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**THE EFFECT OF DIFFERENT MILK PRICING SCHEMES ON A SELECTION  
INDEX FOR SOUTH AFRICAN HOLSTEIN CATTLE**

by

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**MAGISTER SCIENTIAE AGRICULTURE**

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## PREFACE

This dissertation is presented in the form of three separate articles augmented by a general introduction, the history of the Holstein and general conclusions.

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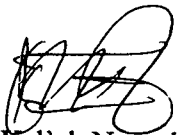
All staff members of the Department of Animal, Wildlife and Grassland Sciences;

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Above all, my Creator and Saviour, for His unfailing love, comfort, grace, counsel, provision and protection.

## DECLARATION

I declare that the treatise hereby submitted by me for **Magister Scientiate Agriculture** degree at the University of the Free State is my own independent work and has not previously been submitted by me at any other University/Faculty. I furthermore cede copyright of the treatise in favour of University of the Free State.



Kal'ab Negash Tesfa

Bloemfontein

November 2002

## CHAPTER 1

### GENERAL INTRODUCTION

The Holstein is the most popular breed used for milk production in South Africa. This breed accounts for 70 percent of the total milk volume produced in South Africa (Erasmus, 2000). The ultimate goal of genetic improvement of Holstein cattle is to maximize economic merit, which is highly dependent on yield and composition traits. When several traits contribute to the economic merit of an animal, the most suitable method of selection is a selection index, as initially proposed by Smith (1936) and Hazel (1943). A selection index estimates the value of an individual for its aggregate genotype in terms of a linear combination of additive genetic merits for component traits weighted by their respective economic weights (Goddard, 1998).

In order to construct a selection index the following is needed: reliable estimates of the heritability of each trait included, the genetic and phenotypic correlation among them, as well as their relative economic values.

Selection in dairy cattle is primarily for production traits. However, to maximize production a cow should also be fertile and healthy. Both fertility and disease resistance should therefore be included in the index. According to Philipsson *et al.* (1994), failure to include these traits in a selection index decreases efficiency by 15 to 25%. The inclusion of mastitis resistance aimed to reduce the cost of both production and the culling rate, causing production to rise so that the producer captures the total benefits of an increased yield per cow.

Another constraint that affects the economic importance of a trait is the milk pricing system. In South Africa, the milk pricing system promotes selection for increased milk yield (Du Plessis & Roux, 1999). This selection for increased milk yield leads to increased milk solids, but decreases percentage traits, which are important in the manufacturing of dairy products, such as cheese and butter. Several researchers also detected an antagonistic effect on fertility and udder health when selecting for increased milk yield (Biffani *et al.*, 2002).

Besides genetic parameters, income and costs of production could affect the relative weights of the traits. Breeding is aimed toward future improvement, thus, when future prices and costs are not considered, an uncertainty in breeding objectives might arise. In future, unexpected changes of these parameters might cause the profit function to change with time (Goddard, 1998). According to Wattiaux (1995), the local market value of milk is an important factor to consider when defining selection goals. This is due to the fact that the market price of milk fluctuates among countries and even from region to region within a country.

Economic weights are major factors that need to be considered when choosing the traits to be included in the breeding goal (Amer & Fox, 1992). Hazel (1943) defined the relative economic weight of a trait as a net increase in profit per unit genetic change. This expresses to what extent improvement in genetic merit of a trait can contribute to economic efficiency (Smith, 1983; Groen, 1988).

Gibson (1987) explained the importance of including all sources of costs in determining economic values. This is because the feed cost of milk production is substantial and different for each component (Hillers *et al.*, 1979; Dommerholt & Wilmink, 1986). Indices that ignored feed costs yielded inflated economic weights with an incorrect balance among the components (Keller & Allaire, 1990). Using different milk pricing systems Gibson (1989a,b) concluded that these caused the economic weights to differ considerably.

Changes in economic weights could affect the response obtained from a selection index. However, some reports have concluded that a selection index is not very sensitive to changes in the economic weights. In a reappraisal of this problem, Smith (1983) tested large changes in economic weights, which resulted in considerable losses in the efficiency of the selection index. The author further added that efficiency is also sensitive to change in the traits, especially when highly variable traits are omitted from the index. Gibson *et al.* (1992) reported that economic weights are insensitive to substantial changes in the parameter values, which mainly involved input costs. The latest reports indicated that monthly income was less sensitive to changes in price of concentrates or price of forages. However, it is highly sensitive to changes in milk price (Vargas *et al.*, 2001). With regard to this, Vargas *et al.* (2002) conducted a sensitivity analysis indicated that the economic values of butterfat, protein and rumen capacity increase significantly with higher prices of milk solids. He added that the economic weights of other traits like survival rate, conception rate and body weight was less sensitive to a change in the price of milk solids.

Du Plessis & Roux (1998) highlighted the need for a comparison of economic weights to be made under the different South African pricing systems. Later, Du Plessis & Roux (1999) devised two selection indices for South African Holstein cattle: one for fresh milk and yogurt, and the other for a butter and cheese pricing system. Both included the live weight of the animal. The response from these indices indicated that the use of the current selection index for fresh milk-yogurt and butter-cheese pricing systems were 25% and 26% more efficient, respectively, than selection for milk yield only.

Although there are reports that indicated the importance of the inclusion of feed costs to calculate the economic values of milk traits, feed costs are not included in this study. The monetary values paid by the different pricing schemes are assumed to be the relative economic value of the traits.

It is therefore obvious, from the literature review, that the milk pricing system is important in determining the income of dairy cattle farmers, causing fluctuation in economic weight, which is defined as the net profit per unit genetic change of a trait. In South Africa, dairy cattle farmers use different marketing channels to sell their products. The companies involved use different milk pricing systems. The question that arises is, can the different milk pricing systems used, affect the selection goals of the South African Holstein breeder?

The objectives of this study were, therefore:

1. to determine the possible fixed effects that could significantly affect milk yield and component traits and to fit them into the model for the estimation of the variance components;
2. to estimate the variance-covariance components and heritability of the five production traits i.e., milk yield (MY), butterfat yield (BFY), protein yield (PRY), butterfat percentage (BFP) and protein percentage (PRP) for use in a selection index;
3. to determine the effect of the different South African milk pricing schemes on a selection index for Holstein cattle utilizing the milk-pricing systems used by the three major milk buyers.

## CHAPTER 2

### HISTORY OF HOLSTEIN CATTLE AND THE GENETIC EVALUATION OF DAIRY CATTLE IN SOUTH AFRICA

#### 2.1 History of Holstein cattle

##### 2.1.1 Origin

In South Africa, at least six breeds of cattle are recognized as dairy breeds. These are the Holstein, Jersey, Ayrshire, Swiss (Brown- and Dairy-), and Dairy Shorthorn. Other breeds, such as the Simmentaler, Red Poll, Dexter and South Devon are only occasionally seen in the milking parlour (Gertenbach, 1991).

The history of the Holstein can be traced back over 2000 years. The name Friesian was derived from the Provinces of Friesland in the Netherlands and Holstein from Schleswig-Holstein in the Rhine delta region where the breed had its beginnings. In Europe, where it is known as the Fries, Friesian or Holstein, the breed had been developed as a dual-purpose animal (both meat and dairy). However, since the late 19th century American breeders have concentrated solely on its milk-producing ability. It was also there that the name Holstein-Friesian was first used. Most countries that have relied on importation from Canada or the United States have adopted this name (Maher, 1997).

Friesian cattle were introduced to South Africa in 1850 from the province of Friesland, Holland when General Cuyler of Uitenhage in the Eastern Cape Province imported the first so-called purebred Friesland cattle. This year is therefore regarded as marking the beginning of the purebred Friesland industry in South Africa. On the 21<sup>st</sup> of October, 1912 a meeting was held in Bloemfontein, where it was decided to institute the Friesland Cattle Breeders' Association of South Africa (F.C.B.A. of S.A.). This association has since its inception been active in improving the registration system. In the early 1960's the first Holsteins were imported from Canada, followed by thousands of doses of semen

straws from the USA and Canada. Finally, the name of the Association was changed to South African Holstein Society (SAHS). Today the SAHS strives to enhance the profitability of the Holstein cattle breeders and dairy producer (Campher *et al.*, 1998).

### **2.1.2 Distribution**

The Holstein is a widely distributed breed across the world. In South Africa, the Holstein is the dominant dairy breed. According to Hallowell & Mostert (2001), the Holstein breed is distributed throughout the country, accounting for 73% & 77% in 1991/1992 and 54% & 73% in 2000/2001 of all registered and unregistered dairy cattle participating in the National Dairy Animal Improvement Scheme respectively.

### **2.1.3 Breed characteristics**

The well-known white and black colour characterizes the Holstein cattle. It is a large-framed animal - a healthy calf weighs approximately 30kg at birth; the mature cow's weight varies from 550 to 650 kg and on average it stands 58 inches tall at the shoulder. Bulls often exceed 1000 kg. The outstanding characteristic of the Holstein is its milking ability. Production is characterized by high milk yields with a relatively low butterfat and protein percentage. Ease of milking and a good temperament enhance the merit of the breed. Compared to other breeds, the butterfat and protein content per liter milk produced is low, but the total amount of butterfat and protein produced per lactation is high. This is due to the capability of Holstein breed to produce large volumes of milk (Gertenbach, 1991).

Holstein heifers can be mated at 15 months of age, or when they have reached a weight of 330 kg (63 % of mature weight). The average age at first calving is 28 months. Their gestation period is approximately, 284 days with an average inter calving period of 406 days for registered and unregistered Holsteins.

