red**	**Norwegian Red x Holstein**
1st lactation: Heifers	710	292	325
Milk (kg)	5,356	5,339	5,149
Fat (%)	3.99	3.97	3.93
Protein (%)	3.46	3.45	3.45
Somatic Cell Count	190,000	137,000	131,000
Calving interval (months)	15.6	11.9	11.4
Conception at first insemination (%)	57	60	60
2nd lactation: Surviving (%)	89	92	90
Milk (kg)	6,215	6,104	5,865
Fat (%)	3.9	3.9	3.9
Protein (%)	3.49	3.49	3.49
Somatic Cell Count	189,000	178,000	152,000
Calving interval (months)	15	13	12
Conception at first insemination (%)	46	56	55
3rd lactation: Surviving (%)	67	73	78
Milk (kg)	6,536	6,486	6,248
Fat (%)	4.0	4.0	4.0
Protein (%)	3.55	3.55	3.54
Somatic Cell Count	226,000	218,000	207,000
Conception at first insemination (%)	48	61	63

Table 10: Irish results (GENO Global, 2010b).

The conception rate for the purebred Norwegian Red and the crosses was better in the first lactation than for the purebred Holsteins. The differences increased even more after the first lactation. Even with the loss of income from production traits like protein and fat, the total economic difference between Holstein and Norwegian Red was 144 Euro, while the crosses had 1 Euro less (143 €) (Begley, 2010).

Northern Ireland

In 1999 the Agricultural Research Institute of Northern Ireland imported 230 Norwegian Red heifer calves to 19 farms, where they could compare 11-12 Norwegian Red heifers over 4-5 lactations with a similar number of purebreed Holsteins. This was not a crossbreeding experiment, but it is important for showing the adaptation of Norwegian Red to new environments, as compared to a Holstein of the similar age (Refsdal, 2010). The Norwegian Red showed results of high fertility, as well as easier calvings and less stillborn calves. In this case the milk yield was also lower, however, the quality was higher (Hersleth, 2006).

	Holstein	**Norwegian Red**
1st lactation: No. of Heifers	130	154
Milk (kg)	6,264	5,956
Fat+Protein (%)	7.07	7.17
Somatic Cell Count	85,000	59,000
1st insemination pregnancy	41	55
Calving Interval (Days)	399	389
2nd lactation: No. of Cows	96	107
Milk (kg)	6,789	6,550
Fat+Protein (%)	6.94	7.08
Somatic Cell Count	102,000	76,000
1st insemination pregnancy	39	60
Calving Interval (Days)	390	379
3rd lactation: No. of Cows	54	71
Survival rate (%)	41.54	46.10
Milk (kg)	7,415	7,257
Fat+Protein (%)	6.96	7.17
Somatic Cell Count	105,000	89,000
1st insemination pregnancy	35	65
Calving Interval (Days)	397	376

Table 11: Northern Irish results (GENO Global, 2010b)

The dairy industry in Northern Ireland is similar to the one in Ireland. The calving is concentrated in February and March so the animals need good oestrus signs and the ability to become pregnant on first insemination. Money is lost if they calve after the optimal period. Fertility was therefore one of the main traits they were investigating. The culling of Norwegian Red due to low fertility was 11.5 % while it was 28.5 % for the Holstein Friesian over five lactations. In average the herd life after the first calving was 1559 days for the Norwegian Red and 1133 days in the Holstein Friesian (Refsdal, 2010). In addition to the milk production the bulls intended for slaughter were also evaluated. 64 bulls raised on the same diet of 50/50 dry matter of concentrates and grass silage were compared. The Holstein bulls had a higher DM intake but worse feed conversion rate than the Norwegian Red. The Norwegian Red also had a better conformed carcass whilst the Holstein had more tender meat. Carcass weight and fat qualities were similar, even if the Holstein had a higher live weight gain and slaughter weight (Kirkland et al., 2007).

Canada

The Canadian crossbreeding program is still in its early phase, but the farmers have expressed their satisfaction through surveys made by Dr. Ted Burnside, Technical advisor for Geno Global in June-September 2009. In the survey he asked how pleased they were on a scale of 1 to 9, with 9 being the best. 60 farmers with altogether more than thousand Holstein and Norwegian Red crosses were asked and 37 answered. The average of their answers has been summarized in table 12 (Burnside, 2010).

Trait	**Holstein x Norwegian Red**	**Holstein**
Calving Ease	**7.42**	6.78
Stillbirths	**7.28**	6.81
Milk Production	6.68	**7.54**
Fat Production	**7.30**	7.11
Protein Production	**7.19**	7
Mastitis	**7.41**	6.59
Digestive & Metabolic	**7.65**	6.95
Feet & Leg Problems	**7.59**	6.57
Temperament	6.46	**7.22**
Udder Confirmation	6.54	**7.32**
Feet & Leg Confirmation	**7.41**	6.51

Trait	Holstein x Norwegian Red	Holstein
Body Condition Score	**7.24**	6.76
Conception Rate	**6.59**	6.15
Retained Placenta, Metritis, Cystic Ovaries	**7.42**	6.89
Overall	6.76	**6.79**

Table 12: Result of survey among Canadian farmers (Burnside, 2010)

The calves born were generally smaller than the purebred Holstein, but healthier. The farmers had chosen the Twoplus program to achieve animals with better resistance to mastitis and ketosis. This, in addition to the easy calving and the heterosis effect, resulted in satisfied farmers (Burnside, 2010). The preliminary results from the 60 farms shows 372 Norwegian Red x Holstein crosses in first lactation.

1st lactation Cows	Holstein	Norwegian Red x Holstein
Milk (kg)	8.569	8.575
Fat (%)	3.79	3.96
Protein (%)	3.15	3.31
Somatic Cell Count	145,900	120,600
First Calving		
Number of calving	5,221	381
Calving difficulties: None	52.5	58.8
Moderate	33.7	31.8
Severe	13.7	9.4
Stillborn	11.9	6.3
Later Calving		
Number of calving	10,599	478
Calving difficulties: None	67.9	70.5
Moderate	26.1	26.3
Severe	5.9	3.2
Stillborn	5.7	4.6

Table 13: Canadian Results (GENO Global, 2010b).

