Aus dem Institut für Agrar- und Ernährungswissenschaften
(Geschäftsführender Direktor: Prof. Dr. R. Jahn)

der Naturwissenschaftlichen Fakultät III
(Dekan: Prof. Dr. P. Wycisk)

der Martin-Luther-Universität Halle-Wittenberg

BROWN SWISS × HOLSTEIN CROSSBRED COWS COMPARED TO PURE HOLSTEIN COWS FOR CALVING TRAITS, PRODUCTION, AND CONFORMATION MEASUREMENTS IN FIRST, SECOND, AND THIRD LACTATION

Dissertation

zur Erlangung des akademischen Grades
doctor agriculturarum (Dr. agr.)

vorgelegt von
Diplomagraringenieur Stefan Blöttner
geboren am 24.03.1981 in Rudolstadt

Gutachter: Prof. Dr. Hermann H. Swalve
Prof. Dr. Nicole Kemper
Prof. Dr. Bradley J. Heins

Verteidigung am: 23.01.2012

Halle/Saale 2012

TABLE OF ABBREVIATIONS

AI	=	artificial insemination
BS	=	Brown Swiss
BS × HO	=	Brown Swiss × Holstein
CD	=	calving difficulty
cm	=	centimeter
d	=	day
DFB	=	days to first breeding
DIM	=	days in milk
DNA	=	deoxyribonucleic acid
EBV	=	estimated breeding values
F_1	=	first generation cross
F_2	=	second generation cross
F_3	=	third generation cross
GS	=	genomic selection
h^2	=	heritability
kg	=	kilogram
mm	=	millimeter
n	=	number of observation
PTA	=	predicted transmitting ability
SB	=	stillbirth
SE	=	standard error
SCS	=	somatic cell score
SMR	=	Schwarzbuntes Milchrind (dairy breed)
U.K.	=	United Kingdom
U.S.	=	United States

SUMMARY

The intention of the study is described in the title: *Brown Swiss × Holstein crossbred cows compared to pure Holstein cows for calving traits, production, and conformation measurements in first, second and third lactation.* The thesis is divided into five chapters.

CHAPTER I gives a general introduction in the topic of crossbreeding in several animal and plant species and the reason for crossbreeding in livestock species. The thesis reports the evolution of Holstein dairy cattle during the last three decades and the reasons for crossbreeding with Holstein. Further, this chapter provides a brief overview about the effect of heterosis, gives some details of the dairy breeds that are recommended for crossbreeding. Also crossbreeding in beef cattle, and briefly crossbreeding in sheep, horses, pigs and poultry is provided to summarize the topic of crossbreeding in other livestock species. Finally, CHAPTER I reports briefly about synthetic breeds.

CHAPTER II has an extensive introduction in the topic of crossbreeding and is published in Journal of Dairy Science 94:1058-1068.

Furthermore, the objectives for research and experimental design for this study are presented here. The main topic and objective was to compare Brown Swiss × Holstein crossbred cows with pure Holstein cows for gestation length, birth weight of the calves, calving difficulty, stillbirth, fertility, body weight, back fat thickness, and hoof disorders across the first three lactations. An additional objective was to compare the groups for body measurements and hoof measurements in first lactation. The results have shown that Brown Swiss × Holstein cows had advantages over pure Holstein for most of the functional traits. Those traits are lowly heritable traits, and also traits in which we expect an improvement as a result of heterosis.

CHAPTER III discusses the effect of crossbreeding on production traits of cows and is published in Journal of Dairy Science 94:5212-5216. The objective here was to compare the two experimental groups for milk, fat and protein production, SCS, and milking speed in first, second and third lactation, and for udder measurements in first and second lactation. In contrast to the majority of present literature for dairy crossbreeding, the results show no significant differences for production during the first three lactations. Furthermore, milking speed in this study has a tendency to be slower for Brown Swiss × Holstein cows compared to pure Holstein cows.

CHAPTER IV analyses a subset of production data from first and second lactation and is published in Interbull Bulletin 40:2010, Proceedings of the Interbull Meeting in Barcelona, Spain, August 21-24. The analysis for both lactations was done separately to estimate differences between the groups within lactation. Therefore, the model used was analogous to the model used in national evaluations in Germany. The objective of this study was to compare the experimental groups for differences within specific lactation intervals. The results show that no significant differences were found between the breed groups for production traits in first and second lactation. Moreover, the results have indicated that Brown Swiss × Holstein cows were more persistent producers at the end of lactation.

CHAPTER V provides thoughts on implementing a sexed semen scheme into a crossbreeding program. Also, this chapter discusses the topic of feed efficiency and the implementation of crossbreeding on a commercial dairy farm. Moreover, possible suggestions are made on improving a crossbreeding study and further research objectives and an outlook are provided.

CHAPTER I

INTRODUCTION

Motivation for crossbreeding

Combining different breeds to achieve improvements in production, phenotype, and to increase the productivity, all while decreasing inbreeding depression, are motivations to use crossbreeding as a method in livestock breeding. Crossing of two or more lines, strains or breeds to achieve better result than the parent breeds is a scheme that was used first in plant breeding. The publication of the transmission of factors or specific traits from parents to their offspring and through subsequent generations was first published by Georg Mendel in 1865. At this time Mendel's studies gave birth to the concept of genes and the discipline of *'Genetics'* (Acquaah, 2007). Dickerson (1969) describes crossbreeding as an important source of genetic improvement in the efficiency of human food production from livestock through: (1) grading up to superior breeds; (2) heterosis from systematic crossbreeding; and (3) development of new breeds. Furthermore, Hill (1971) reported that 'Crossbreeding has been an established practice for centuries in the domesticated animal species. Breeders have had many objectives: the use of crosses to obtain any benefit there may be from heterosis and particular merits of the individual breeds. Alternatively the crosses have been used to form new populations with desirable characters from each of the paternal breeds. In 1919 the use of single crosses and double crosses between two single crosses made the commercial production of hybrid corn seed economical (Acquaah, 2007). Upon observing the results crossbreeding achieved in plant breeding, the first advantage of crossbreeding in animals was sought in poultry. For production livestock, crossbreeding has also become popular in pigs and beef cattle (Touchberry, 1992; Rishell, 1997; Swalve, 2007; Sørensen, 2008). Swalve (2007) reported the biological facts why crossbreeding has not become economical in dairy cattle compared to swine or poultry. The main reasons are: dairy cows have a long generation interval, the individual animal has a relatively high value and a much lower reproduction rate (≤ 1 offspring per year).

History of Holstein dairy cattle

The Holstein breed has become the most important dairy breed in developed countries in the last 30 years. Originally, Holstein cattle originated from northern Europe in what is today along the coastline from the Netherlands, Germany and the Danish Kingdom. Mügge et al. (1999) pointed out that at the end of the 19th century the first Holstein cows were imported from Europe to the US. Similar breeding organizations have been established both in Europe and the US for the improvement of the Holstein breed. Also during this era, the organized breeding of the black and white breed, (also called old-type Friesian in Germany and the Holstein-Friesian in the U.S.) has begun.

Furthermore, Mügge et al. (1999) reported that in 1965, the first Holstein-Friesian genetics from the US were reintroduced to Germany. In 1972, the breeding objective of old-type Friesian cows in Germany was defined as a dual-purpose (dairy and beef), moderate-framed cow with good adaptability to different farm and environmental conditions. Good milk yield (6,000 kg) and high fat contents (4 %) of the milk were also characteristics of these cows. Furthermore, good beef production for the fattening of bulls was desired, but also excellent adaptation for grazing of milking cows was required. In later years, increasing the milk production level was a new breeding objective for old-type German Friesian cows. This objective was achieved by using U.S. and Canadian Holstein-Friesian bloodlines, which had superior production characteristics (Mügge et al., 1999).

The Holstein-Friesian, later officially named Holstein, has outstanding superiority for milk production compared to other dairy breeds in many environments internationally. Today the global Holstein breed, which is almost completely of U.S. Holstein genes, has replaced many native dairy cattle breeds around the world that do not match up to the Holstein's production level (Hansen, 2006; Heins et al. 2006; VanRaden et al. 2007). Cassell (2001) reported that U.S. Holstein had an increase in milk production from 5,870 kg in 1957 to 11,274 kg for cows born in 1997. Shook (2006) reported that the increase in production resulted from improvements in genetics, nutrition and management. This extreme increase in production in the U.S. Holstein population was similar for all Holstein populations in developed countries due to the sharing of genetic material.

Total merit indices over time

Miglior et al. (2005) reported for Holstein dairy cattle and König et al. (2007) for all breeds of dairy cattle, that during decades prior to 1990, the primary emphasis in selection indices worldwide was on increasing kilograms of milk produced. In the 1970's and 1980's the selection indices included only milk, fat and protein production. Into the early 1990's, for the U.S. Holstein population, productive life and somatic cell score was additionally included in the selection index. Philipsson et al. (1994) reported that Scandinavian countries included health fertility, calving and stillbirth in their selection index for Holsteins. After 2000, most Holstein selection indices included production and functional traits. Beginning in 2003, the U.S. Holstein population removed all emphasis on kg of milk produced in the selection index, instead putting production weight on fat and protein pounds. Then in 2006, daughter pregnancy rate and calving ability (includes sire calving ease, daughter calving ease, sire stillbirth, and daughter stillbirth) was included in the selection index (VanRaden, 2004; Shook, 2006; and USDA, 2010).

Table 1 shows the change in selection indices over time for the German Holstein population. Swalve (2008) reported that until 1996, the only emphasis in the selection index for the German Holstein population was on production. Beginning in 2008, a new reproduction index was implemented in the German Holstein genetic evaluation and was given a relative weight of 10 % of the total merit index (Rensing et al., 2008). The conformation index included dairy type (10 %), body (20 %), feet and legs (30 %) and udder (40%).

Table 1: Total merit index over time for German Holstein from 1998 to April 2008 for milk, conformation (**CI**), somatic cells (**SI**) longevity (**LI**) reproduction (**RI**), fertility (**FI**), calving traits (**CI**) (Swalve, 2011; modified)

Year	Milk	CI	SI	LI	RI	FI	CI	Total
1998 -2002	56	20	14	6	4	-	-	100
2002 - 2008	50	15	5	25	5	-	-	100
April 2008	45	15	7	20	-	10	3	100

For the current study, for Holstein AI sires genetic evaluation is from VIT (www.vit.de). VIT is a nonprofit organization in Germany that conducts the genetic evaluations for pure Holstein, Angler and Jersey. The Holstein sires used in this study were selected based on breeding values at this time. Miglior et al. (2005) reported the genetic evaluation at this time.

The genetic evaluation for Brown Swiss AI sires is calculated by LfL Bavaria (2009) (www.lfl.bayern.de). LfL Bavaria is a nonprofit organization of the federal state of Bavaria, Germany, and does sovereign functions in agricultural research, such as calculating breed evaluations for Fleckvieh, Brown Swiss and Gelbvieh.

Besides the changes in Holstein selection, the Brown Swiss breeding goals over time is also important to the present study, and those indexes show slightly different selection goals over time compared to Holstein. Table 2 shows the relative weights in the total merit index for German Brown Swiss over time.