## **2.2 History of genetic evaluation for dairy cattle in South Africa**

Since the mid 1950's, a dairy cattle breeding in South Africa has expanded immensely. This is mainly due to the development of the AI industry and the milk recording system that made accurate genetic evaluation possible. The National Livestock Improvement Schemes serve as a basis for accurate recording of economically important production traits. In the case of dairy cattle, sires were first evaluated through progeny groups, which led to the utilization of contemporary comparison methods to estimate the breeding values for sires.

Dairy cattle first received breeding values from BLUP methodology when the estimates from a Sire model were calculated in 1987. Animal models have been fitted to dairy records since 1992, and in 1999 a multivariate animal model was fitted for the production traits. Holstein bulls have also been internationally evaluated for production traits since South Africa's affiliation to INTERBULL in the same year, followed by Jersey bulls in the year 2000 (Theron *et al.*, 2001).

## CHAPTER 3

### NON-GENETIC FACTORS INFLUENCING DAIRY CATTLE PRODUCTION TRAITS

#### 3.1 INTRODUCTION

Genetic improvement through selection depends on the accuracy of identifying genetically superior animals. Phenotypic variation is a function of environmental and genetic factors. Estimation of genetic parameters from performance records is customarily based on field data from cows having different lactation lengths, milking frequency, month, year and age of calving, and are kept under different climatic and management conditions. Comparison of this unadjusted data may cause severe under- or overestimation of genetic parameters. Hence, non-genetic factors influencing production should be eliminated statistically. Rege (1991), Lobo *et al.* (2000) and Ojango & Pollott (2001) reported lower heritability estimates for milk yield adjusted to a 305-day lactation length, compared to unadjusted data.

The accuracy of removing the environmental effects from records vary among the different factors (Cassell, 1992). Many authors (Albuquerque *et al.*, 1998; Du Toit *et al.*, 1998; Hallowell *et al.*, 1998; De Waal & Heydenrych, 2001) stressed that standardization for days in lactation, age of calving, season and year of calving, milking frequency etc, is important for dairy cattle genetic evaluation. In the present study, unadjusted performance records were used and thus, prior to the estimation of breeding values, identification of the important non-genetic factors is required. The objective of the study, reported in this chapter, was to identify the non-genetic sources of variation for the inclusion in the subsequent genetic analyses.

## **3.2 MATERIAL AND METHODS**

### **3.2.1 Data**

First lactation records for milk yield (MY), butterfat yield (BFY), protein yield (PRY), butterfat percentage (BFP) and protein percentage (PRP) of Holstein cows were obtained from the South African Holstein Society for animals registered and participating in the National Dairy Cattle Performance Testing Scheme. The data were collected over a period of 21 years from 1980 to 2000. After editing, a total of 150 673 records were available. These were obtained from 113 056 dams and 1 429 sires, distributed over 1205 herds.

### **3.2.2 Statistical analysis**

The General Linear Model (GLM) procedure of SAS (1996) was used to determine the importance of the non-genetic factors. Normally a specific age is used to define age class at calving. However, in some reports the different ages were grouped (De Jager & Kennedy, 1987; Chauhan & Hayes, 1991; Rege, 1991). Similarly, in this study, age was grouped to determine age class. Proper sire distribution across-herds ensures improved accuracy of breeding value estimation (Bourdon, 2000). Therefore, to allow the probability of adequate sire linkage across herds, data were edited to include only sires with at least 15 progeny.

The data were edited to meet the following criteria: - (a) first lactation records of 300-days lactation length; (b) age group at calving, which were limited to four groups; viz. 18 to 23 months: group one; 24 to 29 months: group two; 30 to 35 months: group three and 36 to 41 months: group four; (c) records with available birth dates; (d) records with available sire and dam; (e) abnormal and missing records were excluded; (f) sires with at least 15 progeny and herds with at least 10 records were included in the analysis.

The model used included the following fixed effects: herd, year of calving, age group at calving and milking frequency.

$$Y_{ijklm} = \mu + h_k + y_m + g_j + t_i + a_l + e_{ijklm}$$

where  $Y_{ijklm}$  = phenotypic observation for traits of milk yield (MY), butterfat yield (BFY), protein yield (PRY), butterfat percentage (BFP) and protein percentage (PRP),

$\mu$  = overall mean,

$h_k$  = fixed effect of the k-th herd ( $k=1,2,3,\dots,1205$ ),

$y_m$  = fixed effect of the m-th year of calving ( $m=1980, \dots, 2000$ )

$g_j$  = fixed effect of the j-th age groups at calving ( $j=1,2,3,4$ ),

$t_i$  = fixed effect of the i-th milking frequency ( $i=2,3$ ),

$a_l$  = random animal effect of the l-th animal and

$e_{ijklm}$  = random error with zero mean and variance  $\sigma^2_e$ .

Based on the production means of month, Mostert *et al.* (2001) define six-seasons to be included in the variance analyses. However, in this study, due to the lack of climatological data and the lack of a clear distinction among the means obtained from SAS GLM (1996), it was difficult to define a season effect and hence month of calving was defined as an effect in the analyses.

### 3.3 RESULTS AND DISCUSSION

Results of the analyses are presented in Table 3.2. The main effects (herd, year of calving, age group at calving and milking frequency) were highly significant ( $p < 0.0001$ ). All the interactions, except those between milking frequency and age group at calving, were significant ( $p < 0.05$ ). However, since the quantity of the data affects the test for significance (p-value) and the data being quite substantial, RMSE and  $R^2$  were

used to determine how well the model fitted the data. The  $R^2$  indicated that month of calving and all the interactions in the model for five production traits had only a small contribution. Similarly, milking frequency for butterfat and protein percentage, and age groups at calving for protein percentage also had very small contributions (i.e.  $R^2$  was increased by less than 1% and RMSE reduced by less than 1%). Thus, month of calving and all the interactions were excluded from the model for all traits. Moreover, milking frequency for butterfat and protein percentages, and age group at calving for protein percentage were also excluded from the model.

Milking frequency, age at calving, herd and year explain on average 64.60 %, 62.96 %, 64.36 %, 15.66% and 23.86% of the variation in milk, butterfat and protein yields, butterfat and protein percentage, respectively. Of the effects fitted in the model, the herd effect contributed most to the variation in the production traits. The  $R^2$  improved by 21.9%, 23.15%, 25%, 11.46% and 11.86% for MY, BFY, PRY, BFP and PRP, respectively, when the herd effect was added to the model.

**Table 3.1** Description of data used

	MY	BFY	PRY	BFP	PRP
Number of animals	150673	150673	150673	150673	150673
Number of sires	1429	1429	1429	1429	1429
Number of dams	113056	113056	113056	113056	113056
Mean (kg or %)	6308.21	222.93	199.77	3.55	3.18
SD (kg or %)	1863.59	66.82	57.91	0.38	0.20
CV (%)	29.54	29.97	28.96	10.74	6.38
Max (kg or %)	12296	438	444	5.18	4.31
Min (kg or %)	1942	87	63	1.83	2.17

SD = standard deviation; CV = coefficient of variation; Max = maximum value;  
Min = minimum value.

**Table 3.2.** Analysis of variance for milk yield (MY), butterfat yield (BFY), Protein yield (PRY), butterfat percentage (BFP) and protein percentage (PRP)

SOURCE OF VAR.	DF	MY	BFY	PRY	BFP	PRP
Milking frequency	1	***	***	***	NS	NS
Age group at calving	3	***	***	***	***	NS
Herd	1204	***	***	***	***	***
Month of calving	11	NS	NS	NS	NS	NS
Year of calving	20	***	***	***	***	***
R-Square %	-	64.60	62.96	64.36	15.66	23.86
Error	149444					

\*\*\*  $p < 0.0001$ ; DF = degree of freedom; NS = non-significant

Results from the analyses indicate that milking frequency, year, herd and age were in agreement with the results reported by Rege (1991) and Hallowell *et al.* (1998). Substantial differences for yield and percentage traits across herds were observed. Due to the large number of herds, the least squares means and standard errors of the herd effects are not supplied. The least squares means and the standard error estimates for both yield and percentage traits across year effect are given in Table 3.3, while across milking frequency, age group at calving for milk, butterfat, protein yields and butterfat percentage are presented in Table 3.4

Year effect showed a substantial influence on the milk production traits (Table 3.3). The year effect showed an increasing tendency for milk, butterfat and protein yields, but the opposite happened for the percentage traits.