Israel

The Israeli dairy industry is among the absolute highest producing in the world. Through many decades of intense breeding they have created a cow with an extremely high milk yield, but lower fat and protein content than the Holsteins in other countries. As a consequence they have also had problems with fertility. Israeli farms started to import Norwegian Red semen in 2005 and currently there are almost ten thousand cows of Norwegian Red descent. Trials have been done with both imported semen and embryos. They have been used on Holstein cows at Habonim Farm where 76 % of the 434 cows are Holstein, 17 % are Norwegian Red and Holstein hybrids, while the remaining 7 % are Montbeliarde.

1st lactation	**Holstein**	**Norwegian Red x Holstein**
Number of Animals	51	12
Days of lactation	339	322
Milk (kg)	13,613	13,262
Fat (%)	3.69	3.45
Protein (%)	3.24	3.32
With Embryoes:	**Holstein**	**Norwegian Red**
Number of pregnant	1,262	173
Number of abortions	102	6
Abortion (%)	8.10	3.50
Cows born 2005-2007	**Holstein**	**H x NR x Montbeliarde**
Number of cows	115	25
Milk (kg)	13,943	13,450
Fat (%)	3.14	3.19
Protein (%)	3.51	3.48
Calving difficulties and Stillbirth:		
Number of calvings	311	48
Calvingdifficulties	30	2
Calvingdifficulties (%)	9.65	4.17
Stillborn	25	2
Stillborn (%)	8.04	4.17
Culling		
Total born	383	129
Culled	117	25
Culled (%)	31	19

Table 14: Israeli results (GENO Global, 2010b).

The table shows that the crosses produced only slightly less milk than the purebred Holstein, but due to the much better reproduction results the Habonim Farm now inseminates 28 % of their animals with Norwegian Red semen. Overall the different combinations gave a similar income, but the expenses with Norwegian Red and the crosses were lower (GENO Global, 2010b).

USA

The American dairy industry is dominated by the high yielding Holstein. Their intensive breeding for mainly litres with less importance for solids in the milk, has resulted in a high producing dairy cow with fertility and health problems as a natural consequence. The American Holstein has impressed the farmers worldwide and this has led to the export of animals and semen. Additionally, this has led to the export of one of the American dairy industries biggest problem: inbreeding. Some of their greatest bulls have been so frequently used that a nearly 16 % relationship to themselves can be seen in some of the top sires. Inbreeding has a negative consequence on reproductive traits, resulting in more stillborn calves and lower fertility, as well as lower growth rate and higher disease incidence (Heins et al., 2006a).

Birth year	Inbreeding (%)
1994	3.5
1996	3.9
1998	4.2
2000	4.5
2002	4.8
2004	5.0

Table 15: Average inbreeding of Holstein dams in USA (Heins et al., 2006a).

Since crossbreeding is the opposite of inbreeding it can be used to solve the problem. The hybrid vigour is likely to occur in the traits related to fertility, health and survival, and this is followed with high interest in the States. To compensate the high level of inbreeding several farms in Minnesota have started to cross their animals using Scandinavian semen. Both the Norwegian Red and the Swedish Red are included in the term Scandinavian Red, since they both share many genes. French dairy breeds like Normande and Montbeliarde have also been used. The results showed that there was little difference in the production of the Scandinavian Red x Holstein crosses compared to purebred Holstein, while the Holstein crossed with the French breeds had lower production values (Heins et al., 2006b).

Production traits:	Holstein	Normande x Holstein	Montbeliarde x Holstein	Scandinavian Red x Holstein
Milk (kg)	9,757	8,530	9,161	9,281
Fat (kg)	346.2	319.0	333.8	340.0
Protein (kg)	305.3	276.7	293.0	297.3
Fat (kg) + Protein (kg)	651.4	595.7	626.8	637.3
% of Holstein		-8.6%	-3.8%	-2.2%
Health traits:				
Somatic Cell Count Score[1]	2.4	2.5	2.3	2.2

Table 16: Actual 305-day production for first lactation (Heins et al., 2006b).

[1] Somatic Cell Count Score: A 0-9 scale where 0-3 are regarded healthy (0-141,000), and 7-9 are considered infected (1,131,000-9,999,000). These results are all within the 2 range (36,000-71,000) (Smith et al., 2009).

The pure Holsteins dams were separated into first-calvers and later-calvers to easier distinguish the differences in both calving difficulties and stillbirth. They had been inseminated with semen from the aforementioned breeds, as well as Brown Swiss. The numbers of first-calvers inseminated with Normande were not sufficient and therefore not included (Heins et al., 2006c).

Breed of Sire (Semen)	Holstein	Normande	Monte-beliarde	Brown Swiss	Scandin. Red
1st Calf					
No. of Births	371	-	158	209	855
Calving Diff.	16.4 %	-	11.6 %	12.5 %	5.5 %
Stillbirth	15.1 %	-	12.7 %	11.6 %	7.7 %
2nd-5th Calf					
No. of Births	303	326	2.373	524	515
Calving Diff.	8.4 %	8.7 %	5.4 %	4.9 %	2.1 %
Stillbirth	12.7 %	7.3 %	5.0 %	5.6 %	4.7 %

Table 17: Calving information of Holstein inseminated with different sire breeds (Heins et al., 2006c).

The results showed that all Holstein dams that were not inseminated with Holstein semen had a lower risk of difficult calving and of the calf being stillborn. Since both the sire and dam were pure Holstein in the first category there was a high probability of inbreeding in this category. The American average is 5 %, but as a consequence of this there must be a substantial proportion of them above the critical level of 6.25 %, which is recommended in commercial dairy industry (Heins et al., 2006a).