Table 2: Total merit index over time for German Brown Swiss (Gredler 2004 and LFL Bavaria, 2009, modified)

Year	Production	Fitness	Milking speed	Beef	Total
2002 - 2004	50.3	45.7	4		100
2004 - 2009	48	45	2	5	100

Fitness included longevity (16%), persistency (2.7%), fertility (8.6%), calving ease (1.8%), stillbirth (5.9%) and SCS (10%). The Brown Swiss genetic evaluation has never included conformation index in the total merit index. However, some conformation traits, and especially foot and leg and udder traits, have a positive correlation with longevity. Therefore, they have had positive selection pressure indirectly (LfL Bavaria, 2009).
The selection indices have focused more on functional traits in both Brown Swiss and Holstein breeds during recent years. However, Geno Global (2010) reported that for Norwegian Red cows, selection for increased production and improved animal health and fertility can be obtained simultaneously if the breeding objective is properly defined and if the breeding program is designed to include selection for traits with low heritability. The current breeding program for the Norwegian Red breed shows a simultaneous genetic improvement for milk yield, mastitis resistance and female fertility.

Why crossbreeding in dairy cattle

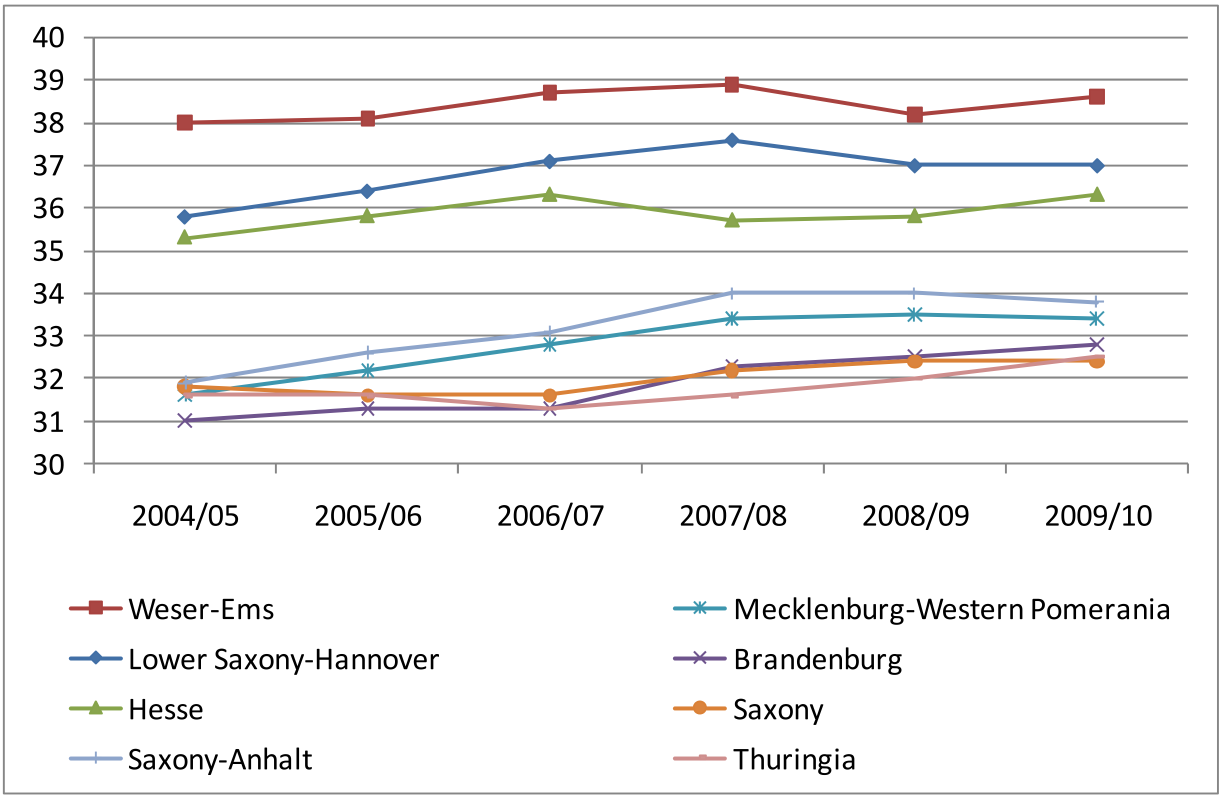
Several studies have reported the antagonistic relationship between production and health and fertility (Simianer et al., 1991; Swalve et al. 1992; Shook, 2006). As a result of selecting primarily for production in the Holstein population, the result is increased inbreeding levels. These two factors together have created a decline in fertility and health status of cows, increased calving difficulty and stillbirth rate, and reduced longevity (Pryce et al., 1997; Hansen et al., 2002; Steinbock et al., 2003; Weigel and Barlass, 2003;

VanRaden et al., 2004; Kuhn et al. 2006; Moore and Thatcher, 2006). These problems in Holstein dairy cattle are also consistent with several other dairy breeds, which have selected for production.

The German cattle breeders federation, ADR (2010), reported that over 3.5 million cows participated in milk recording in 2009, and their average production was 7,983 kg. The Holstein population on milk recording contains over 1.8 million cows, making it the most populous dairy breed in Germany. The second largest dairy breed on milk recording is Fleckvieh (733,037 cows) and third largest is Braunvieh (143,109 cows).

By analyzing the dimension of death and culling loss of cows, it becomes clear that change is needed in the German breeding objectives. For German Holstein Swalve (2011) analyzed the average longevity. Figure 1 has longevity in month by region in Germany. It shows that a different for longevity exists between small farms in West Germany (Weser-Ems, Lower Saxony-Hannover, Hesse) and large farms in East Germany (Saxony-Anhalt, Mecklenburg-Western Pomerania, Brandenburg, Saxony, Thuringia). Also Figure 1 shows that a slight increase in longevity is achieved during time.

However, from the total cow population on milk recording 1.3 million cows (39 %) leave the herd per year. The average culling age of a lactating cow in Germany is 5.4 years. The most prominent reasons for culling a cow are: milkability, age and other reasons (26.2 %), sterility (20.7 %), udder diseases (14.8 %), hoof and legs (10.4 %), diseases (10.2 %) and low production (6.5 %) (ADR, 2010).



Firgure 1: Longevity in month for eight regions in Germany from 2004/2005 – 2009/2010, (Swalve, 2011; modified).

Within the Holstein breed the change of the selection index was a necessary adjustment, even though dairy cattle breeders, AI organizations and scientists have worked against the increasing involuntary culling level long before durability was included in the index. To make progress in durability and reproduction by modifying selection indexes and using a progeny test scheme takes many years and is very expensive (Schaeffer, 2006; König et al., 2007; König et al., 2009).

The functional traits, and especially reproduction and fitness traits, have low heritabilities ($h^2 < 0.15$) (Willham and Pollak, 1985), and this limits the speed at which change can be brought about in the commercial population. These traits are of increasing economic importance in modern dairy cattle due to their effect on production costs (Freyer et al., 2008).

A study by VanRaden and Sanders (2003) described crossbreeding as a simple method to increase the health and efficiency of many plants and animals, by introducing favorable genes from other breeds, by removing inbreeding depression, and by maintaining the gene interactions that cause heterosis. Furthermore, Swalve (2004) named three reasons for crossbreeding, (1) the differences between populations or additive-genetic effects, (2) positional effects can be used by improving two traits which have a negative genetic correlation (as shown in pigs for a fertile dam breed ‘A’ and a muscular sire breed ‘B’), and (3) the use of heterosis.

Crossbreeding in dairy cattle has not grown in popularity very much over the past 75 years (Heins et al., 2006), as it has in other species. Touchberry (1992) reported that some of the very first planned experiments involving dairy cattle were genetic experiments undertaken in the 1920’s, and those experiments involved crossbreeding. They were implemented to achieve variation in traits such as milk yield, and fat and protein percentage with a simple Mendelian model. In recent decades, dairy producers were the first to implement modern crossbreeding in dairy cattle without large scale studies being conducted in a research setting.

Weigel and Barlass (2003) and Heins et al. (2006) reported an increasing interest in crossbreeding among U.S. dairy producers at the beginning of the 21st century. Weigel and Barlass (2003) reported three reasons why U.S. dairy producers are interested in crossbreeding: (1) changes in milk pricing have rewarded herds with high fat and protein percentages, and this has enhanced the ability of non-Holstein breeds and breed crosses to compete with Holsteins with regard to income from milk sales; (2) producers have concerns regarding female fertility, calving ease, health, and survival in pure Holstein cows, and (3) inbreeding levels are increasing rapidly in all of the major dairy breeds, and crossbreeding may be an effective option for reducing the impact of inbreeding depression on commercial dairy farms. Furthermore, Heins et al. (2006) and Swalve (2007) reported that dairy producers are seeking ways to reduce calving difficulty of cows and decrease stillbirths of calves in there herds; some have turned to crossbreeding to potentially alleviate problems with these traits caused by the increased unfavorable relationship between production and functional traits. Sørensen et al. (2008) reported further that producers may initiate a crossbreeding design in dairy herds because as herds increase in number of cows per employee, there is a greater need for robust animals that demand fewer health and reproductive treatments. Heins et al. (2010) mentioned that dairy producers around the world have began mating Holstein heifers and cows to Jersey and the Scandinavian Red breeds because these breeds have more capacity to reduce calving difficulty of cows and stillbirth of calves. Finally, the results reported by Heins and Hansen (2010) show that crossbred dairy cows have obvious advantages over pure Holstein cows for survival rate of cows.

Heterosis

The opposite of inbreeding depression is the phenomenon of heterosis, or 'hybrid vigor' (Falconer and Mackay, 1996). The gene level effects of inbreeding are an increase in homozygosity and a decrease in heterozygosity. Therefore, heterosis is an increase in heterozygosity and a decrease in homozygosity. In general, heterosis refers to the superiority of crossbred progeny over the mean of both parental breeds, as shown in Figure 1 (Schüler et al. 2001).

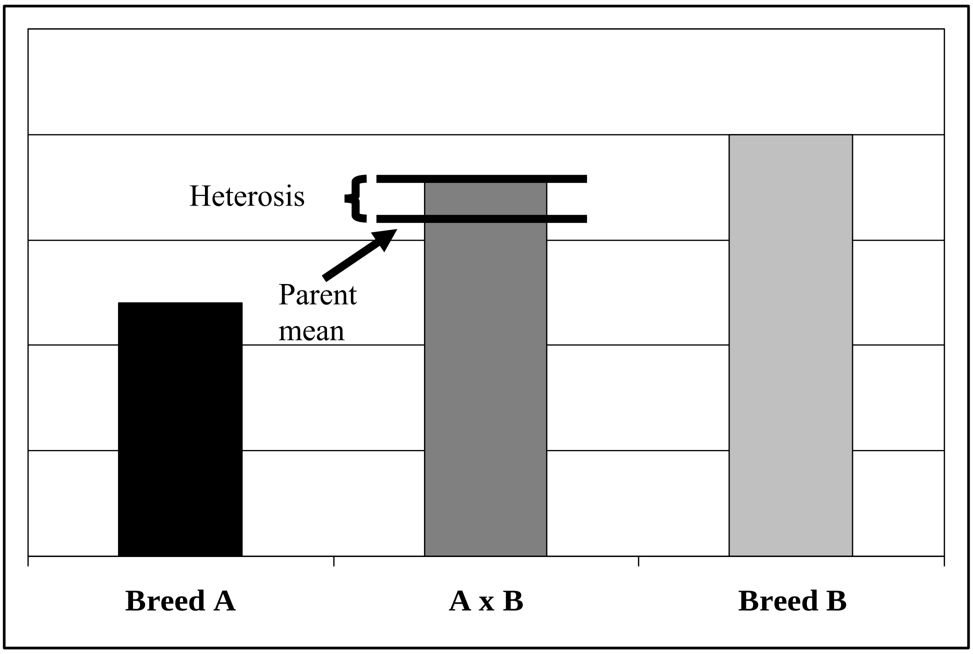


Figure 2: Schematic representation of heterosis: Deviation of crossbred progeny from the parent average (Swalve (2004) modified).