**Table 3.3** Least squares (LS) means and standard errors (SE) estimates for traits of milk yield (MY), butterfat yield (BFY), protein yield (PRY), butterfat percentage (BFP) and protein percentage (PRP) by year

Effect	MY (kg)	BFY (kg)	PRY (kg)	BFP (%)	PRP (%)
Mean	6308.21	222.93	199.77	3.55	3.18
1980	4596.17 ± 42.62	170.26 ± 1.56	153.95 ± 1.33	3.71 ± 0.010	3.34 ± 0.007
1981	4730.17 ± 27.87	176.23 ± 1.02	158.71 ± 0.87	3.74 ± 0.010	3.35 ± 0.004
1982	4910.48 ± 21.84	180.82 ± 0.83	162.18 ± 0.71	3.69 ± 0.007	3.30 ± 0.004
1983	4851.68 ± 21.84	181.62 ± 0.80	163.02 ± 0.68	3.68 ± 0.007	3.29 ± 0.003
1984	5145.58 ± 20.13	188.31 ± 0.74	169.78 ± 0.63	3.68 ± 0.006	3.29 ± 0.003
1985	5240.43 ± 17.65	192.74 ± 0.65	169.15 ± 0.55	3.70 ± 0.005	3.23 ± 0.003
1986	5268.84 ± 17.10	191.34 ± 0.63	168.58 ± 0.53	3.65 ± 0.005	3.20 ± 0.003
1987	5405.78 ± 15.81	195.45 ± 0.58	175.76 ± 0.49	3.64 ± 0.005	3.25 ± 0.002
1988	5640.81 ± 15.52	201.63 ± 0.57	182.00 ± 0.48	3.60 ± 0.005	3.23 ± 0.002
1989	5796.41 ± 14.42	207.86 ± 0.55	187.87 ± 0.47	3.61 ± 0.005	3.24 ± 0.002
1990	5961.76 ± 14.42	213.12 ± 0.53	192.33 ± 0.45	3.60 ± 0.004	3.22 ± 0.002
1991	5976.64 ± 14.38	214.69 ± 0.53	189.86 ± 0.45	3.62 ± 0.004	3.17 ± 0.002
1992	6197.30 ± 13.93	221.58 ± 0.51	196.78 ± 0.43	3.60 ± 0.004	3.16 ± 0.002
1993	6268.07 ± 13.68	224.71 ± 0.50	194.46 ± 0.43	3.61 ± 0.004	3.10 ± 0.002
1994	6625.07 ± 13.27	237.82 ± 0.49	205.53 ± 0.41	3.62 ± 0.004	3.10 ± 0.001
1995	6684.73 ± 13.19	243.48 ± 0.48	208.53 ± 0.41	3.66 ± 0.004	3.11 ± 0.002
1996	6562.58 ± 13.65	237.67 ± 0.50	203.80 ± 0.43	3.63 ± 0.004	3.10 ± 0.002
1997	6990.63 ± 13.64	252.35 ± 0.50	221.25 ± 0.43	3.61 ± 0.004	3.15 ± 0.002
1998	7118.75 ± 13.92	253.89 ± 0.51	217.32 ± 0.73	3.57 ± 0.004	3.05 ± 0.002
1999	7090.38 ± 14.64	253.33 ± 0.54	218.40 ± 0.46	3.57 ± 0.005	3.07 ± 0.002
2000	7080.41 ± 23.65	252.47 ± 0.87	220.74 ± 0.74	3.57 ± 0.007	3.11 ± 0.004

**Table 3.4** Least squares (LS) means, standard errors (SE) and coefficient of variation (CV) estimates for traits of milk yield (MY), butterfat yield (BFY), protein yield (PRY), butterfat percentage (BFP) by milking frequency and age groups at calving

Effects	N	LS mean $\pm$ SE			
		MY (kg)	BFY (kg)	PRY (kg)	BFP (%)
Mean		6308.21	222.93	199.77	3.55
MF					
2	107063	5329.40 $\pm$ 7.73	193.58 $\pm$ 0.28	170.83 $\pm$ 0.24	-
3	43610	6503.24 $\pm$ 12.89	234.16 $\pm$ 0.47	206.31 $\pm$ 0.40	-
AGGP					
1	6361	5354.76 $\pm$ 16.14	207.46 $\pm$ 0.59	173.06 $\pm$ 0.50	3.85 $\pm$ 0.01
2	93100	5920.69 $\pm$ 8.210	208.81 $\pm$ 0.30	187.46 $\pm$ 0.26	3.55 $\pm$ 0.01
3	39954	6099.11 $\pm$ 9.057	216.10 $\pm$ 0.33	193.64 $\pm$ 0.28	3.56 $\pm$ 0.01
4	11258	6290.71 $\pm$ 12.77	223.13 $\pm$ 0.47	200.11 $\pm$ 0.40	3.57 $\pm$ 0.01

N= number of observations; MF= milking frequency; AGGP = age group at calving.

Results from Table 3.4 indicate that means of milk, butterfat and protein yields increased with increase of milking frequency. Similar report by Harding (1995) noted that cows milked twice a day yielded 40% more milk than those milked once. Milking three times a day yielded 5-20% more than milked twice a day. This variation in milk yield may be due to less intramammary pressure as a result of frequent milk excretion; increased stimulation of hormones for milk synthesis, reduced negative feedback on secretory cells in alveolar lumen (Schmidt & Van Vleck, 1974). From the present study the expression of yield traits increased with an increase of age at first calving. However, there was no clear indication whether butterfat percentage decreased or increased with age. In a report by Pirlo *et al.* (2000), butterfat percentage was remains relatively constant and protein percentage gradually decreases with 0.10 to 0.15 units with increasing age. Results from Tukey's studentized range (HSD) test for variable indicated that, except between the

means of age group 3 and 4, there was a significant difference ( $p < 0.05$ ) among the means of the age group at first calving for MY, BFY, PRY and BFP.

### **3.3 CONCLUSIONS**

The results indicate the importance of known non-genetic factors influencing milk traits. In this study, month of calving had little or no effect on milk, butterfat, and protein yields, as well as percentage traits. Correct adjustment for milking frequency, age at calving, herds and year of calving are important for accurate breeding value prediction. Furthermore, knowing the magnitude of their effect on production is a good guideline for management practice. In this study, herd effect showed a large influence on production traits, emphasising the difference between feeding regimes (full feeding, pastures etc) as well as different managers.

## **CHAPTER 4**

### **VARIANCE COMPONENT, HERITABILITY, GENETIC AND PHENOTYPIC CORRELATION ESTIMATES FOR MILK TRAITS**

#### **4.1 INTRODUCTION**

Milk yield and composition traits are the most important factors influencing the profitability of dairy cattle farmers, accounting for between 80 to 90% of gross income (Everett & Pearson, 1992). Improvement of these traits should therefore receive first priority in any selection program. Progress is largely dependent on the effective utilization of the additive genetic variance. This necessitates accurate estimations of the genetic parameters for the traits concerned.

Besides heritability and variation of each trait, knowledge of genetic relationships among traits is crucial. This is because unfavourable genetic correlations could lead to a situation where genetic improvement in a specific trait is possible, but undesirable when aggregate genotype value is concerned. An efficient selection plan for prediction of possible correlated changes in traits when selection has been applied for other traits, is therefore a prerequisite. The objective of the study, as reported in this chapter, was to obtain estimates of variance components, heritabilities, genetic and phenotypic correlations for milk (MY), butterfat (BFY) and protein (PRY) yields as well as butterfat (BFP) and protein (PRP) percentages.

#### **4.2 MATERIAL AND METHODS**

##### **4.2.1 Data**

Data used in this study comprised of a total of 150 673 first lactation production records of the South African Holstein breed, which are registered and participated in the National

Dairy Cattle Performance Testing Scheme from 1980 to 2000. Records were obtained from 113 056 dams and 1 429 sires, distributed over 1 205 herds. For a more detailed description see Chapter 3.

#### 4.2.2 Statistical Analysis

Univariate and bivariate analyses were conducted using ASREML procedures of Gilmour *et al.* (2000). A direct animal model was fitted for all traits. The basic model was as follows:

$$y = Xb + Zu + e$$

where:  $y$  = a vector of observations for milk, butterfat, protein yields, and butterfat and protein percentages,  
 $b$  = a vector of fixed effects consisting of milking frequency, age at calving, herd, and year of calving,  
 $u$  = a random vector associated with the additive genetic effect of the animal,  
 $X$  &  $Z$  = incidence matrices for fixed and random effects respectively and  
 $e$  = a vector of unknown residual effects.

The expected means and the variance structure for the effects in the general statistical model for univariate analysis were assumed to be:

$$\begin{array}{lll} E(y) = Xb & E(u) = 0 & E(e) = 0 \\ \text{Var}(u) = A\sigma_a^2 & \text{Var}(e) = I\sigma_e^2 & \text{Var}(y) = ZAZ'\sigma_a^2 + I\sigma_e^2 \end{array}$$

where  $A$  is the numerator relationship matrix,  $I$  an identity matrix,  $\sigma_a^2$  the direct additive genetic variance and  $\sigma_e^2$  the residual variance. All the remaining (co) variances due to dominance and epistatic deviations were assumed to be zero. The relationship matrix was constructed using the full pedigree information.

The solutions to the equations were obtained solving the mixed model equations of Henderson (1984).

$$\begin{bmatrix} X'X & X'Z \\ Z'X & Z'Z + A^{-1}\alpha \end{bmatrix} \begin{bmatrix} \beta \\ u \end{bmatrix} = \begin{bmatrix} X'y \\ Z'y \end{bmatrix}$$

where  $\alpha = \sigma_e^2/\sigma_a^2 = (1 - h^2)/h^2$

The following bivariate mixed model was fitted to estimate the (co) variance components and genetic, environmental and phenotypic correlations.

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} + \begin{bmatrix} Z_1 & 0 \\ 0 & Z_2 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}$$

where  $y_1$  and  $y_2$  = vectors of phenotypic measurements;  $X_1$  and  $X_2$  = incidence matrices relating records and fixed effects;  $b_1$  and  $b_2$  = vectors of the fixed effect for the two traits;  $Z_1$  and  $Z_2$  = incidence matrices relating records and random effects;  $u_1$  and  $u_2$  = vectors of the additive genetic effects of the animal;  $e_1$  and  $e_2$  = vectors of random residual effects. Heritabilities for additive genetic effects were estimated as follows:

$$h^2 = \sigma_a^2/\sigma_p^2$$

$$\sigma_p^2 = \sigma_a^2 + \sigma_e^2$$

where  $h^2$  = heritability estimates,  
 $\sigma_a^2$  = additive genetic variance,  
 $\sigma_p^2$  = phenotypic variance and  
 $\sigma_e^2$  = residual (environmental) variance.