Breed of Dam and Sire	**Holstein**	**Normande x Holstein**	**Montebeliarde x Holstein**	**Scandinavian Red x Holstein**
1st Calf				
No. of Births	676	262	370	264
Calving Diff.	17.7 %	11.6 %	7.2 %	3.7 %
Stillbirth	14.0 %	9.9 %	6.2 %	5.1 %
2nd Calf				
No. of Births	307	190	75	69
Calving Diff.	3.1 %	3.3 %	0.2 %	1.9 %
Stillbirth	3.7 %	4.7 %	5.9 %	2.3 %

Table 18: Calving difficulties and Stillbirths (Heins et al., 2006c).

When the next generation was bred differences were also observed. The Brown Swiss was not included in this evaluation since the number of sires was not sufficient to create enough combinations for breeding (Heins et al, 2006c).

For survival the results were quite good and almost identical for all the crosses. The pure Holstein was the only one that differed from the others, but this might be due to possible inbreeding. Percentage has been given after one month, five months, as well as at the end of expected lactation at 305 days. The result at 305 days show that twice as many pure Holstein are culled compared to the others at this stage.

Breed	**Holstein**	**Normande x Holstein**	**Montebeliarde x Holstein**	**Scandinavian Red x Holstein**
No. of Animals	692	465	655	434
30 days (%)	95	98	98	98
150 days (%)	91	96	96	96
305 days (%)	86	93	92	93
Second calf at 20 months	66	82		
Days to first breeding	69	62	65	66
% 1st Service Conception Rate	22	35	31	30
Days Open	150	123	131	129

Table 19: Survival after calving and fertility (Heins et al., 2006d).

The research done by Heins et al. has shown that the crosses made with Holstein and Norwegian and Swedish Red are fully compatible with the French breeds in regards to fertility and survival and additionally have an advantage in milk production and easy calving, as well as a low frequency of stillborn calves.

A later trial was initiated with Holstein and crosses with Norwegian Red and these animals started to calf in 2009. The early results from one of the farms are very promising.

	Holstein	**Norwegian Red x Holstein**
No. of cows	75	47
Milk (kg)	11,469	10,885
Fat (%)	3.88	3.67
Protein (%)	2.95	3.01
Empty Days (Days)	153	119
1st Service Conception	35	58
Somatic Cell Count	46,000	44,000
Fertility	38 % (2512 inseminations)	43 % (787 inseminations)

Table 20: Preliminary results after 1st lactation (GENO Global, 2010b).

Rest of the World

Currently Geno is exporting semen, embryos and animals of Norwegian Red to more than 20 countries, divided on four continents. In addition to those mentioned here, the most important countries are Italy, Germany, Holland and Poland, but also in far away countries like Madagascar, outside the coast of Africa, and Mongolia, in the middle of the Asian continent, the Norwegian Red is either being crossed in or raised.

Hungary

Crossbreeding in Hungary doesn't have the best history. An attempt at mixing Jersey and local dairy breeds ended with a catastrophe. The animals did not have a uniform size, and the production was minimal. As a consequence of this, Hungarian dairy farmers were sceptical when GeneBank Semex Magyarország bought a volume of semen from Geno Global with the intention to try and crossbreed the local Holstein with Norwegian Red. The Slovakians had also said no to a similar proposal. GenBank had to keep the semen in quarantine for one year before they could start to use it, and even then they were only classified as an experimental breed. Since the Norwegian Red doesn't have its own association in Hungary it could not be sold easily. The use was only limited for research and if the result was not satisfactory the future would not look so bright for further use. A contract was signed on Oct. 31st, 2006 and the program was lead by GenBank and the Hungarian Holstein Association, as well as the University of West Hungary, who would be in charge of the evaluation afterwards. 4000 doses were sold to different interested farms but due to unfortunate events the project disappeared from the surface (Veres Z. GeneBank Semex Hungary, personal communication, Nov. 24th, 2008).

A new contract was signed that introduced the Szent Istvan University to the program and a renewed interest was created. The first calves were born in the spring of 2008. They would be registered in the database of the Holstein Association and the Norwegian bulls would get their breeding index calculated on behalf of their performance in Hungary. The most essential trait for the Hungarian dairy farmer is milk production, so if the crosses don't deliver enough milk they will not be popular. Hopefully these Norwegian Red crosses possess some of the traits that have made the breed as sought after on the world marked as it is today. Decades of breeding for health and fertility have given it an advantage over many breeds used for crossbreeding. Eight Norwegian bulls had been selected for use on Hungarian Holstein cows. From the early, unofficial reproductive data gained from the inseminations performed with imported semen and Hungarian Holstein a 75 days non-return rate and insemination rate can be established. The average for the Norwegian Red bulls was 48 % for the 75 days non-return rate and 3.09 for the insemination rate. In comparison, the Hungarian average was 52.2 % and 2.81. When examining the numbers from the individual Norwegian Red bulls, one can see that there is a great variety, as well as quality differences between the selected bulls. While most of them give poor or below average results, some show good results. Some of the bulls also have some daughters that have started their first lactation in the beginning of July 2010 and lactation information from these is also included. First lactating heifers from the same farms born in the same time period are also given for comparison.

Brenden - HU20107/NO5694

Born: October 24th, 1999

Colour: Red

Polled: No

Dam: NO00116 Kronros, Dam's sire: NO04502 J. Husveg, Dam's dam: NO04231 Y. Voyen

Sire: NO06563 Backgard, Sire's sire: NO86626 Tron, Sire's dam: NO111516 Selma

This bull has an excellent index for milk production, with both high milk yield and solids, according to the Norwegian standards. He also scored very good for temperament and udder traits. Among his less favourable traits are short teats, as well as a short distance between the hind teats. This bull still has an excellent breeding value in Norway and more than seven thousand lactating daughters. The problem might be that his genes are too popular and his use carries a risk of inbreeding (GENO Bull Catalogue, 2010). The initial Hungarian results show a surprisingly high number of services, but the non-return rate was good (HNDb, 2010).