The experimental design and objective of the current study (see CHAPTER II) was to compare the phenotypic performance of F_1 Brown Swiss × Holstein cows with pure Holstein cows. The estimation of heterosis was not part of this research. Estimation of heterosis requires four breeding groups: '*A*', '*B*', '*A*×*B*' and the reciprocal '*B*×*A*'. Equation

[1.1] (Schüler et al., 2001) shows the calculation of heterosis based on four breeding groups (*'A'*, *'B'*, *'A×B'* and *'B×A'*, respectively).

$$\frac{1}{2}(AB + BA) - \frac{1}{2}(A + B) = h_{AB} \qquad [1.1]$$

Falconer and Mackay (1996) describe heterosis in equation [1.2] where M_{F1} = mean genotypic value of the F_1, $M_{\overline{P}}$ = mid-parent value, d = dominance and y = differences of the gene frequency.

$$H_{F_1} = M_{F_1} - M_{\overline{P}}$$

$$= \Sigma dy^2 \qquad [1.2]$$

The amount of heterosis in equations [1.1] and [1.2] is expressed as the difference between the F_1 generation and the mid parent values.

Falconer and Mackey (1996) make three conclusions from equation [1.2]:

(1): If some loci are dominant, but the traits they express are antagonistic, then their effects will tend to cancel out, and no heterosis can be observed, despite the dominance at the individual loci.

(2): The amount of heterosis is something specific to each particular parent combination. Even within the same two parent breeds, the genes by which two lines differ will not be the same for all pairs of lines, so different pairs of lines will have different values of Σdy^2 and will show different amounts of heterosis.

(3): If the lines crossed are highly inbred, and so completely homozygous, the difference of gene frequency between them can only be 0 or 1. The heterosis as shown by equation [1.2] is then the sum of the dominance deviations (*d)* of those loci that have different alleles in two lines. Swan and Kinghorn (1992) divide the genetic basis of crossbreeding into two major components: additive and nonadditive effects. The additive genetic effect for the trait of interest is the simple weighting according to level of representation of each parental breed in the crossbred genotype. The same authors explain that the nonadditive effect of crossbreeding is heterosis, whereas heterosis is usually attributed to the genetic interactions within loci (dominance) and the interactions between loci (epistasis). For epistasis , Freyer et al. (2008) reported that according to the dominance hypothesis, nonadditive genetic effects are those caused by heterozygosity at a gene locus (dominance and overdominance), combinations of dominant genes at different loci, and various types of nonallelic gene-gene interactions, such as additive × additive, dominant × dominant, and additive × dominant gene interactions (epistasis). Furthermore, Sørensen et al. (2008) mentioned that under the assumption of the dominance model, where epistatic effects are neglected, F_1 heterosis is assumed to be the dominance effect.

Table 1 has selected studies evaluating heterosis levels in several traits for crossbred dairy cattle. It is obvious that the amount of heterosis occurs in different levels based on breeds used and traits analyzed.

Table 2. Literature overview for selected studies evaluating level of heterosis for production and reproduction for crossbreeding in dairy cattle.

Author	Breeds	n	Trait	Level of heterosis (%)
McDowell and McDaniel (1968)	Ayrshire Brown Swiss Holstein	n = 226	Days open Production	4 – 15 8 – 10
Touchberry (1992)	Holstein Guernsey	n = 788	Service per conception First service to conception Milk production	12.8 17.6 4.1 – 12.0
McAllister (1994)	Holstein Ayrshire	n = 5,070	Production (lifetime yields) Lifetime economic performance	16.5 – 20.0 >20
VanRaden and Sanders (2003)	Ayrshire Brown Swiss Guernsey Jersey Milking Shorthorn Holstein	n = 756,893	Production	3.4 – 4.4

Hansen (2006) reported that in a simple rotational crossbreeding system with three breeds, the first two generations have the potential for capturing 100 % of the available heterosis for any trait of interest. A two and three-breed cross has 100 % heterosis, this implies that the crossbred will have double the production average of the parent mean. In the third generation where a crossbred cow is bred back to the earliest parent breed, the available heterosis is 75 %, and is the lowest experienced in any generation. In a three breed rotational system, all subsequent generations have an average of 86 % of the heterosis available. Including a fourth breed in the rotational system would result in 93 % of heterosis available after the first few generations. With regard to the number of breeds included in the rotational system, the major increase in heterosis is expected when three breeds are used. The level of available heterosis in a two breed rotational system is only 67 %, on average.

Dairy breeds for crossbreeding

VanRaden (2004) pointed out that: "Specialized breeds selected for different traits can make more profit than a single breed selected for many traits." Hansen (2006) questioned how many breeds can be found for crossbreeding that have (1) high genetic merit for most traits of interest, (2) offer complementarities to one another for traits in a mating system, and (3) are adapted to the environmental conditions of the specific dairy operation (level of nutrition, grazing versus confinement, stall size etc.). Furthermore, Hansen (2006) reported that besides these requirements for dairy breeds used in a crossbreeding system, the population size, the genetic relationship between breeds, and an efficient breeding program within the breed are some points to consider when choosing specific breeds. Most commercial dairy producers moving to a crossbreeding program currently have pure Holstein cows. Therefore, a crossbreeding design with Holstein dairy cattle as the foundation dairy breed will be considered. Scenarios may be different for herds beginning with other purebred cattle or crossbred cows. The information listed for the following individual dairy breeds was provided by either an AI organisation or breeder association for that particular breed.

Jersey: The Jersey breed has highest fat production of all dairy cattle breeds. Further properties are good health, longevity and fertility relative to Holstein cows (Frahm, 1990). New Zealand has 600,000 Jersey cows, making it the world's largest Jersey population. Jerseys perform well in intensive grazing programs and confinement systems. The Danish Jersey population has about 64,269 cows on milk recording with an average production of 6,560 kg milk, 384 kg fat and 264 kg protein (LIC, 2011; Viking Genetics, 2010).

Scandinavian Red: The Scandinavian Red breed consists of four dairy breeds the Norwegian Red**,** the Swedish Red**,** the Danish Red and the Finnish Ayrshire; each Nordic country has its own red breed. The breeds share similar ancestry, mostly Ayrshire and Shorthorn, and exchange sires of sons (Heins et al., 2006). Similarities exist between all four breeds, therefore they are collectively regarded as Scandinavian Red. The *Norwegian Red* population has 290,000 cows with 95 % of the cows on milk recording. The average annual production in Norway is 6,500 kg milk, 273 kg fat and 215 kg protein. Levels of stillbirth and calving difficulty in Norwegian Red are low, with an overall mean (all parities) stillbirth rate of about 2%, and 95% of the cows reported to have an easy calving. A large proportion of Norwegian Red cows are polled (Geno Global, 2010; Hersleth, 2006). The **Swedish Red** breed population is about 125,878 cows with an average production of 8,730 kg milk, 375 kg fat and 304 kg protein (Viking Genetics, 2010). The **Danish Red** cow population is about 41,049 cows with an average production of 8,634 kg milk, 361 kg fat and 301 kg protein (Viking Genetics, 2010). Frahm (1990) reported that in a minor extent Danish Red were inseminated with Red Holstein from the U.S. and Canada. This fact makes Danish Red unfavorable in terms of the genetic relationship between breeds. The **Finnish Ayrshire** population is about 148,996 cows, making it the largest Ayrshire population in the world. The breed has an average production of 8,630 kg milk; 370 kg fat and 299 kg protein (Viking Genetics, 2010).

Normande: The Normande breed was first developed in north western France, but now has other smaller populations in many countries. The Normande population is approximately 1 million cows in France with 300,000 cows under milk recording with an average production 6,350 kg of milk, 229 kg protein, and 279 kg fat per lacation. (Normande Genetics, 2010).

Montbeliarde: The Montbeliarde breed is based in the Franche-Comte region of France and was introduced to North America and other countries globally over the past decade (Heins et al., 2010). The cow population in France is close to 360,000 cows on milk recording and is the second largest dairy breed in France, while Holstein is the most common. The average production in France is about 7,486 kg milk, 291 kg fat and 258 kg protein annually (Coopex, 2010).

Brown Swiss: Brown Swiss has more robustness, better fertility, more longevity, and better survival compared to pure Holstein cows. Additionally, they have more milk production compared to Simmental cows and Tyrol Grey cows (De Marchi et al., 2007; Garcia-Peniche et al. 2006; Bytyqi et al. 2007). The modern Brown Swiss cow in Germany has high production levels and is characterized by the highest protein percent of German dairy breeds (ADR, 2010). The German Brown Swiss is most commonly found in the rough mountainous Alp region and grassland foothills in the southwest of Germany. The average production is about 7,026 kg milk, 296 kg fat and 254 kg protein.

Fleckvieh: The Fleckvieh breed is a dual purpose breed with high milk production and high beef production. The average production is about 7,000 kg milk, 273 kg fat and 259 kg protein, the daily gain for young bulls of 1.300 g, with a meat amount of 70 % (ASR, 2011).

Crossbreeding in beef cattle

Sørensen (2008) reported that crossbreeding has been used extensively in beef cattle. Gregory and Cundiff (1980) mentioned that the basic objective of beef cattle crossbreeding systems is to optimize simultaneously the use of both non-additive (heterosis) and additive (breed differences) gene effects. Long (1980) mentioned that crossing breeds for beef production has become a generally recommended and accepted practice. The same author reported that increasing the efficiency of beef production systems by genetic methods rests primarily on two procedures: (1) selection within breeds to improve critical traits, and (2) selection among breeds and/or combining breeds to produce individuals that better fit production conditions and resources. Therefore, new breeds were bred which are capable to adapt better to the local environmental conditions (Gregory and Cundiff, 1980).

In Germany, the total cattle population are dairy breeds 6.3 million (49 %) and dual-purpose breeds 5.1 million (40 %). Only 1.5 million (11%) of the total cattle population are beef breeds or beef crossbred animals in Germany. Whereas the division between purebred beef breeds (50 %) and beef × beef crosses (50 %) is equal. The major beef consumed is from young bulls and oxen (50%), followed by cows (35%) and heifers (11%) (ADR, 2010; LfL Bavaria, 2009). Consequently the major production of veal and beef originated from dairy breeds and dual-purpose breeds. Also experimental research on beef cattle crossbreeding is done to obtain the genetic parameters for estimation of breeding values, and to evaluate the suitability of the breeds for crossbreeding in terms of increasing productivity (Brandt et al., 2010). Another common practice in Germany is mating beef bulls with dairy cows. Based on the total cattle population 4 % (ADR, 2010) are beef × dairy crosses. Types of crosses are sometimes found include: Charolais × Holstein, Belgium Blue × Holstein and Blonde d' Aquitaine × Braunvieh to produce male and female offspring for the local beef market and to enhance farm profitability (Schüler et al., 2001; Wolfova et al., 2007).