Similarly, the genetic and phenotypic correlation between two traits was calculated as follows:

$$r_{G_{ij}} = \sigma_{aj} / (\sigma_a^2 \sigma_j^2)^{1/2}$$

$$r_{p_{ij}} = \sigma_{pij} / (\sigma_{pi}^2 \sigma_{pj}^2)^{1/2}$$

$$\sigma_{pij} = \sigma_{aj} + \sigma_{eij}$$

where

- $\sigma_{aj}$  = genetic covariance for traits i & j,
- $\sigma_{pij}$  = phenotypic covariance for traits i & j,
- $\sigma_{eij}$  = environmental covariance for traits i & j,
- $r_{G_{ij}}$  = genetic correlation between traits i & j,
- $r_{p_{ij}}$  = phenotypic correlation between traits i & j and
- $\sigma_a^2$  &  $\sigma_p^2$  = genetic and phenotypic variances respectively.

## 4.2 RESULTS AND DISCUSSION

Estimates of variance components and heritabilities from the univariate analysis and genetic and phenotypic correlation from the bivariate analyses for milk traits are given in Tables 4.3 and 4.4, respectively. Estimates of genetic and phenotypic variance from the bivariate analyses were very close to the univariate estimates, and, therefore, heritability estimates from bivariate analyses are not given. The heritability estimates of the present study were in agreement with most of the results reviewed in the literature (Table 4.1).

Heritability estimates in this study varied from medium (butterfat and protein yields) to high (milk yield and percentage traits). More rapid genetic progress can be expected through selection for percentage traits followed by yield traits. Knowledge of the genetic correlation among these traits is also important for efficient breeding designs.

Estimates of the genetic and phenotypic correlations with their standard errors are presented in Table 4.4. Results summarized in the literature indicated that both the genetic and phenotypic correlation among yield traits were highly positive (Table 4.2.) These authors and others (Du Toit *et al.*, 1998; Hallowell *et al.*, 1998; Banga & Rautenbach, 1999; Du Plessis & Roux, 1999; Anonymous, 2000; Hallowell & Mostert, 2001; Biffani *et al.*, 2002; Rensing *et al.*, 2002), however, reported a negative genetic correlation of milk yield with butterfat and protein percentages.

In the past decades, since South African dairy cattle breeders started to favour selection for milk yield, there has been a remarkable increase in the average genetic progress for milk, butterfat and protein yields. However, the unfavourable genetic correlation between milk yield and percentage traits has contributed to the deterioration of the latter traits (Hallowell & Mostert, 2001). The deterioration in percentage traits is more pronounced in Holstein cattle than in other breeds.

As expected, both genetic and phenotypic correlations among yield traits in the present study were highly positive. This indicates that selection for milk yield will result in a positive correlated selection response in butterfat and protein yield.

**Table 4.1** Literature values obtained for heritability estimates of milk yield (MY), butterfat yield (BFY), protein yield (PRY), butterfat percentage (BFP) and protein percentage (PRP)

Model	Breed	MY	BFY	PRY	BFP	PRP	Source
Sire	Holstein	0.28	0.31	0.20	0.61	0.59	De Jager & Kennedy (1987)
Sire	Holstein	0.28 - 0.46	0.21	-	0.11 - 0.13	-	Rege (1991)
Sire	Holstein	0.30	0.20	0.28	0.64	0.41	Pander <i>et al.</i> (1992)
		-	0.38	-	0.63	-	Visscher & Thompson (1992)
		0.47	0.52	0.45	0.72	0.64	Brotherstone (1994)
Animal	Holstein	0.20	0.18	0.18	-	-	De Mataweva & Berger (1997)
		0.28	0.22	0.25	-	-	Spelman & Garrick (1997)
Animal	BWC*	0.29	0.20	0.20	0.15	0.10	Strabel & Szwaczkowski (1997)
Animal	Ayrshires	0.20 - 0.34	0.19 - 0.32	0.18 - 0.30	0.38 - 0.45	0.46 - 0.53	Hallowell <i>et al.</i> (1998)
		0.25 - 0.38	0.27 - 0.35	0.18 - 32	-	-	Van Tassell <i>et al.</i> (1999)
MT-SL-BLUP-AM	SA-Holstein	0.35	0.31	0.33	-	-	Anonymous (2000)
"	SA-Jersey	0.30	0.27	0.30	-	-	"
ST-SL- BLUP-AM	SA-Ayrshires	0.34	0.31	0.31	-	-	"
Test Day	New Zealand- Holstein	0.35	0.28	0.31	-	-	"
Animal	Holstein	0.09 - 0.34	0.09 - 0.34	0.07 - 0.30	-	-	Mandizha <i>et al.</i> (2000)
Animal	Holstein	0.29	-	-	-	-	Ojango & Pollott (2001)
Random Regression	Holstein	0.34	0.32	0.30	-	-	Pereira <i>et al.</i> (2001)
Animal	Holstein	0.13	0.22	0.09	-	-	De Groot <i>et al.</i> (2002)
Random Regression	Jersey	0.31	-	-	-	-	Guo <i>et al.</i> (2002)
MLMC**		0.57	0.44	0.44	-	-	Liu <i>et al.</i> (2002)
		0.29 - 0.33	-	-	-	-	Ojango & Pollot (2002)
Animal	Holstein	0.315	0.273	0.283	0.415	0.535	Present Study

BWC = Black White cattle; \*\* MLMC =multiple lactation multiple country model; MT= Multiple trait; ST= single trait; BLUP = Best linear unbiased prediction; AM = Animal model

**Table 4.2** Literature values obtained for the genetic correlation (Below the diagonal) and phenotypic correlation (above the diagonal) for milk yield (MY), butterfat yield (BFY), protein yield (PRY), butterfat percentage (BFP) and protein percentage (PRP)

Trait	MY	BFY	PRY	BFP	PRP	SOURCE
MY	-	0.57	0.82	-0.43	-0.64	De Jager & Kennedy (1987)
BFY	0.74	-	0.66	0.48	-0.14	„
PRY	0.90	0.80	-	-0.16	-0.16	„
BFP	-0.33	0.29	-0.11	-	0.56	„
PP	-0.43	-0.05	-0.02	0.55	-	„
MY	-	0.75	-	-0.10	-	Rege (1991)
BFY	0.95	-	-	0.26	-	„
BFP	-0.20	-0.004	-	-	-	„
MY	-	0.83	0.94	-0.32	-0.45	Pander <i>et al.</i> (1992)
BFY	0.72	-	0.86	0.28	-0.11	„
PRY	0.94	0.81	-	-0.14	-0.13	„
BFP	-0.56	0.25	-0.25	-	0.56	„
PRP	-0.53	0.21	-0.08	0.69	-	„
MY	-	0.87	0.96	-	-	De Matawewa & Berger (1997)
BFY	0.61	-	0.90	-	-	„
PRY	0.88	0.71	-	-	-	„
MY	-	-	-	-	-	Anonymous (2000)
BFY	0.73	-	-	-	-	„
PRY	0.90	0.80	-	-	-	„
MY	-	0.86	0.93	-0.20	-0.22	Roman & Wilcox (2000)
BFY	0.75	-	0.89	0.28	0.02	„
PRY	0.90	0.87	-	-0.03	0.12	„
BFP	-0.21	0.49	0.19	-	0.46	„
PP	-0.56	-0.18	-0.11	0.63	-	„
MY	-	0.87	0.83	-	-	De Groot <i>et al.</i> (2002)
BFY	0.36	-	0.82	-	-	„
PRY	0.34	0.56	-	-	-	„
MY	-	-	-	-	-	Rosati & Van Vleck (2002)
BFY	0.88	-	-	-	-	„
PRY	0.95	0.38	-	-	-	„
BFP	-0.08	0.41	-0.04	-	-	„
PP	-0.12	0.44	0.31	0.65	-	„
MY		0.83	0.95	-0.06	-0.05	Present study
BFY	0.79		0.85	0.32	0.01	„
PRY	0.91	0.85		-0.12	0.10	„
BFP	-0.09	0.26	-0.15		0.37	„
PP	-0.10	-0.01	0.01	0.37		„

**Table 4.3** Estimates of variance component and heritability from the univariate analysis for milk yield (MY), butterfat yield (BFY), protein yield (PRY), and butterfat percentage (BFP) and protein percentage (PRP)

Parameters	MY	BFY	PRY	BFP	PRP
Mean	6308.21	222.93	199.77	3.550	3.180
SD.	1863.59	66.82	57.91	0.38	0.20
CV %	29.54	29.97	28.96	10.76	6.380
$\sigma_a^2$	404851	470.05	353.30	0.053	0.018
$\sigma_c^2$	882098	1252.70	891.20	0.075	0.015
$\sigma_p^2$	1286949	1722.75	1244.50	0.129	0.033
$h_a^2$	0.315	0.273	0.284	0.415	0.535
SE.	0.0071	0.0070	0.0070	0.0072	0.0068

Standard deviation (SD.); coefficient of variation (CV%); direct additive genetic variance ( $\sigma_a^2$ ); residual variance ( $\sigma_c^2$ ); phenotypic variance ( $\sigma_p^2$ ); direct heritability ( $h_a^2$ ) and standard error (SE.).