	HU20107 mean	**Nor. Red mean**	**Hung. Holstein mean**
NR75 days (%)	50.85 (44 cows)	48 (569 cows)	52.2 (8293 cows)
Services	4.17 (102 services)	3.09 (635 services)	2.81 (8353 services)
Milk (kg)[1]	7355 (2 cows)	7527 (24 cows)	8112 (185 cows)
Fat (kg)[1]	302 (2 cows)	293 (24 cows)	307 (185 cows)
Fat (%)	4.10	3.89	3.78
Protein (kg)[1]	240 (2 cows)	255 (24 cows)	266 (185 cows)
Protein (%)	3.26	3.39	3.28

Table 21: Information about sire HU20107 (HNDb, 2010).

[1] 305 days estimated

Ulsaker - HU20108/NO5277

Born: October 9th, 1999

Colour: Red

Polled: No

Dam: NO00188 Sommerli, Dam's sire: NO03923 M. As

Sire: NO04357 J. Harnesmyr, Sire's sire: NO03454 J. Steinsvik, Sire's dam: NO00360 Angela

His most positive traits are milking speed and udder conformation, but as a consequence of the speed there is also some leakage. He is a very popular bull in Norway with more than nine thousand lactating daughters (GENO Bull Catalogue, 2010). His own fertility results, based on services in Hungary, were good; both compared to the other Norwegian Red bulls and the Holstein bulls, however, the non-return rate at 75 days was poor. His daughters also had very high lactating results, exceeding both the other crossbreeds and the mean of the pure Holsteins in the comparison group (HNDb, 2010).

	HU20108 mean	**Nor. Red mean**	**Hung. Holstein mean**
NR75 days (%)	36.52 (115 cows)	48 (569 cows)	52.2 (8293 cows)
Services	2.75 (115 services)	3.09 (635 services)	2.81 (8353 services)
Milk (kg)[1]	8216 (5 cows)	7527 (24 cows)	8112 (185 cows)
Fat (kg)[1]	316 (5 cows)	293 (24 cows)	307 (185 cows)
Fat (%)	3.85	3.89	3.78
Protein (kg)[1]	269 (5 cows)	255 (24 cows)	266 (185 cows)
Protein (%)	3.27	3.39	3.28

Table 22: Information about sire HU20108 (HNDb, 2010).

[1] 305 days estimated

Rormark - HU20109/NO5339

Born: April 1st, 1997

Colour: Red

Polled: No

Dam: NO00311 Roselin, Dam's sire: NO03923 M. As

Sire: NO4208 S. Arvoll, Sire's sire: NO3144 S. Berger

This bull gave a slightly lower milk production, but this was compensated with a high protein percentage. Low occurrence of calving difficulties and good resistance to diseases are also some of his best traits. There are less than two thousand daughters with registered lactation in the Norwegian Dairy Herd Records (GENO Bull Catalogue, 2010). In accordance to this, his two Hungarian daughters scored high on protein, but apart from this the results were not so good (HNDb, 2010).

	HU20109 mean	**Nor. Red mean**	**Hung. Holstein mean**
NR75 days (%)	33.4 (17 cows)	48 (569 cows)	52.2 (8293 cows)
Services	3.52 (52 services)	3.09 (635 services)	2.81 (8353 services)
Milk (kg)[1]	6737 (2 cows)	7527 (24 cows)	8112 (185 cows)
Fat (kg)[1]	255 (2 cows)	293 (24 cows)	307 (185 cows)
Fat (%)	3.79	3.89	3.78
Protein (kg)[1]	228 (2 cows)	255 (24 cows)	266 (185 cows)
Protein (%)	3.39	3.39	3.28

Table 23: Information about sire HU20109 (HNDb, 2010).

[1] 305 days estimated

Elvevoll - HU20110/NO5621

Born: June 8th, 1999

Colour: Black

Polled: Yes

Dam: NO00260 Siri, Dam’s sire: NO03698 F. Dalland

Sire: NO04680 Risa, Sire’s sire: NO03852 F. Aksland, Sire’s dam: NO00252 Lina

He has good index for health, legs and udder, making him the sire of nearly three and a half thousand daughters in Norway (GENO Bull Catalogue, 2010). This bull has a low scoring on fat yield in the Norwegian Total Merit Index, but his Hungarian daughters, on the contrary, are producing high fat milk. The offspring show very good milk production, as well as good fertility response with own-semen, compared to the other bulls in the trial, thus making him one of the top bulls in this evaluation (HNDb, 2010).

	HU20110 mean	**Nor. Red mean**	**Hung. Holstein mean**
NR75 days (%)	47.9 (119 cows)	48 (569 cows)	52.2 (8293 cows)
Services	2.83 (150 services)	3.09 (635 services)	2.81 (8353 services)
Milk (kg)[1]	7712 (4 cows)	7527 (24 cows)	8112 (185 cows)
Fat (kg)[1]	320 (4 cows)	293 (24 cows)	307 (185 cows)
Fat (%)	4.15	3.89	3.78
Protein (kg)[1]	264 (4 cows)	255 (24 cows)	266 (185 cows)
Protein (%)	3.42	3.39	3.28

Table 24: Information about sire HU20110 (HNDb, 2010).

[1] 305 days estimated

Skjenaust - HU20111/NO5794

Born: August 19th, 2000

Colour: Red

Polled: Yes

Dam: NO00236 Breline, Dam's sire: NO04581 Nylokken, Dam's dam: NO00195

Sire: NO04680 Risa, Sire's sire: NO03852 F. Aksland, Sire's dam: NO00252 Lina

This bull didn't succeed on the Norwegian market. His Norwegian daughters didn't give enough milk and additionally were slow milkers. To balance this his daughters rarely had mastitis and had a low frequency of stillbirths. In Norway, merely less than eight hundred daughters were registered in lactation (GENO Bull Catalogue, 2010). The low quantity of milk is also seen in Hungary, but the volume of solids is very good and partly compensates this. Furthermore, his reproductive results were not among the best either (HNDb, 2010).