Crossbreeding in sheep, horse, poultry and pigs

Reasons for crossbreeding in sheep are to increase productivity, better wool production and improvement in fattening and carcass performance (Miller and Dailey, 1951; Sidwell, et al., 1971; Schüler et al., 2001; von Lengerken et al., 2006). Furthermore, Thomas (2006) provides an extensive review on crossbreeding in sheep and breeds can be used for crossbreeding. The author concluded that crossbreeding in sheep increase the productivity of commercial sheep flocks from hybrid vigor and breed complementarity.

Crossbreeding in horses is used as a method for upgrading to a pure breed. In the 1950's, German work horses were bred up into sport horse. This was done by breeding thoroughbred stallions from England, Arabian stallions, and the Trakehner stallions to local mares. The offspring from those crosses was selected based on the pure-bred criteria (von Lengerken et al., 2006).

In poultry and pigs, terminal crossbreeding has become the major breeding strategy for at least four decades. Crossbred females improved female fertility, which caused the high reproduction rates resulting in an increased number of offspring per generation.

Terminal crossbreeding involves three- or four-breed crosses. These breeds were generated to fulfill the market requirements for high quality and abundant protein production. In the first generation, F1 crosses created productive male and fertile female lines, and these were then crossed to generate homogeneous offspring in the second generation. This system for pork and poultry production has created a clear separation between the major breeds commonly used in the industry. But also, it has created specialty markets for producers of those breeding lines. Breeders produce parent stocks and sell those genetics to multipliers. The breeders also do their own genetic evaluation and improvement for their genetically diverse lines and flocks. The stock breeders produce mainly single crosses. From those single crosses the commercial multiplier producers generate the second generation double crosses. These stock producers sell animals to finisher growers who produce meat in both pigs and broilers chickens, and also egg in layer hens.

Synthetics

Synthetic breeds are artificial breeds that are bred from several base breeds (Schüler et al., 2001). Most synthetic breeds were designed to accomplish the purpose of combining different characteristics from different breeds in one new breed. A common breeding practice is combining several different base breeds to make progress in one trait.

One example of a synthetic breed in beef cattle is the ‘Uckermärker’, which is an independent breed in Germany, and it is a cross between Charolais and Fleckvieh with good fattening and carcass traits. In North America, ‘Santa Gertrudis’ is a cross of Brahmann and Beef Shorthorn. The new breed included the prematurity and good fatting ability from the European beef breed and the resistance for heath and parasites from Zebu and to fulfill market requirements (von Lengerken et al., 2006).

A few synthetic breeds were also developed in horses. Synthetic horse breeds include the Hunter horse and the Haflinger. The Hunter horse is a cross between English thoroughbred × working horses in the U.K. The breeding objective when developing the Hunter horse was to combine the robustness from the working horse with the riding traits from the thoroughbred. The Haflinger (Noriker × Arabian), from the north of Italy, was similar reasons as the Hunter horse (von Lengerken et al. 2006).

Almost all pigs and dairy cattle in the former east of Germany are bred as part of synthetic breeds. The LEICOMA swine breed which is a synthetic breed composed of four pig breeds (German Landrace × Dutch Landrace × Duroc × German belted pig).

LEICOMA is known as a fertile, stress resistant dam line with good growth ability, good meat quality and good adaptation in large herds (von Lengerken et al. 2006).

Synthetic breeds are no longer common in Germany for dairy cattle breeding. The most noted German synthetic breed is the Schwarzbunte Milchrind, or SMR, first published by Schönmuth (1963). Freyer et al. (2008) has published an extensive review of the SMR breed's development. Figure 3 shows the theoretical breeding scheme for the SMR breed. The composite breed is developed by a crossbreeding program based on a 3-breed cross. The goal of the breed was to emphasize dual-purpose cattle with high milk fat and protein content, but also with udder conformation acceptable for machine milking. Annual milk production of a cow was targeted to reach 5,000 to 6,000 kg reaching at least 200 kg of fat and 165 kg of protein. Breeders also sought sufficient muscling for a body weight of 600 kg, and 128 to 132 cm in height at withers (Freyer et al., 2008).

With the exception of New Zealand's KiwiCross, the use of synthetic breeds is not widespread in dairy cattle, and not promoted by geneticists for commercial milk production. The development of the KiWiCross is reported by LIC (2010) and Teara Govt (2010). New Zealand dairy farmers were dissatisfied with their Holstein cows and started breeding in the late 20th century Holstein with Jersey cows to produce the 'KiWiCross'. Whereas, a KiWiCross are crossbred animals with less than 87.5 % of one of the main dairy breeds (Spelman et al. 2010). They required a medium-sized, fertile, easy-calving cattle that will not suffer leg and foot problems when travelling from paddock to parlour. The result, the 'KiWiCross', was based on the hybrid vigour boosts its milk-solids production, conception and calving rates. Today, the New Zealand cow population on milk recording (2.8 Million cows) is dominated by Holstein (41.6%) and 'KiWiCross' (36.3 %), followed by Jersey (13.3 %), Ayrshire (0.8 %) and other breeds (7.9%) (LIC, 2011).

Schüler et al. (2001) reported some ideas on synthetic breeds from a geneticist view point. Inspecting a scheme involving three breeds, the first generation is the same as an F_1

cross when developing a synthetic breed in an individual herd. Likewise, the second generation is similar to a 3-breed cross, and generations after this utilize crossbred sires mated to crossbred cows. . The more lines or races involved in a synthetic breed, the longer it takes for the new race to provide a uniform phenotype. Schüler et al. (2001) identified the following three problems for synthetic breeds: (1) It is difficult to predict the final yield of a synthetic breed since heterosis decreases after the first few generations, (2) Pseudo-correlations are created between traits by linkage disequilibrium as generations are crossed, (3) recombination losses are typical for synthetic breeds, and so the productivity of these cows is less than the productivity of cows in a rotational crossbreeding scheme.

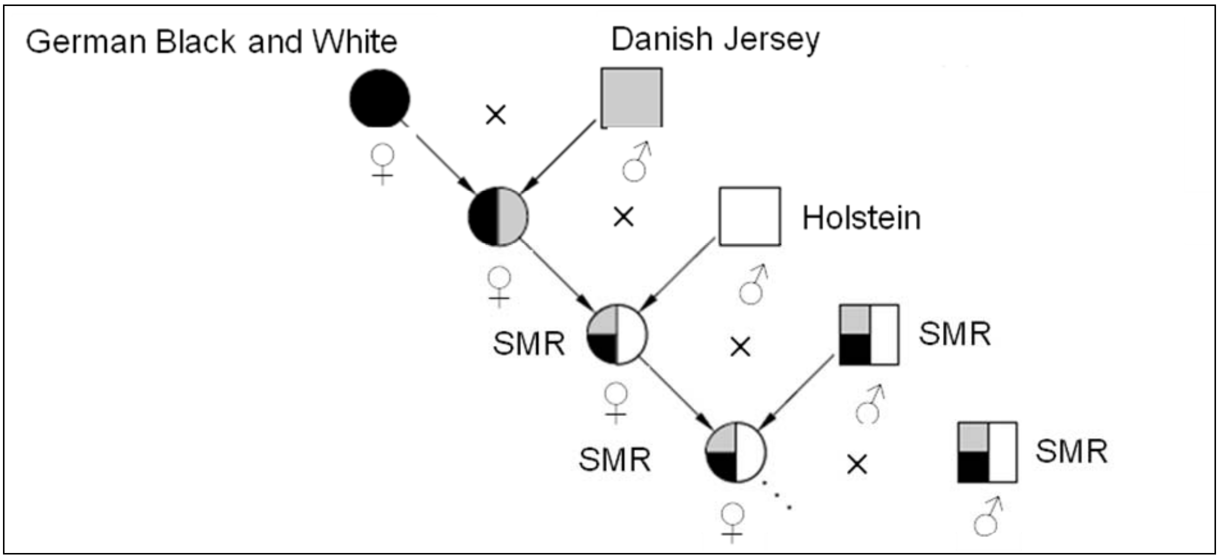


Figure 3. Breeding schema for the ‘Schwarzbunte Milchrind’ (SMR) (Schüler et al., 2001, modified)

Genetic level of sires of cows in the current study

There were 20 AI sires used in this study - 10 pure Holstein sires and 10 Brown Swiss sires. They are labeled A to J within each breed. Table 2 contains the genetic evaluations for these 20 sires, including number of daughters per sire; total merit index at the time of selection of sires in 2002; total merit of sires in 2009; PTA for production; and EBV values for SCS, longevity, udder, conformation and milking. The genetic information for all sires is from the August 2009 German genetic evaluation. All Brown Swiss AI sires were progeny tested in either Germany or Italy, and all Holstein AI sires were progeny tested in Germany. The weighted means of total merit 2002 for Brown Swiss sires is calculated without consideration of sire B and sire C, because those sires had no total merit evaluation in 2002. The production index for Brown Swiss sires B (130) and C (150) was used as selection criterion. The weighted mean production PTAs for Brown Swiss sires were +381 kg of milk, +13 kg of fat, and +15 kg of protein; and the weighted mean production PTAs for Holstein sires were +793 kg for milk, +20 kg for fat and +28 kg for protein. Weighted EBVs for other traits are calculated in Table 2. The weighted means for total merit were above breed averages both at the time sires were selected and also when 2009 EBVs were calculated. CHAPTER II provides more detailed information about the experimental design and sire selection for the current study.

Table 3: Number of daughters of sires, total merit index (**TM**) 2002, TM 2009, PTA for milk, fat and protein production, SCS index (**SI**), longevity index (**LI**), udder index (**UI**), conformation index (**CI**) and milking speed index (**MI**) for Brown Swiss AI sires and Holstein AI sires.

Sires	n	TM 2002	TM 2009	Milk	Fat	Protein	SI	LI	UI*/CI	MSI
Brown Swiss										
A	9	131	114	527	12	8	107	119	101	115
B	8	†	103	223	15	13	99	91	111	118
C	6	†	89	589	19	17	79	70	93	85
D	6	130	111	-321	-3	10	105	103	103	109
E	6	135	128	919	31	28	104	117	110	123
F	5	115	103	278	7	13	95	90	101	78
G	5	133	131	662	2	22	107	130	99	102
H	4	126	116	407	28	18	120	103	114	99
I	3	115	102	166	18	17	88	86	98	71
J	3	123	105	152	-6	5	103	101	111	113
Weighted average		127	110	381	13	15	101	102	104	104
Holstein										
A	11	136	115	1295	10	47	94	111	100	103
B	8	134	105	36	19	19	113	107	107	104
C	7	140	116	700	8	26	117	120	116	108
D	6	137	107	980	3	23	98	108	121	103
E	5	128	106	475	44	17	113	106	113	92
F	4	134	113	662	14	26	100	117	109	99
G	4	132	109	419	59	13	116	110	100	101
H	2	137	143	1778	40	55	128	132	117	88
I	2	130	115	1357	28	24	113	120	107	115
J	1	126	111	1366	21	36	101	109	98	96
Weighted average		135	112	793	20	28	107	112	109	102

† Brown Swiss sire B and C had no TM in 2002 available and where not included for calculating the weighted means of TM 2002 for BS sire.
* UI values in this column are for BS sire
** CI values in this column are for HO sire

References

Acquaah, G. Principles of plant genetics and breeding. 2007. Blackwell Publishing, 350 Mainstreet Malden, MA, USA ISBN-13:978-1-4051-3646-4

ADR. 2010. Arbeitsgemeinschaft Deutscher Rinderzüchter e.V. Cattle production in Germany 2009. Edition 2010.