**Table 4.4** The genetic correlation (below the diagonal) and phenotypic correlation (above the diagonal) for milk yield (MY), butterfat yield (BFY), protein yield (PRY), butterfat percentage (BFP) and protein percentage (PP)

Trait	MY	BFY	PRY	BFP	PRP
MY	-	0.83 ± 0.001	0.95 ± 0.001	-0.06 ± 0.001 *	-0.05 ± 0.001 *
BFY	0.79 ± 0.007	-	0.85 ± 0.001	0.32 ± 0.003	0.01 ± 0.003
PRY	0.91 ± 0.003	0.85 ± 0.006	-	-0.12 ± 0.003	0.01 ± 0.003
BFP	-0.09 ± 0.004 *	0.26 ± 0.016	-0.15 ± 0.017	-	0.37 ± 0.002
PRP	-0.10 ± 0.004 *	-0.01 ± 0.025	0.10 ± 0.015	0.37 ± 0.002	-

\* = No convergence; the values given in the table are the intermediate ones.

The genetic correlation among yield traits, that is milk and butterfat, milk and protein, and butterfat and protein yields were in agreement with the results obtained by Pander *et*

*al.* (1992), Anonymous (2000) and Roman & Wilcox (2000), while the genetic correlation obtained for butterfat yield and butterfat percentage were in agreement with those obtained by Pander *et al.* (1992). De Jager & Kennedy (1987) obtained genetic correlations for protein yield and butterfat percentage similar to those in the present study. The genetic relationships between butterfat yield and protein percentage, and protein yield and protein percentage were, however, negative and low and not in agreement with any of the literature values reviewed.

Although the log-likelihood iterations of the bivariate analysis between milk yield and percentage traits of the present study did not converge, both the genetic and phenotypic correlations of the intermediate values were negative. These values were compared with results in the literature. The genetic correlation between milk yield and butterfat percentage was in agreement with results obtained by Rege (1991) and Rosati & Van Vleck (2002), and that between milk yield and protein percentage was in agreement with results by Rosati & Van Vleck (2002). This negative genetic correlation between milk yield and percentage traits will result in unfavourable selection response for butterfat and protein percentage when selection is applied to milk yield. Inclusion of percentage traits in the index could prevent this phenomenon. Due to the presence of a positive genetic relationship between butterfat yield and butterfat percentage, as well as protein yield and protein percentage, the inclusion of both yield traits in the index as alternative to prevent the deterioration of percentage traits can be investigated.

### 4.3 CONCLUSIONS

Heritability estimates found in the present study were in agreement with the results reviewed in the literature and, therefore, these parameters can be used for the genetic evaluation of the South African Holstein cattle. The estimates varied from medium (butterfat and protein yields) to high (milk yield, and butterfat and protein percentage). Therefore, faster genetic progress is expected through selection for protein and butterfat percentage followed by the yield traits.

The highly positive genetic relationships between yield traits indicated that a favourable correlated response to selection for butterfat and protein yields can be anticipated when selection for milk yield is applied. The presence of a negative genetic correlation between milk yield and percentage traits would, however, result in a negative correlated response. In planning breeding goals for South African Holstein cattle, it is important to consider percentage traits in the breeding goals by including them in the index - either to improve them, or at least to halt their further deterioration.

## CHAPTER 5

### COMPUTING A SELECTION INDEX USING DIFFERENT MILK PRICING SCHEMES

#### 5.1 INTRODUCTION

Economic feasibility of an animal breeding program requires the definition of weighting factors for the construction of a selection index, which relates to combined selection objectives. Estimation of the relative economic values and genetic parameters for each trait in the selection index is important. Dairy farmers are at different levels of production and use different marketing channels for their products. Therefore, to develop a national selection index as breeding objective, consideration of the effect of the milk pricing system used by the different marketing channels is important. In addition, since breeding is geared towards future genetic improvement (Groen, 1989a; Groen *et al.*, 1997), considering the effect of the future milk price in developing a selection index could bring substantial improvement on the targeted objective.

Selection by definition is the process that determines which individuals become parents, how many offspring they may produce, and how long they remain in the breeding population (Bourdon, 2000). Selection for a single trait is relatively simple, since only the best animals for the trait are selected, preferably based on the BLUP animal model estimated breeding values. However, profitability depends on the aggregate genetic value of all traits involved in the breeding goal. Overall genetic improvement based on the target-breeding goal could be attained through combined selection based on a selection index.

The selection index is influenced by relative economic values, genetic and phenotypic parameters (Van Vleck *et al.*, 1987; Moore *et al.*, 1992; Weller, 1994; Falconer &

Mackay, 1996; Du Plessis & Roux, 1999; Dzama *et al.*, 2001; Onge *et al.*, 2002). Changing any one of these components could affect the weighting factor of any of the traits in the index as well as selection response for the trait and aggregate response.

In a reappraisal of the effect imposed by the genetic parameters and economic values on a selection index, Moore *et al.* (1992) compared two indices using the same economic values, but two different genetic parameters from Ayrshires and Holstein breeds. As a result lower weighting factors of the index from Ayrshires were reported as compared to the one derived from the Holstein breed.

Similarly, the effect of economic values on a selection index relates to the returns and costs of production. These parameters vary among dairy farmers and are the primary reasons of fluctuating farmers' profit under the same levels of production. In turn, this fluctuation of profit affects the magnitude of the economic value of traits in the selection index. Of all sources of returns in dairy cattle, return derived from milk sale is the primary reason of varying profit among farmers. Sivanadian *et al.* (1998) stressed the importance of milk pricing under current and future conditions on the expected genetic response to a selection index for Canadian dairy cattle. There are reports, indicating that economic values were relatively insensitive to substantial changes in individual cost items (Gibson *et al.*, 1992; Vargas *et al.*, 2001). However, they are highly sensitive to the change of the milk price (Gibson *et al.*, 1992; Vargas *et al.*, 2001; Onge *et al.*, 2002; Vargas *et al.*, 2002).

South African dairy cattle farmers use different marketing channels for their milk. These marketing channels have different milk pricing systems. The question that arises is, can the milk pricing system used by different schemes affect the selection goals of the South Africa dairy cattle breeder?

The objective of this study was to determine the effect of the milk pricing systems on the selection index for Holstein cattle by employing the milk pricing systems used by three South African milk buyers.

## 5.2 MATERIAL AND METHODS

### 5.2.1 Data

Variance components, heritabilities, and genetic and phenotypic correlations among yield traits were reported in Chapter four. An average level of production of 6308 kg, 223 kg and 200 kg for milk (MY), butterfat (BFY) and protein (PRY) yield, respectively, was used for all milk buyers. These parameters (Table 5.2) and the monetary values expressed in Rand (R)/kg for each trait in the index (Table 5.1) were used for the further analyses.

### 5.2.2 Statistical Analysis

The classical selection index theory developed by Hazel (1943) is the basic tool to combine the available phenotypic records of biological traits into an index and to rank the animals according to the index value of each animal. In practice, the predicted breeding values are used as a source of information to be combined into an index to predict aggregate or index breeding values.

The algebraic background of calculating the weighting factor for given traits is as follows (Hazel *et al.*, 1994):

$$H = v_1g_1 + v_2g_2 + v_3g_3 + \dots + v_n g_n \quad (1)$$

where  $H$  = aggregate breeding value,

$v_i$  = an economic value of the trait in the breeding objective,

$g_i$  = breeding value for a trait in the breeding objective.

$$I = b_1X_1 + b_2X_2 + b_3X_3 + \dots + b_iX_i \text{ (Hazel } et al., 1994): \quad (2)$$

where  $I$  = Selection index,

$b_i$  = weighting factor for the  $i^{th}$  trait in the index, and

$X_i$  = phenotypic records for the  $i^{th}$  trait in the index.

The weighting factor for each trait in the index can be obtained by the following formula (Hazel *et al.*, 1994):

$$\begin{aligned} bP &= Gv \\ b &= P^{-1}Gv \end{aligned} \quad (3)$$

where  $P$  = the phenotypic variance-covariance matrix,

$G$  = the genetic variance-covariance matrix,

$b$  &  $v$  = the vectors of the index weighting factors and economic values, respectively.

The variances of the aggregate value ( $\sigma_H^2$ ) and index ( $\sigma_I^2$ ) were calculated as follow (Dommerholt & Wilmink, 1986):

$$\sigma_H^2 = v' C v \quad (4)$$

$$\sigma_I^2 = b' P b \quad (5)$$

where  $C$  is the variance-covariance matrix between  $g_1$ ,  $g_2$  and  $g_3$ . If the traits in the breeding objective and in the index are the same, then  $C = G$ .

If an alternative selection index is used to rank the animals for a particular situation, the relative change of efficiency in the selection using this alternative selection index, can be calculated using the method suggested by Dommerholt & Wilmink (1986). Firstly, it is assumed that index ( $I_i$ ) favours more genetic progress than index ( $I_j$ ). Then the

relationship between the two selection indices will be computed from their genetic correlation,  $r_{I_i I_j}$ , as follows:

$$r_{I_i I_j} = (b_i' P b_j) / ((b_i' P b_i) (b_j' P b_j))^{1/2} \quad (6)$$

where  $r_{I_i I_j}$  = the correlation between the two indices ( i.e.  $I_i$  and  $I_j$ ),

$P$  = the phenotypic variance-covariance matrix,

$b_i$  &  $b_j$  = the vectors of the weighting factors for  $I_i$  and  $I_j$ , respectively.

The relative change of efficiency in the selection when using  $I_j$ , instead of  $I_i$  to rank the animals, could be obtained  $(1 - r_{I_i I_j})$  by deducting the correlation between the two indices from one. Weller (1994) explained that the correlation of two indices can be computed from the ratio of the standard deviation of the indices.

The Desire program (Kinghorn, 2000) was used to calculate the weighting factors and to predict the expected responses under different milk pricing systems. Desire calculates the factors and predicts the responses simultaneously. Primarily, Desire is designed to explore the possible outcomes of a breeding program in terms of predicted genetic gains for a number of traits considered. When a desired gain of a trait is fixed, Desire restricts the possible genetic change in other traits. Here, inputs of the relative economic values and genetic parameters of MY, BFY and PRY are merely given to the program to compute the weighting factors and to predict the expected responses of the traits.