	HU20111 mean	**Nor. Red mean**	**Hung. Holstein mean**
NR75 days (%)	42.2 (83 cows)	48 (569 cows)	52.2 (8293 cows)
Services	3.43 (83 services)	3.09 (635 services)	2.81 (8353 services)
Milk (kg)[1]	6789 (5 cows)	7527 (24 cows)	8112 (185 cows)
Fat (kg)[1]	270 (5 cows)	293 (24 cows)	307 (185 cows)
Fat (%)	3.98	3.89	3.78
Protein (kg)[1]	242 (5 cows)	255 (24 cows)	266 (185 cows)
Protein (%)	3.56	3.39	3.28

Table 25: Information about sire HU20111 (HNDb, 2010).

[1] 305 days estimated

Dvergsnes - HU20112/NO5734

Born: May 7th, 2000

Colour: Red

Polled: No

Dam: NO00286 Frida, Dam's sire: NO04811 Sorkmo, Dam's dam: NO00236

Sire: NO04926 Skjaeret, Sire's sire: NO03945 K. Fredvang, Sire's dam: NO00216 Sylvia

Low protein percentage and below average fertility were some of the problems this bull had in Norway. The occurrences of calving difficulties was low, but in the end not too many daughters were born from this bull; only a quarter of a thousand (GENO Bull Catalogue, 2010). The Hungarian results are fair, but the high numbers of services and low fat are very poor in comparison to the other bulls (HNDb, 2010).

	HU20112 mean	**Nor. Red mean**	**Hung. Holstein mean**
NR75 days (%)	50.7 (71 cows)	48 (569 cows)	52.2 (8293 cows)
Services	5.5 (100 services)	3.09 (635 services)	2.81 (8353 services)
Milk (kg)[1]	7764 (6 cows)	7527 (24 cows)	8112 (185 cows)
Fat (kg)[1]	285 (6 cows)	293 (24 cows)	307 (185 cows)
Fat (%)	3.67	3.89	3.78
Protein (kg)[1]	257 (6 cows)	255 (24 cows)	266 (185 cows)
Protein (%)	3.31	3.39	3.28

Table 26: Information about sire HU20112 (HNDb, 2010).

[1] 305 days estimated

Hoftun - HU20330/NO5703

Born: October 25th, 1999

Colour: Red

Polled: No

Dam: NO00245, Dam's sire: NO03593 F. Jonland, Dam's dam: NO00177

Sire: NO04705 Kommisrud, Sire's sire: NO03698 F. Dalland, Sire's dam: NO00225

The milk production of this bull's daughters was below the population mean, but there was rarely any leakage. He gave excellent fertility traits and high resistance to diseases, however the offspring often suffered from dropped udders since they had very bad udder attachment. Nearly three hundred Norwegian daughters gave lactation data (GENO Bull Catalogue, 2010). For unknown reasons none of his Hungarian daughters are currently lactating (HNDb, 2010).

	HU20330 mean	**Nor. Red mean**	**Hung. Holstein mean**
NR75 days (%)	100 (34 cows)[2]	48 (569 cows)	52.2 (8293 cows)
Services	1.62 (34 services)[2]	3.09 (635 services)	2.81 (8353 services)
Milk (kg)[1]	-	7527 (24 cows)	8112 (185 cows)
Fat (kg)[1]	-	293 (24 cows)	307 (185 cows)
Fat (%)	-	3.89	3.78
Protein (kg)[1]	-	255 (24 cows)	266 (185 cows)
Protein (%)	-	3.39	3.28

Table 27: Information about sire HU20330 (HNDb, 2010).

[1] 305 days estimated

[2] Even if this bull scored very high on fertility traits, it must be reminded that these numbers are unofficial.

Skalholt - HU20331/NO5868

Born: December 7th, 2000

Colour: Red

Polled: No

Dam: NO00474 Sika, Dam's sire: NO04502 J. Husveg, Dam's dam: NO00400

Sire: NO04926 Skjaeret, Sire's sire: NO03945 K. Fredvang, Sire's dam: NO00216 Sylvia

This bull sired almost seven hundred lactating daughters that had low milk production, as well as being slow milkers. Among the positive traits were rare occurrence of stillbirth and good resistance against mastitis (GENO Bull Catalogue, 2010). Even if there are records of possible inseminations there is no data of non-returns or lactations (HNDb, 2010).

	HU20331 mean	Nor. Red mean	Hung. Holstein mean
NR75 days (%)	-	48 (569 cows)	52.2 (8293 cows)
Services	-	3.09 (635 services)	2.81 (8353 services)
Milk (kg)[1]	-	7527 (24 cows)	8112 (185 cows)
Fat (kg)[1]	-	293 (24 cows)	307 (185 cows)
Fat (%)	-	3.89	3.78
Protein (kg)[1]	-	255 (24 cows)	266 (185 cows)
Protein (%)	-	3.39	3.28

Table 28: Information about sire HU20331 (HNDb, 2010).

[1] 305 days estimated

Discussion

The crossbreeding of Hungarian Holstein-Friesian and Norwegian Red has not managed to copy the results seen in other countries. There has also been a great variation between the bulls used in this project. The best bulls have shown acceptable results when it comes to milk production in their daughters, while the reproduction does not correspond with the international results; neither in Norway nor for Norwegian Red worldwide. When comparing only the top 3 bulls with the data from the Holsteins, the results are satisfying for the milk but the reproductive results are still lower than expected. However, these are not the numbers of the crossbreeds, they are the result of imported semen that has been transported and stored for a long time and there might have been complications during this process.