ASR. 2011. Arbeitsgemeinschaft Süddeutscher Rinderzucht- und Besamungsorganisationen e.V. www.asr-rind.de accessed November 3, 2011

Brandt, H., A. Müllenhoff, C. Lambertz, G. Erhardt and M. Gauly. 2010. Angus and Simmental beef cattle and the reciprocal crosses estimation of genetic and crossbreeding parameters for preweaning traits in German. J Anim Sci.88:80-86.

Braunvieh.de. 2010. http://www.braunvieh.de/Die-rasse_eng.htm accessed November 30, 2010

Bytyqi, H., J. Ødegård, H. Mehmeti, M. Vegara, and G. Klemetsdal. 2007. Environmental sensitivity of milk production in extensive environments: A comparison of Simmental, Brown Swiss, and Tyrol Grey using random regression models. J. Dairy Sci. 90: 3883-3888.

Cassell, B. and J. McAllister. 2010. Dairy Crossbreeding: Why and How. http://www.extension.org/pages/Dairy_Crossbreeding:_Why_and_How accessed May 5, 2010

Coopex 2010. http://www.coopex.com/index-en.php accessed November 30, 2010

De Marchi, M.., R. Dal Zotto, M. Cassandro, and G. Bittante. 2007. Milk coagulation ability of five dairy cattle breeds. J. Dairy Sci. 90: 3986-3992.

Dickerson, G. 1969. Experimental approaches in utilising breed resources. Anim. Breed. Abstr., 87, 191-202

Fahr, R-D. and G. von Lengerken. 2003. Milcherzeugung. ISBN 3-87150-726-1

Frahm, K. 1990. Rinderrassen in den Ländern der Europäischen Gemeinschaft. 2., neu bearbeitete und erweiterte Auflage. ISBN 3-432-92382-1

Freyer, G., S. König, B. Fischer, U. Bergfeld, and B. G. Cassell. 2008. Invited Review: Crossbreeding in dairy cattle from a German perspective of the past and today. J. Dairy Sci. 91:3725–3743

Garcia-Peniche, T. B., B. G. Cassell, and I. Misztal. 2006. Effects of breed and region on longevity traits through five years of age in Brown Swiss, Holstein, and Jersey cows in the United States. J. Dairy Sci. 89: 3672-3680.

Geno Global 2010. http://www.genoglobal.no/ accessed November 30, 2010

Gredler, B. 2004. Einfluss wirtschaftlicher Gewichte und genetischer Parameter auf den Zuchtfortschritt der Zuchtprogramme Fleckvieh Austria und Braunvieh Austria. Universität für Bodenkultur. Wien, Österreich. Diplomarbeit.

Gregory K. E. and L. V. Cundiff. 1980. Crossbreeding in Beef Cattle: Evaluation of Systems. J Anim Sci. 51:1224-1242.

Hansen, L.B. 2006. Monitoring the worldwide genetic supply for dairy cattle with emphasis on managing crossbreeding and inbreeding. 8th World Congress on Genetic Applied to Livestock Production, August 13-18, 2006 Belo Horizonte, MG, Brasil

Heins, B. J., L. B. Hansen, and A. J. Seykora. 2006. Production of pure Holsteins versus crossbreds of Holstein with Normande, Montbeliarde, and Scandinavian Red. J. Dairy Sci. 89:2799–2804

Heins, B. J. and L. B. Hansen. 2010. Survival, fertility, and production of Normande×Holstein, Montbeliarde×Holstein, and Scandinavian Red×Holstein crossbred cows compared to pure Holstein cows. 9th World Congress on Genetics Applied to Livestock Production. August 1-6, 2010 Leipzig, Germany,

Hersleth, E. 2006. NRF Norwegian Red Breed - a source for crossbreeding. http://www.milkproduction.com/Library/Articles/NR_a_source_for_crossbreeding.htm. accessed November 30, 2010.

Hill, W. G. 1971. Theoretical aspects of crossbreeding.
Ann. Génét. Sél. anim., 3 (I) 23-34

König, S., S. Lessner, and H. Simianer. 2007. Application of controlling instruments for improvements in cow sire selection. J. Dairy Sci. 90:1967–1980

König, S., H. Simianer, and A. Willam. 2009. Economic evaluation of genomic breeding programs. J. Dairy Sci. 92:382–391

Lengerken, G. von, F. Ellendorf, and J. von Lengerken. 2006. Tierzucht. ISBN 13:978-3-8001-4780-9

LfL Bavaria. 2008. Agrarmärkte Jahresheft 2009. Teilauszug Edition 2008

LfL Bavaria. 2009. Bayerische Landesanstalt für Landwirtschaft. http://www.lfl.bayern.de/itz/rind/bazi/index.php assesed November 11, 2009

LIC, 2010. New Zealand Dairy Statistics 2008-09. http://www.lic.co.nz/pdf/dairy_stats/DAIRY_STATISTICS_08-09.pdf accessed May 5, 2010

LIC, 2011. New Zealand Dairy Statistics 2009-10. http://www.lic.co.nz/pdf/DAIRY%20STATISTICS%2009-10-WEB.pdf accessed November 2, 2011

Long, C. R. 1980. Crossbreeding for beef production: Experimental results. J Anim Sci 51:1197-1223.

McAllister, A.J., A.J. Lee, T.R. Batra, C.Y. Lin, G.L. Roy, J.A. Vesely, J.M. Wauthy, K.A. Winter. 1994. The influence of additive and nonadditive gene action on lifetime yields and profitability of dairy cattle. J. Dairy Sci. 77: 2400-2414

McAllister A. J. 2002. Is crossbreeding the answer to questions of dairy breed utilization? J. Dairy Sci. 85: 2352–2357

McDowell, R. E. and B. T. McDaniel. 1968. Interbreed matings in dairy cattle. I. Yield traits, feed efficiency, type and rate of milking. J. Dairy Sci. 51: 767-777

Miller, K. P. and D. L. Dailey. 1951. A Study of Crossbreeding Sheep. J Anim Sci 10:462-468.

Moore, K. and W. W. Thatcher. 2006. Major advances associated with reproduction in dairy cattle. J. Dairy Sci. 89:1254–1266

Mügge, B., W.-E. Lutz, H. Südbeck, and S. Zelfel. 1999. Deutsche Holstein Die Geschichte einer Zucht. ISBN 3-8001-4538-3

Normande Genetics, 2010. http://www.normandegenetics.com/about-breed.html accessed December 1, 2010

Pryce, J. E., R. F.,Veerkamp, R., Thompson, W. G., Hill. and G, Simm. 1997. Genetic aspects of common health disorders and measures of fertility in Holstein Friesian dairy cattle. Anim. Sci. 65:353-360.

Rensing, S., Z. Liu and F. Reinhardt. 2008. Experiences in combining MACE fertility proofs to the new German daughter fertility index RZR. Proceedings of the 2008 Interbull meeting, Niagara Falls, USA, June 16-19, 2008 Bulletin NO. 38, ISSN 1011-6079

Rishell, W. A. 1997. Symposium: Genetic Selection—Strategies for the future breeding and genetics—historical perspective. Poultry Science 76:1057–1061

Schaeffer, L.R. 2006. Strategy for applying genome-wide selection in dairy cattle. J. Anim. Breed. Genet. 123 218–223

Schönmuth, G. 1963. Zur Züchtung eines milchbetonten Zweinutzungsrindes mit hohem Milchfett- und Eiweißgehalt und bestem Euter. Arch. Anim. Breed. 2:79–92.

Schüler, L., Swalve, H.H., Götz, K-U. 2001. Grundlagen der Quantitativen Genetik, Stuttgart(Hohenheim): Ulmer ISBN 3-8001-2755-5

Shook, G. E. 2006. Major advances in determining appropriate selection goals. J. Dairy Sci. 89:1349–1361

Sidwell, G. M., L. R. Wilson and M. E. Hourihan. 1971. Effect of crossbreeding on wool production production in some pure breeds of sheep and their crosses. IV. J Anim Sci. 32:1099-1102.

Simianer, H., H. Solbu, and L. R. Schaeffer. 1991. Estimated genetic correlations between disease and yield traits in dairy cattle. J. Dairy Sci. 74:4358–4365.

Spelman, R.J., J. Arias, M.D. Keehan, V. Obolonkin, A.M. Winkelman, D.L. Johnson and B.L. Harris. Application of genomic selection in the New Zealand dairy cattle industry. 10th World Congress on Genetic Applied to Livestock Production, August 1-6, 2010 Leipzig, Germany. http://www.kongressband.de/wcgalp2010/assets/pdf/0311.pdf. accessed February 07, 2011

Spermex. 2010. http://www.spermex.de/index.php?id=51&L=1 accessed November 30, 2010

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

Swalve, H. H., C. Topf and H.-J. Langholtz. 1992. Estimation of genetic parameters for differently recorded fertility data in dairy cattle. Journal of Animal Breeding and Genetics 109:241-251

Swalve, H. H. 2007. Crossbreeding in dairy cattle: International trends an results from crossbreeding data in Germany. Lohmann Information 42: 38-46

Swalve, H. H. 2008. Der neue Gesamtzuchtwert: Konzentration auf das Wesentliche. Milchrind 2/2008

Swalve, H.H. 2011. Aktueller Stand der züchterischen Verbesserung von Gesundheit und Funktionalität beim Nutztier. Annual meeting of the German Society for Animal Production (DGFZ) September, 6 2011, Freising-Weihenstephan, Germany

Thomas, D. L. 2006. Useable crossbreeding systems for small and large sheep flocks. http://www.ansci.wisc.edu/extension-new%20copy/sheep/wisline_09/Useable%20 Crossbreeding %20Systems.pdf. accessed January 21, 2011

Touchberry, R.W. 1992. Crossbreeding effects in dairy cattle: The Illinois experiment, 1949 to 1969 J. Dairy Sci. 75: 640-667)

USDA, 2010. United states department of agriculture (USDA), Agricultural Research Service. Net merit as a measure of lifetime profit: 2010 revision. http://www.aipl.arsusda.gov/reference/nmcalc.htm accessed December 23, 2010

VanRaden, P. M. and A. H. Sanders. 2003. Economic merit of crossbred and purebred US Dairy cattle. J. Dairy Sci. 86:1036–1044

VanRaden, P.M. 2004. Invited Review: Selection on net merit to improve lifetime profit. J. Dairy Sci. 87:3125–3131

VanRaden, P. M, M. E. Tooker, J. B. Cole, G. R. Wiggans, and J. H. Megonigal Jr. 2007. Genetic evaluations for mixed-breed populations. J. Dairy Sci. 90:2434–2441

Viking Genetics, 2010. http://www.vikinggenetics.com/en/ accessed November 30, 2010

VIT, 2009. http://service.vit.de/bullkat/bkat1/sel?r=1&s=2&o=1&t=1 accessed November 11, 2009

VIT, 2010. http://www.vit.de/fileadmin/user_upload/vit-fuers-rind/zuchtwertschaetzung/milchrinder-zws-online/Zws_Bes1001_eng.pdf accessed February 15, 2010

Weigel, K. A. and K. A. Barlass. 2003. Results of a producer survey regarding crossbreeding on US dairy farms. J. Dairy Sci. 86:4148–4154

Willham, R.L. and E. Pollak. 1985. Symposium: Heterosis and crossbreeding. J. Dairy Sci 68:2411–2417

CHAPTER II

Brown Swiss × Holstein crossbreds compared to pure Holsteins for calving traits, body weight, backfat thickness, fertility, and body measurements.