The theory of calculating economic values for various situations, selection goal and production circumstances has been extensively discussed by several authors (Brascamp *et al.*, 1985; Smith *et al.*, 1986; Groen, 1989a,b; Amer & Fox, 1992; Groen *et al.*, 1997). Profit equation is a function of costs and returns of production. The price of output and input reflects a deviation in the profit equation from place to place. The return of production is believed to be influenced primarily by the milk pricing system used.

There are indices that have been criticized because they fail to include the costs associated with production of individual milk components (Pearson & Miller, 1979; Allaire & Thaen, 1985; Keller & Allaire, 1990). The most common methods of computing the relative economic values for milk components fall into two categories (Gibson, 1987): viz. those that omit the associated costs of production and thus overestimate the relative weight of the economic values (Hillers, 1984) and those that include costs of production (Groen, 1989a,b; Allaire & Gibson, 1992; Onge *et al.*, 2002; Vargas *et al.*, 2002).

Due to some limitations in calculating the real economic value from field data, the monetary values of milk, butterfat and protein yields used by the major South African milk buyers, in this study, are assumed to be the relative economic values of the traits (Table 5.1). This is under the assumption that the milk price is the only factor that influences economic value with the factors influencing cost of production excluded. As mentioned above a fixed level of production is considered. All other sources such as returns from sale of culled cows and calves, feed costs, replacement and veterinary costs are assumed to be the same across the different herds.

**Table 5.1** Relative economic values of milk (MY), butterfat (BFY) and protein (PRY) yield used to calculate the weighting factors under three South African milk buyers (A, B, C)

Traits	Economic values (in R / kg)		
	A	B	C
MY	0.236	0	0
BFY	12.10	14.80	14.60
PRY	18.15	22.20	17.00

**Table 5.2** Mean values ( $\mu$ ), standard deviation ( $\sigma$ ) and genetic parameters of milk yield (MY), butterfat yield (BFY) and protein yield (PRY) used to calculate the weighting factors and predict the expected responses

Parameters	MY	BFY	PRY
$\mu^{**}$	6308	223	200
$\sigma_p^{**}$	1863	66	57
$h_a^2$	0.315	0.273	0.283
	MY x BFY	MY x PRY	BFY x PRY
$r_g$	0.786	0.912	0.845
$r_p$	0.829	0.946	0.848

\*\* Means and standard deviations (in kg) are for 300-days lactation length.

### 5.3 RESULTS AND DISCUSSION

The aim of genetic evaluation is to develop a well-defined breeding goal. One way of evaluating the effectiveness of a dairy-breeding goal is to calculate the weighting factors in an index and then to predict the expected response to selection. The relative weighting factors and predicted responses to selection for the different milk pricing systems are presented in Table 5.3.

The results showed that the weights and expected responses of the three indices varied. When animals are selected based on the index of the different milk buyers, the population mean of milk, butterfat, protein yield, respectively, will be improved in the next generation as presented in Table 5.3.

From the literature, it has been reported that the efficiency of a selection index is sensitive to the change of the genetic parameters, economic value, and when an important

trait is omitted or an unimportant one is included in the index. In this study, the aim is not to see the effect of the traits included in a selection index, but to investigate the effect of the pricing system of the milk buyers on a selection index. Only yield traits are considered in the index and their genetic parameters are kept constant across the milk pricing systems. The different economic values of the different milk buyers were, however, used. There are reports indicating that the milk pricing systems that favour high milk yield would lead to a decrease in the aggregate genotype response per generation. This is due to the effect of milk yield on the fertility of the cow (Rauw, *et al.*, 1998). Thus it was assumed that the milk pricing systems used do not affect the relative economic value of other dairy traits. Any change in the weights and responses were due to the effect of the milk price on the traits considered.

Selection responses of this study are found to be higher than the responses per generation reported by Dommerholt & Wilmink (1986). Assuming a four - year generation interval for South African Holstein cattle, milk yield response per year of milk buyers B and C were in agreement with responses reported by Legates & Myers (1972), Boettcher *et al.* (1993) and Mandizha *et al.* (2000).

At low milk price, a low weighting factor in the index for milk and protein yields were reported by Veerkamp *et al.* (2002). Some of these were even close to zero. Similar low weights are also reported for butterfat at high protein to butterfat price ratio (Dommerholt & Wilmink, 1986). In this study, the weights and the response of the traits showed to vary, depending on the monetary value paid by the milk buyers. For instance, the monetary value paid for milk yield by milk buyer A was R 0.236/kg compared to the zero value allocated by milk buyers B and C. As a result the weight for milk yield in the case of milk buyer A is higher than for the other buyers.

**Table 5.3.** Relative weights and expected selection responses for milk yield (MY) butterfat yield (BFY) and protein yield (PRY) under the different milk buyers pricing systems (intensity of selection =1)

Milk buyers	Price* ratio	Trait	Economic value (R/kg)	Relative weights	Response (kg) per generation
A	1.5 : 1	MY	0.236	0.16	+546
		BFY	12.1	2.41	+16.6
		PRY	18.15	3.24	+15.6
B	1.5 : 1	MY	0	0.04	+509
		BFY	14.8	3.43	+17.1
		PRY	22.2	5.7	+15.7
C	1.2 : 1	MY	0	0.03	+504
		BFY	14.6	3.48	+17.3
		PRY	17	4.37	+15.5

\* = protein to butterfat price ratio.

The following indices for milk buyers of A ( $I_A$ ), B ( $I_B$ ) and C ( $I_C$ ) were, therefore, calculated (Table 5.3):

$$I_A = 0.16 MY + 2.41 BFY + 3.24 PRY$$

$$I_B = 0.04 MY + 3.43 BFY + 5.70 PRY$$

$$I_C = 0.03 MY + 3.48 BFY + 4.37 PRY$$

Using the computed indices, a small group of Holstein cows were ranked, based on the index values. Ranking of the animals was different in all three of the indices (Table 5.4). These different rankings show the effect of the different milk pricing systems, when using a selection index. The result shows that Holstein cattle breeders using these milk-marketing channels should follow different selection programs.

**Table 5.4.** Animal registration number (REG), milk yield (MY), butterfat yield (BFY), protein yield (PRY), index value, and index ranking for a small group of Holstein cows

REG	MY	BFY	PRY	Index value A	Rank	Index value B	Rank	Index value C	Rank
9214263	11977	420	378	4153.24	1	4074.28	5	3472.77	4
11943875	11818	401	397	4143.57	2	4111.05	3	3484.91	3
10741379	11977	379	405	4141.91	3	4087.55	4	3448.08	5
9642430	11940	389	390	4111.49	4	4034.87	7	3416.22	8
18639419	11996	369	401	4107.89	5	4031.21	8	3396.37	9
14349013	11081	432	390	4077.68	6	4148.00	2	3540.09	2
19287655	11624	418	373	4075.74	7	4024.80	9	3433.37	6
9160003	12048	411	354	4065.15	8	3909.45	17	3338.70	14
18801530	11856	395	375	4063.91	9	3966.59	11	3369.03	11
18673871	11985	341	402	4041.89	10	3940.43	14	3302.97	17
8999674	10541	433	401	4029.33	11	4192.53	1	3575.44	1
9586819	11738	360	395	4025.48	12	3955.82	13	3331.09	15
17798448	11757	384	374	4018.32	13	3919.20	16	3323.41	16
8205015	11384	346	420	4016.10	14	4036.14	6	3381.00	10
9732512	11469	384	384	4004.64	15	3964.68	12	3358.47	13
18323097	12000	365	371	4001.69	16	3846.65	18	3251.47	18
19141399	12087	389	345	3989.21	17	3784.25	20	3223.98	19
19215284	11358	417	359	3985.41	18	3930.93	15	3360.73	12
10178838	12061	358	367	3981.62	19	3802.28	19	3211.46	20
11016458	10998	411	379	3978.15	20	4009.95	10	3416.45	7

Value index A = 0.16MY + 2.41BFY + 3.24PRY; B = 0.04MY + 3.43BFY + 5.70PRY; C = 0.03MY + 3.48BFY + 4.37PRY

The choice of the selection program depends on the farmer's goal. Some farmers may want to place more emphasis towards protein yield improvement and others towards milk yield or butterfat yield, as well as percentage traits improvement. However, as far as aggregate-breeding values are concerned, better improvement will be made when Holstein farmers select their animals based on the index derived for milk buyer A. This substantial genetic benefit from milk buyer A's index relative to other indices is probably due to the monetary value of the milk yield

**Table 5.5.** Expected aggregate genotype responses, aggregate genotype standard deviation ( $\sigma_H$ ), index standard deviation ( $\sigma_I$ ) and the correlation ( $r_{Iij}$ ) of the indices relative to milk buyer A (intensity of selection =1)

Milk buyers	$r_{Iij}$ **	$\sigma_I$	$\sigma_H$	Aggregate response (kg) per generation
A	1.00	616	1156	578
B	0.97	601	1138	542
C	0.84	516	979	537

\*\* = The correlation between the indices was calculated relative to the index derived using the pricing system of milk buyer A

The standard deviation of the aggregate breeding values and indices, as well as the correlation between indices was calculated (Table 5.5). The results indicated the relative loss or gain in the efficiency of selection when an alternative selection program was used. Relative to the index of milk buyer A, the expected loss of efficiency in selection will be 3 % and 16 % if Holstein cows were selected based on the index of milk buyers B and C, respectively. Smith et al. (1986) reported the occurrence of a considerable loss of

efficiency in selection when large changes in the economic values are made. Recent reports indicate that the change in economic response to selection due to changes in pricing systems ranged from 4.2% - 18.7% (Pieters *et al.*, 1997).