It would have been interesting to have the reproductive results for the daughters of these bulls and compare these to the corresponding Holstein cows. This would be a much better indication for the qualities of the Norwegian Red and we would have expected a positive heterosis for fertility. It is very unfortunate that these numbers were unattainable at this moment, but regarding the future I think there would be great interest for further investigation on the topic. From personal communications with both Veres Zoltán, from GeneBank Semex Hungary and Bognar László, from the Hungarian Holstein Association, I have learnt that the Norwegian Red crossbreds have performed very well and that the farmers are very satisfied with them. Documentation of good results may give the Norwegian Red a green light for more export to Hungary and maybe the neighbouring countries would also become interested when they see that the success from other geographical areas is also applicable to their environment.

Conclusion

In this work I have given a detailed summary about the development of the Norwegian Red Cattle. How it emerged as a crossbred from all the norwegian domestic breeds, with the help of some international blood and what its different characteristics are and how important these are in both historical - and present breeding goals. The results from decades of breeding with a wide spectrum of traits can give valuable data for other breeding associations worldwide, as many are changing their breeding goals from intense milk production to more non-production traits. By studying the development of the characteristics in the Norwegian Red they can gain knowledge of what they may expect themselves when they change their own goals (GENO Global, 2010b).

International trials have shown that both Holstein crossed with Norwegian Red and in some cases also purebred Norwegian Red, could give more income than purebred Holstein cattle. The milk yield is only marginally less, while the solid components often have a higher percentage. Due to the lower body weight these animals are also less demanding to feed and bulls kept for meat production have a lower feed conversion rate. Bringing new blood into the populations is positive and if they at the same time are able to improve the general health and fertility of the animals it will be very beneficial for the farmers. The aforementioned qualities all contribute to better survival and longer herd life for the animals. Crossbreeding trials with Norwegian Red and other breeds have been held in all kinds of keeping environments; from extensive Ireland to intensive Israel with excellent results. Obviously, however, other countries normally want to try it for themselves in their own environment before they start to import in larger numbers. Apparently they like what they see, because GENO Global is currently exporting the same number of semen doses to other countries, as they are selling back home in Norway. The market is far from saturated, as during the first half of 2010 they sold the same amount as during the entire year of 2009 (Mengshoel, 2010). The main markets are the United Kingdom and Italy, with Italy being especially interested in the gender-selected semen that Geno can offer. To coordinate the sale in these countries GENO has established subsidiary companies; GENO Italy in the autumn of 2009 and GENO UK in February 2010. The next market may be China, which would give great opportunities for export. 2000 doses of semen have already been sold here and they have been distributed to their best farms, stretching from Mongolia to Shanghai.

It is important to remember that too much crossbreeding would destroy the genetic variety that creates the basis for the heterosis achieved through planned crossbreeding. It is not a genetic improvement, but taking advantage of a hybrid vigour that occurs when two breeds are crossed. At least two purebred populations are necessary for achieving optimal profit and right now the combination of Holstein-Friesian and Norwegian Red is one of the most exiting on the market (Heins et al., 2006a). Both these breeds and others need to be improved separately with the same thorough breeding that has created them, in order to keep their high standards. The income that GENO will receive from export will help fund the future domestic breeding program for the Norwegian Red, which in turn will keep the breed suitable for crossbreeding with Holstein in years to come (Mengshoel, 2010).

Summary

The international dairy industry has for decades been breeding for a Holstein Friesian cow that has the highest milk yield possible, but this has also led to several problems. As a consequence of this single minded breeding other traits have been neglected, and now the dairy farmers are facing fertility and health problems. A solution that is widely used is crossing the high producing Holstein Frisian with breeds where both reproductive and health traits have been kept at a high level. One of these suggested breeds is the Norwegian Red, where consistent breeding has created a healthy and fertile cow which also produces an acceptable amount of milk.

In this work I have written about the development and main characteristics of the Norwegian Red. This can be used as background knowledge for both breeders and farmers who would like to know more about the breed. I have also summarized the results of different internationals trials where Norwegian Red or crossbreeds of Holstein-Friesian and Norwegian Red which have proven that the Norwegian Red can compete with, and often exceed other breeds used for crossbreeding.

With the help of the Hungarian Holstein Association I have collected data from the Hungarian National Database. Hungarian Holstein Friesian cows at 14 different Dairy farms were inseminated with imported sperm from 8 Norwegian Red bulls, and their daughters started to lactate during the spring of 2010. For this paper only 24 daughters were available, but hopefully in the future more data can be published. The insemination data is not corresponding with results done elsewhere, but the preliminary milking data show that the Norwegian Red might be suitable for crossbreeding in the Hungarian market as well.

References

Andersen-Ranberg, I. M., Heringstad, B., Klemetsdal, G., Svendsen, M., and Steine, T.: Heifer fertility in Norwegian Dairy Cattle; variance components and genetic change. In: Journal of Dairy Science 2003, 86:2706-2714.

Andersen-Ranberg, I. M., Klemetsdal G., Heringstad B., and Steine, T.: Heritabilities, genetic correlations, and genetic change for female fertility and protein yield in Norwegian Dairy Cattle. In: Journal of Dairy Science 2005, 88: 348-355.

Begley, N., Buckley, F., Burnside, E. B., Schaeffer, L., Pierce, K.M. and Mallard, B.A.: Immune responses of Holstein and Norwegian Red x Holstein calves on Canadian dairy farms In: Journal of Dairy Science 2009a, 92:518-525.

Begley, N., Buckley, F., Pierce, K.M., Fahey, A.G., and Mallard, B.A.: Differences in udder health and immune response traits of Holstein-Friesians, Norwegian Red, and their crosses in second lactation. In: Journal of Dairy Science 2009b, 92:749-757.

Begley, Noreen: The Irish experience, Presentation at the GENO annual conference, 23.04.2010
http://www.genoglobal.no/Global/200%20Dokumenter%20Geno%20Global/International%20trials/Norwegian%20Reds%20-The%20Irish%20experience.pdf

Boichard, D.: Estimation of the economic value of conception rate in dairy cattle. In: Livestock Production Science 1990. 24:187–204.