Chapter II is published in Journal of Dairy Science 94:1058-1068

CHAPTER III

Short communication: A comparison between purebred Holstein and Brown Swiss × Holstein cows for milk production, somatic cell score, milking speed, and udder measurements in the first three lactations.

Chapter III is published in Journal of Dairy Science 94:5212-5216.

CHAPTER IV

Brown Swiss × Holstein crossbreds compared to pure Holsteins for production in first two lactations.

Chapter IV is published in Interbull Bulletin 40:2010,

Proceedings of the Interbull Meeting in Barcelona, Spain, August 21-24.

CHAPTER V

GENERAL DISCUSSION

Use of sexed determined semen

A desired goal for livestock producers is the early selection for offspring sex. Sorting sperms into X- and Y sperms made the objective of a pre-selection of the offspring feasible (Chebel et al.; 2010). Furthermore, the same authors mentioned that for dairy producers the control of offspring sex could allow to selectively breed their animals. Schenk et al. (1999) reported that sex pre-selection will hasten genetic progress, increase production efficiency and provide greater flexibility in livestock management. For sperm sexing, Johnson et al. (1999) named that the Beltsville technology is currently the only effective means of altering the sex ratio of offspring in livestock. The method is based on the flow-cytometric separation of X- and Y chromosome-bearing sperm based on X/Y DNA content difference. Figure 2 shows stained and sorted sperm on a fluorescence-activated cell sorter. The technique of the sperm sexing technology is extensively reviewed by Garner et al. (1983), Johnson et al. (1999) and Moore and Thatcher (2006).

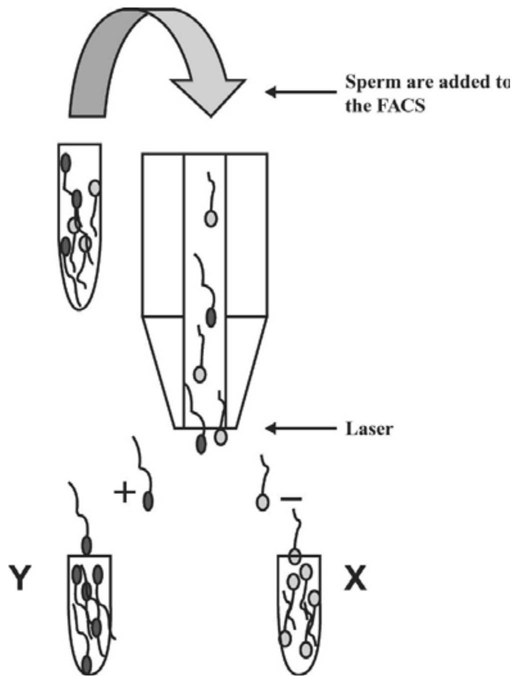


Figure 2. Schematic for sexing semen. Sperm are labeled with Hoechst 33342, a nucleic acid stain, and sorted on a fluorescence activated cell sorter (FACS). X-bearing sperm contain more DNA and thus fluoresce more, allowing them to be separated from Y bearing sperm (Moore and Thatcher, 2006)

Hohenboken (1999) reported four effects sexed semen has on the dairy industry: (1) generate replacement heifers, (2) create dairy cows for milk production, (3) selling dairy heifers as breeding stock and (4) produce bull calves with good carcass and fattening abilities for slaughtering. Wolfova et al. (2007) mentioned that using sexed semen to generate dairy female replacements would substantially increase the portion of dairy cows available to produce crossbred progeny. Furthermore, sexed semen would allow producing bulls for progeny testing from a smaller number of elite dams to ensure that all of them produce sons.

The question of interest here is how the effects of using sexed semen on crossbreeding are. A quite possible option is a three step breeding scenario where the first step is the breeder, the second step the multiplier and finally the producer. A separation as described, is already known from the poultry and swine industry. For monogastric animals the advantages are the high reproduction rate and lesser values per animal. Those facts make the separation between breeding and production among others feasible.

Wolfova et al. (2007) reported an implementation of crossbreeding and their effects with beef bulls on commercial dairy farms. However, based on the results presented by these authors a theoretical implementation can be made up for the use of sexed semen and crossbreeding in dairy cattle. The utilization of sexed semen increases the number of females born for milk production and the number of male calves born for fattening. It is conceivably that dairy producers use sexed semen to produce F_1 dairy × dairy crossbreds. For U.S. Holstein dairy cattle, Norman et al. (2010) reported the use of sexed semen increased from 1.4 % in 2006 to 17.8 % in 2009. Those F_1 dairy × dairy terminal crosses can be used to increase the number of cows in the herd with specific improvements e.g. improved milk contents, reduced dystocia or better fertility. Furthermore, it is quite possible that dairy produces use a rotational crossbreeding system to generate there own F_2 and F_3 generation to utilize heterosis from crossing different dairy breeds. The benefit of sexed semen would result in a reduction of undesirable crosses e.g. male dairy × dairy crosses. Moreover, sexed semen can increase the number of required female and male F_1, F_2 and F_3 crosses for milk and beef production, respectively. A dairy producer would obtain a benefit when using crossbreeding and sexed semen under the assumption that he does not focus on purebred breeding, selling purebred animals and the availability of sexed semen from dairy and beef breeds.

The major issues with this theoretical approach are to convince dairy producers and the AI industry. A rethinking of the dairy producers and the AI industry would help to establish a practical, comprehensive and working crossbreeding scheme with sexed semen. Furthermore, the scenarios shown here is an approach, how sexed semen could influence respectively increases the diversity in the dairy cattle industry. It is quite reasonable that dairy producers use sexed semen together with crossbreeding in the future. Even with an increased portion of costs per unit semen, resulting from higher costs for sexing bovine semen; this technique will have a benefit to dairy producers. Moreover, further options will open up for dairy producers and the AI industry when a solid market for crossbreed animals generates. Finally, the scenario of using sexed semen together with crossbreeding requires a well organised and diverse number of purebred dairy and beef breeds.

Feed efficiency

Brown Swiss × Holstein cows in this study had more body weight and backfat thickness than pure Holstein cows during first three lactations (CHAPTER II). In a previous study by Blöttner et al. (2007) feed intake during day 7 to 56 postpartum in first lactation was evaluated. The study found that Brown Swiss × Holstein cows were significantly higher for feed intake and dry matter intake than pure Holstein cows. An expected result of increased feed intake is an increase in body weight and backfat thickness. Recently Heins et al. (2008 a) reported that Jersey × Holstein crossbred cows had significantly less milk production and protein production, significantly fewer days open and a significantly greater proportion of Jersey × Holstein were pregnant at 150 and 180 d postpartum than pure Holstein cows. Furthermore, Heins et al. (2008 b) reported for a subset of cows from the study by Heins et al. (2008 a) that feed intake and feed efficiency were not significantly different from 4 to 150 d of first lactation. In conclusion, from these studies, feed efficiency was equal between the experimental groups but significantly less milk production and better fertility was reported for Jersey × Holstein cows than pure Holstein cows.

Vallimont et al. (2010) reported that feed intake is an important management tool because of its relationship with other economic important traits including production, reproduction and health. González et al. (2008) found in there study for Holstein cows that a variation for feed intake made an earlier detection of ketosis and lameness possible. Furthermore, Coleman et al. (2010) uses residual solids production as a measurement of feed efficiency that identifies animals that produce greater volumes of milk solids at similar levels of feed intake without excessive body tissue mobilization and with improved fertility performance.

Implementation of crossbreeding

The decision to set up a crossbreeding design is a decision with benefit but also with disadvantages, however, crossbreeding in dairy cattle has become a philosophical question than a logical decision. The major reason why dairy producers start crossbreeding is the unfavourable health and fertility status of cows as a consequences from selecting dairy cattle only on production. The major issue, and this is the only problem crossbreeding brings along, is the sacrifice of selling purebred dairy heifers and cows. Selling breeding stock can be an extra source of income on some dairy farms. However, the short production period of approximately three lactations and the high health cost reduce the potential number of heifers and cows sold. Consequently, dairy producers are not able to sell those cows. The key question a dairy producer has to ask is: what is the major source of income on my farm? Is the major earning, selling purebred heifers and cows for breeding then the shift to crossbreeding is unfavorable. However, if selling milk is the major source of income then farmers can seriously think about crossbreeding. The advantages of crossbred cows are reported in the literature and include reduced dystocia and stillbirth and an improved fertility.

Cassell and McAllister (2010) reported issues that should be considered in crossbreeding. The authors describe crossbreeding programs are long-term decisions, and producers should plan crossbreeding strategies carefully and have reasonable expectations of the process. Furthermore, four factors were named that should be considered when designing a crossbreeding program: (1) **Breed additive merit:** Breeds used in crossing programs need to function well as dairy cows and the producer should like the particular breed as purebred as well as crossbred combinations. (2) **Breed complementation:** Strengths of one breed can be used to offset or complement weaknesses of another. (3) **Within breed selection:** The ability to pick and choose parents is just as important for crossbreeding programs as it is in purebred herds. Large population sizes (to provide choices between bulls and bull dams) and readily available genetic evaluations are essential to rapid genetic progress. A producer who wants to use some unique strain in a crossbreeding program won't have many choices available when picking AI bulls. There may be no genetic evaluations to guide the selection process at all. These are serious limitations to the utility of such breeds for commercial milk production and (4) **Heterosis**. In addition to (3) McAllister (2002) reported for crossbreeding selection of sires is based on their genetic evaluations, in purebred for individual traits or indexes, and Sørensen et al. (2008) mentioned that for crossbreeding to be profitable, systematic breeding strategies have to be followed consistently, and breeds should be used that, to a certain degree, are equal with respect to total merit.

In previous decades conventional breeding program were used to select young sire. A new method to enhance the efficiency of a breeding program is genomic selection (GS). GS shortens the waiting period of a young sire and provides the required information earlier than a conventional breeding program. However, the first official proofes for Germany based on GS was published in August 2010 (VIT, 2010). The effect GS will have in the future on purebred dairy cattle will also have a direct impact for crossbreeding. The selection of young sires based on their genomic total merit index will bring an additional benefit for crossbreeding. For the same reason GS improves a pure dairy bred e.g. for low heritable traits (König and Swalve, 2009).