Even though the choice of the selection program depends on the farmer's goals, selection based on milk buyer A's pricing system will bring a substantial profit in comparison to the pricing system used by the other milk buyers (Table 5.5). In the study to detect the effect of economic values obtained from three different milk pricing (butterfat pricing, multiple component pricing, and end product pricing based on cheese yield) systems on profit of five dairy cattle (Ayrshires, Brown Swiss, Guernsey, Holstein and Jersey) breeds, Keller & Allaire (1990) found that the change on profit of the breeds were differently suited to the three marketing systems. For instance, compared to other milk pricing systems, under the butterfat pricing system Holstein generated the highest profit, however, this milk pricing system yielded the lowest profit for the rest of the breeds.

Furthermore, to detect this effect of a reduced monetary value for milk yield and the effect of protein to butterfat price ratio on weighting factor and response of the traits, some changes were made in the pricing system used by the milk buyers. The relative weights and response to selection for the modified price are given in Tables 5.6 and 5.7

**Table 5.6.** Relative weights and expected selection responses for milk yield (MY) butterfat yield (BFY) and protein yield (PRY) under a modified milk buyers' pricing system (intensity of selection = 1)

Milk buyers	Price * ratio	Trait	Economic value (R/kg)	Relative weights	Response per generation
A	1.5 : 1	MY	0	0.03	+509
		BFY	12.1	2.81	+17.1
		PRY	18.15	4.66	+15.7
B	1.5 : 1	MY	0	0.04	+509
		BFY	14.8	3.43	+17.1
		PRY	22.2	5.7	+15.7
C	1.2 : 1	MY	0	0.03	+504
		BFY	14.6	3.48	+17.3
		PRY	17	4.37	+15.5

\* = Protein to butterfat price ratio.

Keeping the price of the other components unchanged, the price for milk yield paid by milk buyer A is set to zero (Table 5.6). The relative weight of milk yield decreased from 0.16 to 0.03, and the selection response of the trait decreased by 37 kg per generation. This is almost the amount the aggregate genetic response from milk buyer index A exceeds that of milk buyer index B and C. Furthermore, a comparison was made among the weights and responses of the milk buyer index found in Tables 5.3 and 5.6. As the price of the milk yield decreased, the weights for butterfat and protein yield increased. The rate of increment in weights was higher for protein than for butterfat. Although the modified prices that affect the weights for butterfat and protein yield were high, the changes in response for these traits were small. Butterfat and protein yield increased by +0.5kg and +0.1kg, respectively, per generation.

Milk buyer B paid a higher price for both butterfat and protein yield than by milk buyer A. However, the responses to selection of the traits are found the same when using either index. This is probably due to the effect of the protein to butterfat price ratio, which was the same (1.5: 1) for both milk buyers (Table 5.6). The price ratio for protein to butterfat in milk buyer C was closer to one in comparison to A or B. As a result, the response in milk and protein yield seems to be lower. However, the difference was very small.

To investigate the effect of the price ratio, different sets (1.5: 1, 2.2: 1 and 0.9: 1) of protein to butterfat price ratio were allocated to milk buyer A, B and C, respectively. The lowest responses for milk and protein yields were obtained in milk buyer C while it was the highest for milk buyer B. In contrast, the butterfat response was the highest for milk buyer C and the lowest for milk buyer B. The intermediate price ratio of milk buyer A yielded the intermediate responses for all three of the traits considered (Table 5.7).

**Table 5.7.** Relative weights and expected selection responses for milk yield (MY) butterfat yield (BFY) and protein yield (PRY) under a modified milk buyers' pricing system (intensity of selection = 1)

Milk buyers	Price* ratio	Trait	Economic value (R/kg)	Relative weights	Response (kg) per generation
A	1.5 : 1	MY	0	0.03	+509
		BFY	12.1	2.81	+17.1
		PRY	18.15	4.66	+15.7
B	2.2 : 1	MY	0	0.04	+514
		BFY	10.2	2.24	+16.8
		PRY	22.2	5.71	+15.9
C	0.9 : 1	MY	0	0.02	+497
		BFY	14.6	3.37	+17.5
		PRY	13	3.39	+15.4

\* = protein to butterfat price ratio

The study reveals the effect of milk pricing systems on a selection index, however, an index that ignored feed costs yielded inflated index weights with an incorrect balance between the milk components (Hillers *et al.*, 1979; Dommerholt & Wilmink, 1986; Keller & Allaire, 1990). This is because feed cost of milk production is substantial and different for each milk component (Dado *et al.*, 1993; Montgomerie, 2000). Therefore, in future, the inclusion of all sources of cost is important to determine the real economic value for each milk buyer.

#### 5.4 CONCLUSIONS

The results found in this study provide some information about the importance of the effect of milk pricing systems on the weighting factors for a selection index for the South African Holsteins. Across the different milk pricing systems, the weighting factors and response to selection varied. Changes of animal's rank and loss or gain of efficiency in

selection was observed when an alternative milk pricing system was used. This study also reveals the effect of the protein to butterfat price ratio on the weights and responses. The results obtained, depending on the farmer's breeding goals, indicate that the South African Holstein breeders should follow different selection programs depending on the milk buyers.

Since this study was done under certain assumptions, a future study based on field data, which include feed cost, should be conducted to calculate the real economic value of the traits. Such a study will enable the investigation of the real effect of the milk pricing system on a selection index. It is also recommended that, in future, other breeds should be included in a study to compare the effect of milk price systems among dairy cattle breeds.

## CHAPTER 6

### GENERAL CONCLUSIONS

The drawing of general conclusions to the results obtained in this study is difficult, as they are open to a wide range of interpretations. The validity of the results also depends on the approach of the method and other factors used to estimate the parameters. With this in mind, some general conclusions are made from results obtained in the present study.

The results firstly confirm the importance of non-genetic factors as sources of variation in milk traits of South African Holstein cattle. Therefore, defining the non-genetic factors into the appropriate model is important for accurate breeding value prediction. The failure to include these factors would result in an over-and/or underestimation of the genetic parameters and thus, the use of these parameters in selection could result in undesired or decreased genetic change.

The heritability estimates and genetic relationships found in this study were in agreement with the results reviewed in the literature. The heritability estimates for butterfat and protein yield were medium, while for milk yield, butterfat and protein percentage the heritabilities were high. Therefore, faster genetic improvement is expected for South African Holsteins through selection for milk yield and percentage traits followed by butterfat and protein yield.

The results show the presence of a highly positive genetic relationship among the yield traits. This relationship indicates that favourable correlated response to selection for butterfat and protein yields could be expected when selection is applied for milk yield. The negative genetic relationship between milk yield and the percentage would, however, result in an unfavourable correlated response in the percentage traits. Therefore, in planning breeding goals for South African Holstein cattle, it is important to consider

percentage traits in the goals by including them in the index – either to improve them, or at least to curb their further deterioration.

Furthermore, the study provides some information about the importance of milk pricing system on defining a selection index. The results showed that the weighting factors and expected responses among the three milk buyers varied. The study also highlights the effect of protein to butterfat price ratio on the index weights and responses. Changes of an animal's ranking and/or the relative loss or gain of efficiency in a selection index when an alternative milk pricing systems is used indicates that the South African Holstein breeders should follow different selection programs depending on buyer.

Since the study was done under certain assumptions, a future study is needed to assess the effect of the inclusion of feed cost on the real economic value of the traits. It is also recommended that, in future, other breeds should be included in a study to compare the effect of milk price systems among dairy cattle breeds

## ABSTRACT

A total of 150673 first lactation records of South African Holstein lactating cows were used to estimate the genetic parameters of milk (MY), butterfat (BFY), and protein (PRY) yields, and butterfat (BFP) and protein (PRP) percentages. The data comprising 113 056 dams and 1 429 sires, distributed over 1 205 herds, were collected over a period of 21 years, 1980 to 2000.

The study was aimed at the following aspects: to determine the non – genetic factors influencing milk traits for use in the model for a subsequent genetic analysis; to estimate the variance-covariance components and heritabilities of all traits. Finally, to calculate the weighting factors for a selection index and predict the expected response to selection when using different milk pricing systems.

Five fixed effects were defined, viz: milking frequency, age at calving, herd, month of calving and year of calving. Analysis of variance indicated that all effects were highly significant ( $p < 0.0001$ ) explaining on average 64.60%, 62.96%, 64.36%, 15.66% and 23.86% of the total variation for MY, BFY, PRY, BFP and PRP, respectively. Considering the  $R^2$  and RMSE as an option, month of calving for all traits, milking frequency for BFP and PRP, and age at calving for PRP showed a minor contribution to the variation and were, thus, excluded from the model for the subsequent analysis.

Heritability estimates varied from medium for BFY and PRY to high for MY, BFP and PRP. This indicates that faster genetic progress will be possible through selection of MY, BFP and PRP. The highly positive genetic correlation among yield traits indicates selection for milk yield will result in a favourable response with butterfat and protein yield. However, it will lead to an unfavourable response to selection for the percentage traits. This is due to a negative genetic correlation between milk yield with percentage traits.

Using the Desire program, weighting factors and expected response per generation for milk, butterfat and protein yield were calculated under three milk buyers (A, B and C) pricing systems. The standard deviations of alternative breeding objectives and selection indices were also calculated.