Burnside, Ted: 2009 Report on Canadian Crossing Results, 11.02.2010
www.dairycrossbreeding.com

Garmo, R. T., Waage, S., Sviland, S., Henriksen, B., Østerås, O. and Reksen, O.: Reproductive Performance, Udder Health, and Antibiotic Resistance in mastitis Bacteria isolated from Norwegian Red cows in Conventional and Organic Farming. In: Acta Veterinaria Scandinavica 2010, 52:11.

GENO – Characteristics in breeding program (In Norwegian) 21.09.2009
www.geno.no/Forsiden/NRF/Egenskapene-i-avlsarbeidet/

GENO – Breeding progress (In Norwegian) 14.01.2010
www.geno.no/Forsiden/NRF/Avlsmessig-utvikling/

GENO Global – Total Merit Index, 21.11.2007
www.genoglobal.no/Home/Norwegian-Red-Characteristics/Total-merit-index/

GENO Global – Breeding Program, 21.11.2007
www.genoglobal.no/Home/Norwegian-Red-Characteristics/Breeding-program/

GENO Global – Breeding Objective, 10.01,2008
www.genoglobal.no/Home/Norwegian-Red-Characteristics/Norwegian-Red/

GENO Global – About Geno, 26.01.2010a
www.genoglobal.no/Home/About-Geno/

GENO Global – International trials, 28.01.2010b
www.genoglobal.no/Home/International-trials/

GENO Global – Crossbreeding, 26.01.2010c
http://www.genoglobal.no/Home/Crossbreeding/

GENO Italy, 26.07.2010
www.genoitaly.it/home.do

GENO Sire catalogue, 26.07.2010
www.oksekatalog.no/en/

GENO UK, 26.7.2010
www.geno-uk.com/

Hansen, M., Misztal I., Lund M. S., Pedersen J., and. Christensen. L. G: Undesired phenotypic and genetic trend for stillbirth in Danish Holsteins. In: Journal of Dairy Science 2004. 87:1477–1486.

Harbers, A., Segeren L. and de Jong G.: Genetic parameters for stillbirth in the Netherlands. In: Interbull Bull 2000. 25:117–122.

Heins, B., Hansen, L.B. and Seykora, T.: Crossbreeding Trials in California. In: Red Cow Symposium 2005 proceedings. 16.01.2006a
http://www.milkproduction.com/Topics/conferences/red_cow_symposium.htm

Heins, B., Hansen, L.B. and Seykora, T.: Production of Pure Holsteins Versus Crossbreds of Holstein with Normande, Montbeliarde, and Scandinavian Red. In: Journal of Dairy Science, 2006b. 89:2799-2804

Heins, B., Hansen, L.B. and Seykora, T.: Calving Difficulty and Stillbirths of Pure Holsteins versus Crossbreds of Holstein with Normande, Montbeliarde, and Scandinavian Red. In: Journal of Dairy Science, 2006c. 89:2805-2810.

Heins, B., Hansen, L.B. and Seykora, T.: Fertility and Survival of Pure Holsteins Versus Crossbreds of Holstein with Normande, Montbeliarde, and Scandinavian Red. In: Journal of Dairy Science, 2006d. 89:4844-4951.

Heringstad, B., Klemetsdal G., and Ruane J.: Clinical mastitis in Norwegian Cattle: Frequency, variance components and genetic correlation with protein yield. In: Journal of Dairy Science, 1999. 82:1325–1330.

Heringstad, B., Rekaya R., Gianola D., Klemetsdal G., and Weigel K. A.: Genetic change for clinical mastitis in Norwegian Cattle: a threshold model analysis. In: Journal of Dairy Science 2003, 86: 369-375.

Heringstad, B., Chang Y. M., Gianola D., and Klemetsdal G.: Multivariate Threshold Model Analysis of Clinical Mastitis in Multiparous Norwegian Dairy Cattle. In: Journal of Dairy Science 2004, 87:3038-3046.

Heringstad, B., Chang Y. M., Gianola D., and Klemetsdal G.: Genetic analysis of clinical mastitis, milk fever, ketosis, and retained placenta in three lactations of Norwegian Red cows. In: Journal of Dairy Science 2005, 88:3272–3281.

Heringstad, B., Chang Y. M., Andersen-Ranberg I. M., and Gianola D.: 2006. Genetic analysis of number of mastitis cases and number of services to conception using a censored threshold model. In: Journal of Dairy Science 89:4042-4048.

Heringstad, B., G. Klemetsdal, and T. Steine.: Selection responses for disease resistance in two selection experiments with Norwegian Red cows. In: Journal of Dairy Science 2007, 90: 2419-2426.

Heringstad, B., Y. M. Chang, M. Svendsen., and D. Gianola.: Genetic analysis of calving difficulty and stillbirth in Norwegian Red cows. In: Journal of Dairy Science 2007, 90: 3500-3507.

Heringstad, B. and Sivertsen, K.N.: Milk abilities and mastitis. In: Buskap – Journal for Norwegian Cattle Farmers 2010, 5:8.

Hersleth, Egil: NRF Norwegian Red Breed – a source for crossbreeding. In: Article from the Red Cow symposium 2005 proceedings. 16.01.2006
http://www.milkproduction.com/Topics/conferences/red_cow_symposium.htm

Hersleth, Egil: NRF-History part 1. In: Buskap – Journal for Norwegian Cattle Farmers 2010a, 1:31-33.

Hersleth, Egil: NRF-History part 2. In: Buskap – Journal for Norwegian Cattle Farmers 2010b, 2:41-43.

Hungarian National Database (HNDb), 2010 (Acquired with the help of Ruszkai Krisztina in the Hungarian Holstein Association).

Kadarmideen, H. N., Thompson R., and Simm G.: Linear and threshold model genetic parameters for disease, fertility and milk production in dairy cattle. In: Animal Science 2000, 71:411–419.

Kirkland, R. M., Patterson, D. C., Keady, T. W. J., Moss, B. W. and Steen, R. W. J.: Beef production potential of Norwegian Red and Holstein-Friesian bulls slaughtered at two ages. In: Animal 2007, 1:10,1506-1514.