Improvement of a crossbreeding study

The current study was conducted to compare two experimental groups especially for production, functional traits and measurements of the cow's body. In conclusions of the experimental design, to favour is an increased number of cows per experimental group as reported in this study. For conformation traits it is not essentially necessary to have repeated measurements of cows within lactation. Furthermore, measuring the cow once or twice per lactation; and continuously across lactations would be entirely sufficient. As a result, this improvement would allow measuring more cows per experimental group.

Outlook

In conclusion, the current study found that BS × HO cows were competitive with pure HO cows for traits analyzed in CHAPTER II and an advantage over pure HO cows was reported for fertility. Furthermore, CHAPTER III reported that BS × HO cows were an alternative with respect to production traits and SCS compared to pure HO cows.

In addition to this, CHAPTER IV analyzed daily production for BS × HO cows and pure HO cows and found no differences for daily milk (kg), fat (kg) and protein (kg) production during the first two lactations. Therefore, BS × HO cows were significant different for fat (%) and protein (%) during the first two lactations than pure HO cows.

The findings on functional traits in CHAPTER II verify the advantages of F1-crosses in dairy cattle. The assumption made here and aim of the current study was conducted to evaluate the competitiveness of F1-crossbred cows compared with pure Holstein cows. The basic idea was the use of F1 crossbred cows in conventional dairy herds for milk production. Therefore it is thinkable that breeders with registered HO cows produce their own replacement heifers and additionally crossbreed heifers for milk production. However, mating pure HO cows with non-HO AI sire to generate F1 dairy crossbreed cows for milking production is difficult based on the biological facts as reported by Swalve (2007). Especially the low reproduction rate in dairy cattle makes a nucleus breeding program difficult and excessively expensive. Therefore, in poultry and swine the high reproduction rate with 82 – 105 saleable chicks per hen per year and 25 – 28 piglets per sow per year are outstanding. These facts make a nucleus production feasible compared to dairy production. The results reported in CHAPTER III on milkability and udder dimension are unfavorable for dairy producers change from automated milking to robotic milking.

Therefore, future research should address to the question of estimating heterosis and the expected level of heterosis from crossing Brown Swiss and Holstein dairy cattle.

A question of interest for future analysis is the economical benefit a dairy producer achieves by using sexed semen either with crossbreeding or without crossbreeding.

The effect crossbreeding has on longevity of cows and the economical analysis of crossbreeding in dairy cattle should be investigated in the future. In the literature many studies report advantages and disadvantages of crossbred cows and purebred cows for the complex of functional traits and production. Furthermore, number of calves born, breeding stock sold and proportion of days sick versus days a cow stayed in the herd are questions of economical importance.

Very few studies evaluated feed efficiency and feed intake. Therefore, future research should consider the question of feed intake and feed efficiency especially for crossbred cows. However, the results reported by Heins et al. (2008 b) and Blöttner et al. (2007) indicated that differences for feed intake between different crossbred groups exist. Furthermore, the investigation of feed intake should focus on two practical terms (1) can crossbred cows economically challenge in terms of production, fertility and health of cows, when feed intake is different from pure Holstein cows; and (2) is an increased feed intake unfavorable under the viewpoint of income over feed coast and dwindling natural resources?

References

Blöttner, S., B. Fischer, T. Engelhard and H.H. Swalve. 2007. The competitiveness of F1 Brown-Swiss x Holstein crosses in the intensive environment of a high-yielding dairy herd. Book of Abstracts of the 58th Annual Meeting of the European Association for Animal Production, August 26-29, Dublin, Ireland (see appendix page 113)

Chebel, R. C., F. S. Guagnini, J. E. P. Santos, J. P. Fetrow, and J. R. Lima. 2010. Sex-sorted semen for dairy heifers: Effects on reproductive and lactational performances. J. Dairy Sci. 93 :2496–2507

Coleman, J., D. P. Berry, K. M. Pierce, A. Brennan, and B. Horan. 2010. Dry matter intake and feed efficiency profiles of 3 genotypes of Holstein-Friesian within pasture-based systems of milk production. J. Dairy Sci. 93:43184331

Garner, D. L., L. A. Johnson, S. Lake, N. Chaney, D. Stephenson, D. Pinkel, and B. L. Gledhill. 1983. Quantification of the X- and Y chromosome-bearing spermatozoa of domestic animals by flow cytometry. Biol. Reprod. 28:312–321.

González, L. A., B. J. Tolkamp, M. P. Coffey, A. Ferret, and I. Kyriazakis. 2008. Changes in feeding behavior as possible indicators for the automatic monitoring of health disorders in dairy cows. J. Dairy Sci. 91:1017–1028

Heins, B. J., L. B. Hansen, A. J. Seykora, D. G. Johnson, J. G. Linn, J. E. Romano, and A. R. Hazel. 2008 a. Crossbreds of Jersey × Holstein compared with Pure Holsteins for production, fertility, and body and udder measurements during first lactation. J. Dairy Sci. 91:1270–1278

Heins, B. J., L. B. Hansen, A. J. Seykora, A. R. Hazel, D. G. Johnson, and J. G. Linn. 2008 b. Crossbreds of Jersey × Holstein compared with pure Holsteins for body weight, body condition score, dry matter intake, and feed efficiency during the first one hundred fifty days of first lactation. J. Dairy Sci. 91:3716–3722

Hohenboken, W.D. 1999. Applications of sexed semen in cattle production. Theriogendogy 52:1421-1433

König, S. and H. H. Swalve. 2009. Application of selection index calculations to determine selection strategies in genomic breeding programs. J. Dairy Sci. 92 :5292–5303

Johnson, L. A., G. R. Welch and W. Rens. 1999. The Beltsville sperm sexing technology: high-speed sperm sorting gives improved sperm output for in vitro fertilization and AI. J Anim Sci. 77:213-220.

Moore, K. and W. W. Thatcher. 2006. Major advances associated with reproduction in dairy cattle. J. Dairy Sci. 89:1254–1266

Norman, H. D., J. L. Hutchison, and R. H. Miller. 2010. Use of sexed semen and its effect on conception rate, calf sex, dystocia, and stillbirth of Holsteins in the United States. J. Dairy Sci. 93:3880–3890

Schenk, J.L., T.K. Suh, D.G. Cran, and G.E. Seidel, Jr.. (1999). Cryopreservation of flow-sorted bovine spermatozoa. Theriogenology 52:1375-1391

Swalve, H. H. 2007. Crossbreeding in dairy cattle: International trends an results from crossbreeding data in Germany. Lohmann Information 42: 38-46

Vallimont , J. E., C. D. Dechow, J. M. Daubert, M. W. Dekleva, J. W. Blum, C. M. Barlieb, W. Liu, G. A. Varga, A. J. Heinrichs, and C. R. Baumrucker. 2010. Genetic parameters of feed intake, production, body weight, body condition score, and selected type traits of Holstein cows in commercial tie-stall barns. J. Dairy Sci. 93 :4892–4901

Wolfova M., J. Wolf, J. Kvapilík, and J. Kica. 2007. Selection for profit in cattle: II. economic weights for dairy and beef sires in crossbreeding systems. J. Dairy Sci. 90:2456–2467

ZUSAMMENFASSUNG

Das Ziel der Studie ist im Titel beschrieben: *Braunvieh × Holstein Kreuzungskühe im Vergleich mit Reinzucht Holsteinkühen für Merkmale der Kalbung, Merkmale der Milchleistung und des Exterieurs in der ersten, zweiten und dritten Laktation.*

Die Arbeit ist in vier Kapitel unterteilt.

KAPITEL I gibt eine allgemeine Einführung in das Thema der Kreuzung und den Hintergrund warum Kreuzungszucht beim Nutztier angewendet wird. Die Arbeit berichtet über die Entwicklung der Rasse Holstein und die Gründe für Kreuzungszucht mit Holstein. Es wird die Anpassung des Zuchtzieles der Rasse Holstein global sowie für Deutschland beschrieben. Eine kurze Übersicht über die Wirkung der Heterosis wird gegeben und die Milchrindrassen, die für die Kreuzungszucht verwendet werden können. Abschließend wird in KAPITEL I über die Kreuzungszucht beim Fleischrind, die Kreuzungszucht bei Schafen, Pferd, Schein und Geflügel sowie über synthetische Rassen berichtet.

KAPITEL II ist im Journal of Dairy Science 94:1058-1068 veröffentlicht und gibt eine umfangreiche Einführung in das Thema der Kreuzungszucht. Darüber hinaus sind die Ziele für dieses Forschungsprojekt und die Versuchsplanung für die vorliegende Arbeit vorgestellt. Das Hauptanliegen und Ziel war es, beide Versuchsgruppen für die Merkmale Trächtigkeitsdauer, Geburtsgewicht der Kälber, Kalbenverlauf, Totgeburten, Fruchtbarkeit, Körpergewicht, Rückenfettdicke und Klauenprobleme in den ersten drei Laktationen zu vergleichen. Des Weiteren wurden die Versuchsgruppen für Körpermaße und Klauenmaße in der ersten Laktation verglichen. Die Ergebnisse haben gezeigt, dass hier Braunvieh x Holstein Kühe Vorteile gegenüber Reinzucht Holsteinkühen für die meisten der funktionellen Merkmale hatten. Dies wird vor allem für Merkmale deutlich, die sich züchterisch schwierig bearbeiten lassen, da sie eine niedirge Heritabilität aufweisen.

KAPITEL III ist im Journal of Dairy Science 94: 5212-5216 veröffentlicht und diskutiert die Kreuzungszucht hinsichtlich der Milchleistung beider Versuchsgruppen. Das Ziel dieser Arbeit war es, die Versuchsgruppen für Milch-, Fett- und Eiweißleistung, SCS und Melkbarkeit in der ersten, zweiten und dritten Laktation sowie Eutermaße in der ersten und zweiten Laktation zu vergleich. Im Vergleich mit der Literatur haben die Ergebnisse gezeigt, dass keine signifikanten Unterschiede für die Leistungsmerkmale in allen drei Laktationen gefunden wurden. Darüber hinaus wurde festgestellt, dass sich die Melkbarkeit der Braunvieh × Holstein Kreuzungskühe nachteilig im Vergleich zu Reinzucht Holstein Kühen darstellte.

KAPITEL IV ist im Interbull Bulletin 40 im Jahr 2010 erschienen und wertet Milchleistungsdaten der ersten und der zweiten Laktation aus. Die Analyse der beiden Laktationen wurde getrennt durchgeführt, um Unterschiede zwischen den Versuchsgruppen innerhalb der Laktation zu beschreiben. Das verwendete Modell war analog zu dem Modell, welches für die Zuchtwertschätzung in Deutschland genutzt wird. Das Ziel der Untersuchung war es, die Versuchsgruppen hinsichtlich der Unterschiede innerhalb definierter Intervalle innerhalb Laktation zu vergleichen. Die Ergebnisse haben gezeigt, dass keine signifikanten Unterschiede zwischen den Versuchgruppen für die Leistungsmerkmale der ersten und zweiten Laktation gefunden wurden. Darüber hinaus konnte festgestellt werden, das Braunvieh x Holstein Kühe eine höhere Kapazität für Milchleistung am Ende jeder Laktation hatten.