Lang-Ree, Rasmus: Irish Milk Production – grass and crossbreeding. In: GenoBULLetin – English version of "Buskap" - Journal for Norwegian Cattle farmers 2009, 1:10-14. www.genoglobal.no/Home/Geno-BULLetin/

Lang-Ree, Sverre: Introduction to crossbreeding. In: Buskap – Journal for Norwegian Cattle Farmers 2010: 5, 26-27.

Mayne C.S., McCoy M.A., Lennox S.D., Mackey D.R., Verner M., Catney, D.C., McCaughey W.J., Wylie A.R., Kennedy B.W., Gordon F.J McCoy, M.A., Lennox, S.D., Catney D.C., Wylie A. R. G. and Kennedy B. W.: Fertility of dairy cows in Northern Ireland. In: The Veterinary Records 2002, 150:707-713.

Mengshoel, P.: NRF breaks through Internationally (In Norwegian). In: Bondebladet, national newspaper, 29.07.2010 www.bondebladet.no/mat-og-marked/2010/07/20/nrf-slaar-gjennom-internasjonalt.aspx

Meyer, C. L., Berger P. J., Koehler K. J., Thompson J. R., and Sattler C. G.: Phenotypic trends in incidence of stillbirth for Holsteins in the United States. In: Journal of Dairy Science 2001, 84:515–523.

Monardes, H.G., Cue, R.I. and Hayes, J.F.: Correalation Between Udder Conformation Traits and Somatic cell Count in Canadian Holstein Cows. Journal of Dairy Science 1990, 73:1337-1342.

Monsen, Arve: Christian Wriedt – utdypning, In: Store Norske Leksikon (snl.no), 28.06.2010, www.snl.no/.nbl_biografi/Christian_Wriedt/utdypning

Murray R.D., Downham D.Y., Clarkson M.J., Faull W.B., Hughes J.W., Manson F.J., Meritt J.B., Russel W.B., Sutherst J.E. and Ward W.R.: Epidemiology of lameness in dairy cattle: description and analysis of foot lesions. In: Veterinarian Records, 1996, 138:586-591.

National Veterinary Institute: Surveillance and control programmes for terrestrial and aquatic animals in Norway. Annual Report 2005 Oslo, Norway, NVI; 2006. 09.07.2010 http://www.vetinst.no/eng/Research/Publications/Surveillance-and-Control-Programs-annual-reports/The-NOK-Report-2005

Philipsson J, Banos G, Arnason T: Present and future uses of selection index methodology in dairy cattle. In: Journal of Dairy Science, 1994, 77:3252-3261.

Philipsson, J., Steinbock L., and Johansson K.: Differences in genetic variation of calving traits in Swedish Holstein and Swedish Red cattle. In: Proc. 8th WCGALP 2006, Belo Horizonte, Brazil. CDROM Commun. no. 01-24.

Pryce J. E., Conington J., Sorensen P., Kelly H. R. C. and Rydhmer L: Breeding strategies for organic livestock, In: Vaarst et al., Animal health and welfare in organic agriculture, 2003; 378.

Refsdal, A. O.: Reproductive performance of Norwegian cattle from 1985 to 2005: trends and seasonality. In: Acta Veterinaria Scandinavica 2007, 49:5.

Refsdal, A.O.: Fertility and herd life in trails abroad. In: GenoBulletin – English version of "Buskap" - Journal for Norwegian Cattle Farmers 2010a, 1:16-17. www.genoglobal.no/Home/Geno-BULLetin/

Refsdal, A.O.: Calving difficulties and stillbirth. In: GenoBulletin – English version of "Buskap" - Journal for Norwegian Cattle Farmers 2010b, 2:10-11. www.genoglobal.no/Home/Geno-BULLetin/

Rogers, G. W.: Holstein breeding goals now look more like NRF goals. In: GenoBulletin – English version of "Buskap" - Journal for Norwegian Cattle Farmers 2010a, 1:18-20.. www.genoglobal.no/Home/Geno-BULLetin/

Roxström, A., Strandberg E., Berglund B., and Emanuelson U.: Genetic and Environmental Correlations Among Female Fertility Traits and Milk Production in Different Parities of Swedish Red and White Dairy Cattle. Acta. Agriculture Scandinavia 2001, 51:7–14.

Sehested, Erling: The polled wave is coming. In: GenoBULLetin – English version of "Buskap" - Journal for Norwegian Cattle Farmers 2010, 2:6-7. www.genoglobal.no/Home/Geno-BULLetin/

Smith, J.W., Chapa, A.M., Gilson, W.D. and Ely, L.O.: Somatic Cell Count Benchmarks. Animal and Dairy Science Department, April 2009. University of Georgia, USA. 11.07.2010 http://pubs.caes.uga.edu/caespubs/pubs/PDF/b1194.pdf

Steinbock, L., Näsholm A., Berglund B., Johansson K. and Philipsson J.: Genetic effects on stillbirth and calving difficulty in Swedish Holsteins at first and second calving. In: Journal of Dairy Science 2003, 86:2228–2235.

TINE – Norwegian Dairy: Annual Report 2009. 12.07.2010 www.jarlsberg.com/page?id=2990

Walsh, S., Buckley, F., Berry, D.P., Rath, M., Pierce, K., Byrne, N. and Dillon, P.: Effects of breed, feeding system, and parity on udder health and milking characteristics. In: Journal of Dairy Science 2007, 90:5767-5779.

Walsh, S., Buckley, F., Pierce, K., Byrne, N., Patton, J. and Dillon, P.: Effects of breed, feeding system on milk production, body weight, body condition score, reproductive performance, and postpartum ovarian function. In: Journal of Dairy Science 2008, 91:4401-4413.

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DECLARATION

about the thesis

Me, Nedrebö Vidar

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Norwegian Red, its characteristics, and use in international crossbreeding

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