In **Kapitel V** werden die Verwendung und möglichen Auswirkungen von geschlechtsdeterminiertem Sperma in Kombination mit Kreuzungszucht diskutiert. Des Weiteren wird die Thematik der Futterverwertbarkeit und Futterausnahme diskutiert. Es wird die Durchführung einer praxisorientierten Kreuzungszucht gegeben. Abschließend werden Vorschläge zur Verbesserung einer Kreuzungszucht Studie und Ausblicke gegeben.

APPENDIX

The competitiveness of F1 Brown-Swiss x Holstein crosses in the intensive environment of a high-yielding dairy herd

S. Blöttner[1], F. Rosner[1], M. Wensch-Dorendorf[1], B. Fischer[2] and H. H. Swalve[1]

[1]Institute of Agricultural and Nutritional Sciences (IANS), Animal Breeding, Martin-Luther-University Halle-Wittenberg, Germany
[2]Experimental station LLFG-ZTT Iden, Germany

Aim of the project

A F1 - cross BS x HOL

Assessment of the "procedure"

„Two breed terminal cross"
Brown Swiss (BS) x Holstein (HOL)

This is not a „crossbreeding experiment" in the strict sense from which crossbreeding parameters can be estimated

Background:

- Hypothesis: Better functional traits in crosses?
- A terminal cross would work if semen sexing would (really) be possible

A pure Holstein cow from the control group

Time frame of the experiment

Plans: Summer 2002; inseminations started in autumn of 2002

- Period to cover: 2003 to 2008/2009
  - » Calvings July 03 till April 04
  - » Calf rearing July 03 till Aug. 04
  - » Heifer rearing Nov. 03 till June 06
  - » Inseminations Aug. 04 till Oct. 06
  - » 1st Lactation July 05 till July07
  - » 2nd Lactation from July 06
  - » 3th Lactation from July 07

General overview of the crossbreeding experiment

	BS x HOL	HOL x HOL	Total
Pregnancies	124	131	255
Calves born total	134	134	268
Living calves at day 7	119	115	234
Neonatal losses till day 7	15	19	34
Neonatal losses (%)	11.2	14.2	12.7
Living females at day 7	66	56	122
Losses day 7 till day 180	8	2	10
Females in rearing	58	54	112
Losses day 180 till 1st insemination	1	0	1
Females inseminated	57	54	111
Losses till calving / not pregnant	2	3	5
Heifers calved	55	51	106
Culled after calving	5	6	11
Milking 1st parity	50	45	95
Milking 2nd parity	45	42	87
Milking 3th parity (07/07)	-	1	1

Test day model first parity for: milk yield, fat(%), protein(%), fat (kg), protein (kg), scs and milk urea

$$y_{imno} = as_1 + as_2\left(\frac{t}{c}\right) + as_3\left(\frac{t}{c}\right)^2 + as_4 ln\left(\frac{c}{t}\right) + as_5\, ln^2\left(\frac{c}{t}\right) + psfg_m + komb_n + cow(komb)_{o(n)} + e_{imno}$$

y_{imno} = traits for the test day model
t = days in milk
c = length of lactation (c = 330)
as_1; as_2; as_3; as_4; as_5 = mathematical function (Ali and Schaeffer, 1987) to account for the lactation curve
$psfg_m$ = season of production-feed group
$komb_n$ = genotype-age of calving
$cow(komb)_{o(n)}$ = cow nested in komb
e_{imno} = residual effect

Comparison of milk production traits for first lactations on a per day basis (test day model analysis)

* α < 0,05 (n = 95 heifers that calved; weekly recordings (except SCS n = 781), n = 4063 test day records n= Number of Observations)

trait	BS x HOL	s.e.	HOL x HOL	s.e.
Milk yield	29,06	1,19	29,25	1,22
Fat (%)	4,31	0,12	4,20	0,12
Protein (%)	3,72*	0,06	3,63*	0,06
Fat (kg)	1,23	0,04	1,20	0,04
Protein (kg)	1,07	0,03	1,04	0,03
SCS	1,91	0,26	2,28	0,27
Milk urea (mmol/l)	5,49*	0,04	5,28*	0,04

LS Means for milking speed

* α < 0,05 (1=morning 2=noon, 3=night n =25707)

Trait	BS x HOL	s.e.	HOL x HOL	s.e.
Milk yield_1 (kg/milking)	9,27	0,22	9,47	0,26
Milk yield_2 (kg/milking)	9,18	0,21	9,36	0,22
Milk yield_3 (kg/milking)	9,29	0,22	9,41	0,23
Milkingspeed_1 (in s)	312,51*	10,26	269,82*	10,77
Milkingspeed_2 (in s)	307,26*	10,27	264,57*	10,78
Milkingspeed_3 (in s)	312,40*	7,65	283,30*	7,91
Average milk flow rate_1 (kg/min)	1,88*	0,06	2,14*	0,07
Average milk flow rate _2 (kg/min)	1,91*	0,07	2,17*	0,07
Average milk flow rate_3 (kg/min)	1,92	0,06	2,07	0,06
Total milk flow (kg/min)	1,90*	0,05	2,12*	0,06
Total milk yield (kg/milking)	27,72	0,63	28,23	0,66

Model includes: Days in milk, genotype, feeding group

LS Means for metabolic parameters before calving

*α = <0,05 (Blood: BS X HOL n = 104, HOL n = 95; Urine: BS X HOL n = 69, HOL n = 63;)

trait	BS x HOL	s.e.	HOL x HOL	s.e.
Glutamat-dehydrogenase	14,17*	2,29	18,42*	2,30
Blood urea	3,62*	0,16	3,15*	0,16
Magnesium	0,95	0,009	0,93	0,009
Alkalosis	239,04*	8,06	213,86*	8,47
Net excretion of acids and bases	156,02*	7,37	131,32*	7,75
Base-acid-quotient	3,39*	0,16	2,90*	0,17

LS Means for metabolic parameters after calving

*α = <0,05 (Blood/Urine: BS x HOL n = 136, HOL x HOL n = 128)

Trait	BS x HOL	s.e.	HOL x HOL	s.e.
Glutamat-dehydrogenase	15,19	1,19	14,20	1,22
Blood urea	4,20*	0,11	3,66*	0,11
Magnesium	0,99*	0,01	0,96*	0,01
Alkalosis	192,72*	5,00	172,62*	5,27
Net excretion of acids and bases	104,55*	4,87	81,55*	6,31
Base-acid-quotient	2,41*	0,07	2,22*	0,07

Model includes: genotype, age at calving, year-season, day sampled (relative to calving)

LSMeans for daily feed-, energy-, protein- and crude fiber intake

* α < 0,05 (Individual feed intake measured during day 7 post partum to 56 post partum BS x HOL n = 110 HOL x HOL n = 87)

Trait	BS x HOL	s.e.	HOL x HOL	s.e.
Freshmatter (kg)	39,40*	0,65	37,29*	0,72
Draymatter(kg)	17,00*	0,28	16,14*	0,31
ME (MJ)	188,33	3,09	179,32	3,40
NEL (MJ)	121,60*	2,00	115,18*	2,20
XP (g)	3029,93	49,53	2890,11	54,55
nXP (g)	2890,68*	47,46	2730,60*	52,29
RNB (g N)	23,98	1,57	26,35	1,73
xFA (g)	2686,36*	44,82	2550,22*	49,29

Model includes: genotype, days in milk

Conclusions

- Brown Swiss crosses do well under the conditions of a high production level farm: Milk production equals pure Holsteins
- With respect to losses, both groups are equal
- Brown Swiss crosses have lower milking speed compared to pure Holsteins
- Brown Swiss crosses consume more feed
  ➡ Lower efficiency?

Blöttner et al. (2007). Poster at 58th Annual Meeting of the European Association for Animal Production, August 26-29, Dublin, Ireland

ACKNOWLEDGEMENTS

I would like to acknowledge the following people for their support and their help, who made it possible to write this doctoral thesis.

Prof. Dr. Hermann H. Swalve for giving me the opportunity to work and study with him at animal breeding group Halle, for the chance he gave me to stay for a sabbatical at the University of Minnesota and to write the doctoral thesis with him. Thank you.

Prof. Dr. Leslie B. Hansen for accepting me as a visiting scholar at his group at University of Minnesota and for his support. I still remember the very helpful discussions, the wonderful grad student suppers and the many laughs we had together during my time at the UMN. Thank you.

Prof. Dr. Bradley J. Heins for his never ending support and his advice who made it possible to end here. I always found help and support in either situation of life. Thank you.

Dr. Monika Wensch-Dorendorf for advising and supporting me during the last years. The very helpful and straightforward leading discussions during several coffee breaks and the emotional and moral support you gave me all the time. Thank you.

I wish to express my warm and sincere thanks to the whole team of LLFG Iden, for helping me with data recording, providing data for this thesis and taking care of the animals. Thank you.

I also wish to thank my colleagues at animal breeding group Halle and St. Paul for their collegiality and help.

Finally, I thank my beloved girlfriend Lydia for her never ending support during my doctoral study. Additional thank goes to my family, my grad student friends Bianca, Kerstin, Amy, Philipp, Marten, Benno and Gunter; my buddies from RadUnion Halle, my close friend in Thuringia and all my friends in the whole world for their never ending moral support and that they were always there for me. Thank you folks, I do appreciate this.

Selbstständigkeitserklärung

Eidesstattliche Erklärung

Ich erkläre hiermit an Eides Statt, dass ich die vorliegende Dissertation selbstständig und unter Verwendung der angegebenen Literatur und Hilfsmittel angefertigt habe. Hiermit erkläre ich, dass mit dieser wissenschaftlichen Arbeit noch keine vergeblichen Promotionsversuche unternommen wurden. Des Weiteren erkläre ich, dass keine Strafverfahren gegen mich anhängig sind.

Halle/Saale, 25.11.2011 Unterschrift:

Scientific career

Education:

10/2001 – 04/2006 Studying agricultural science at Martin-Luther-University-Halle-Wittenberg. Focus: Animal science.

Topic of the diploma thesis: "*Untersuchungen zur Messung der Eischalenstabilität als Merkmal in der Zucht von Legehennen*".

09/1997 – 07/2000: High-school diploma at Staatliche Berufsbildende Schule Rudolstadt/Thuringia

Academic training

05/2006 – 02/2011: Research associate at the Institute for Animal Breeding and Husbandry with Veterinary Clinic (new name since 09/2006: Institute of Agricultural and Nutritional Sciences) Focus: "Crossbreeding in dairy cattle"

07/2008 – 12/2008: Sabbatical term at University of Minnesota, Saint Paul Minnesota (USA). Study group dairy genetics with Prof. Dr. Leslie B. Hansen

10/2006 – 12/2006: Research assistant in the working group Biometrics and agricultural computer science at the Martin-Luther-University Halle-Wittenberg

03/2006: Research Assistant at the Institute for Animal Breeding and Husbandry with Veterinary Clinic, Martin-Luther-University Halle-Wittenberg

10/2005 – 12/2005: Research assistant in the working group Biometrics and agricultural computer science at the Martin-Luther-University Halle-Wittenberg

10/2004 – 12/2004: Research assistant in the working group Biometrics and agricultural computer science at the Martin-Luther-University Halle-Wittenberg

05/2003 – 08/2003: Research Assistant at the Institute for Nutritional Sciences the Martin-Luther-University Halle-Wittenberg