The weighting factors for milk, butterfat and protein yields were 0.16, 2.41 and 3.24 for milk buyer A, 0.04, 3.43 and 5.70 for milk buyer B and 0.03, 3.48 and 4.37 for milk buyer C, respectively. While the expected response for the corresponding traits, when the intensity of selection equals one, were +546kg, +16.6kg and +15.6kg for MY, BFY, PRY respectively in the case of milk buyer A, +509kg, +17.1kg and +15.7kg for milk buyer B and +504kg, +17.3kg and +15.5kg for milk buyer C.

The correlations of indices of B and C with respect to index A were 0.97 and 0.84, respectively. This indicates that the loss of efficiency when selection index B and C were used is 3 % and 16 %, respectively. Rankings of Holstein cows under the three milk-pricing systems were different and this indicates that depending on the choice of their breeding goals South African Holstein breeders should follow different selection programs.

## OPSOMMING

'n Totaal van 150 673 eerstelaktasierekords van Suid-Afrikaanse Holsteinkoeie is gebruik om genetiese parameters van melk- (MO), bottervet- (BVO) en proteïnopbrengste (PRO) te beraam, asook bottervet- (BVP) en proteïnpersentasies (PRP). Die data wat 113 056 koeie en 1 429 vaars bevat, versprei oor 1 205 kuddes, is oor 'n periode van 21 jaar, 1980 – 2000, ingesamel.

Die studie is op die volgende aspekte gerig: om die nie-genetiese faktore te bepaal wat melk-eienskappe affekteer vir gebruik in die model vir 'n genetiese ontleding; om die variansie-kovariansie komponente en oorerflikhede van alle eienskappe te beraam; en ten laaste, om die wegingsfaktore vir 'n seleksie-indeks te bereken en die verwagte responsie op seleksie wanneer verskillende melkprysstelsse gebruik word.

Vyf vaste effekte is gedefinieer, nl. melkfrekwensie, ouderdom met kalwing, kudde, maand van kalwing en jaar van kalwing. Ontleding van variansie het aangetoon dat alle effekte hoogs betekenisvol ( $p < .0001$ ) was, wat gemiddeld 64.6%, 62.96%, 64.36%, 15.66% en 23.86% van die totale variansie vir MO, BVO, PRO, BVP en PRP onderskeidelik verklaar het. Met  $R^2$  en RMSE as 'n opsie het maand van kalwing vir alle eienskappe, melkfrekwensie vir BVP en PRP en ouderdom met kalwing vir PRP 'n baie klein bydrae tot die variansie gemaak en is dit dus uit die model gelaat vir die volgende ontleding.

Oorerflikheidsberamings het gewissel van medium vir BVO en PRO tot hoog vir MO, BVP en PRP. Dit is 'n aanduiding dat vinniger genetiese vordering moontlik sal wees deur seleksie van MO, BVP en PRP. Die hoogs positiewe korrelasie toon aan dat seleksie vir melkopbrengs 'n gunstige responsie met bottervet en proteïnopbrengs tot gevolg sal hê. Dit sal egter tot 'n ongunstige responsie lei op seleksie vir die persentasie-eienskappe. Dit is te wyte aan 'n negatiewe genetiese korrelasie tussen melkopbrengs met persentasie-eienskappe.

Onder die Desire-program is wegingsfaktore en verwagte responsie per generasie vir melk, bottervet en proteïnopbrengs bereken onder drie melkkopers se pryssisteme. Die standaardafwykings van alternatiewe teeltdoelwitte en seleksie-indekse is ook bereken.

Die wegingsfaktore vir melk, bottervet en proteïnopbrengste was 0.16, 2.41 en 3.24 vir melkkoper A, 0.04, 3.43 en 5.70 vir melkkoper B en 0.03, 3.48 4.37 vir melkkoper C onderskeidelik. Die verwagte responsie vir die korresponderende eienskappe met die intensiteit van seleksie gelyk aan een, was +546kg, +16.6kg en +15.6kg vir MO, BVO en PRO onderskeidelik in die geval van melkkoper A, +509 kg, +17.1 kg en +15.7 kg vir melkkoper B en 504kg, +17.3 kg en 15.5 kg vir melkkoper C.

Die korrelasie van indekse van B en C ten opsigte van indeks A was 0.97 en 0.84 onderskeidelik. Dit dui aan dat die verlies van doeltreffendheid met gebruik van seleksie-indeks B en C 3% en 16% onderskeidelik was. Rangskikking van Hosteinkoeie onder die drie melkpryssisteme het verskil en dit dui aan dat Suid-Afrikaanse Holsteintelers verskillende seleksieprogramme moet volg na gelang van die keuse van hul teeltdoelwitte.

## REFERENCES

- ALBUQUERQUE, L.G., KEOWN, J.F. & VAN VLECK, L.D., 1998.** Variance of direct genetic effects, maternal genetic effects, and cytoplasmic inheritance effects for milk yield, and fat percentage. *J. Dairy Sci.* 81 (2): 544-549.
- ALLAIRE, F.R. & THAEN, C.S., 1985.** Perspectives for genetic improvement in economic efficiency of dairy cattle. *J. Dairy Sci.* 68 (11): 3110- 3123.
- ALLAIRE, F.R. & GIBSON, J.P., 1992.** Genetic value of herd life adjusted for milk production. *J. Dairy Sci.* 75 (5): 1349-1355.
- AMER, P.R. & FOX, G.C., 1992.** Estimation of economic weights in genetic improvement using neoclassical production theory: an alternative to rescaling. *Anim. Prod.* 54: 341-350.
- ANONYMOUS, 2000.** National genetic evaluation programs for dairy production traits practiced in Interbull member countries. *Interbull Bulletin* 24: 85-90.
- BANGA, C.B. & RAUTENBACH, L., 1999.** Genetic Progress. In: *South African National Dairy Cattle Performance Testing Scheme, Agriculture Research Council, Irene, South Africa, Annual Report.* 19: 6-11.
- BIFFANI, S., SAMORÉ, A.B. & CANAVESI, F., 2002.** The new selection index for the Italian Holstein. *Proc. of the Interbull Meeting*, Interlaaken, Switzerland. *Interbull Bulletin* 29: 142-146.
- BOETTCHER, P.J., HANSEN, L.B., CHESTER, J.H. & YOUNG, C.W., 1993.** Responses of yield and conformation to selection for milk in a designed experiment with a control population. *J. Dairy Sci.* 76: 267-273.

- BOLDMAN, K.G. & FREEMAN, A.E., 1990.** Adjustment for heterogeneity of variances by production level in dairy cow and sire evaluation. *J. Dairy Sci.* 73: 505-512.
- BOURDON, R.M., 2000.** Understanding Animal Breeding. 2<sup>nd</sup> edition, Prentice Hall, Inc, New Jersey. 17-24.
- BRASCAMP, E.W., SMITH, C. & GUY, D.R., 1985.** Derivation of economic weights from profit equations. *Anim. Prod.* 40: 175-180.
- BROTHERSTONE, S., 1994.** Genetic and phenotypic correlation between linear type traits and production traits in Holstein-Friesian dairy cattle. *Anim. Prod.* 59: 183-187.
- CAMPHER, J.P., HUNLUN, C. & VAN ZYL, G.J., 1998.** South African Livestock Breeding. South African Stud Book and Livestock Improvement Association. 98-99.
- CASELL, B.G., 1992.** Calculating lactation records: Adjustments for early and late test periods. [www://inform.umd.edu/edres/topi/AGRenv/ndd/genetics/adjusting](http://inform.umd.edu/edres/topi/AGRenv/ndd/genetics/adjusting).
- CHAUHAN, V.P.S. & HAYES, J.F., 1991.** Genetic parameters for first lactation milk production and composition traits for Holsteins using multivariate restricted likelihood. *J. Dairy Sci.* 74: 603-601.
- DADO, R.G., MERTENS, D.R. & SHOOK, G.E., 1993.** Metabolizable energy and absorbed protein requirements for milk production. *J. Dairy Sci.* 76: 1575-1588.
- DE GROOT, B.J., KEOWN, J.F., VAN VLECK, L.D. & MAROTZ, E.L., 2002.** Genetic parameters and responses of linear type, yield traits, and somatic cell

- scores to divergent selection for predicted transmitting ability for type in Holsteins. *J. Dairy Sci.* 85 (6): 1578- 1585.
- DE JAGER, D. & KENNEDY, B.W., 1987.** Genetic parameters of milk yield and composition and their relationship with breeding goals. *J. Dairy Sci.* 70: 1258-1266.
- DE MATAWEWA, C.M.B. & BERGER, P.J., 1997.** Genetic and phenotypic correlation among 305-d milk yield, fertility, and survival of Holstein cows. *J. Anim. Sci.* 75 (Suppl. 1): 35
- DE WAAL, H. & HEYDENRYCH, H.J., 2001.** The effect of sampling frequency on the accuracy of estimates of milk-fat yields of dairy cows. *S. Afr. J. Anim. Sci.* 31 (1): 9-11.
- DOMMERHOLT, J. & WILMINK, J.B.M., 1986.** Optimal selection responses under varying milk prices and margins for milk production. *Livest. Prod. Sci.* 14: 109-121.
- DU PLESSIS, M. & ROUX, C.Z., 1998.** Derivation of economic weights for South African Holstein-Friesland. *Proc. of the 36<sup>th</sup> National Congr. of the SASAS.* Stellenbosch, South Africa. 125 -126.
- DU PLESSIS, M. & ROUX, C.Z., 1999.** A breeding goal for South African Holstein in terms of economic weight in percentage units. *S. Afr. J. Anim. Sci.* 29 (3): 237-244.
- DU TOIT, J., VAN WYK, J.B. & VAN DER WESTHUIZEN, J., 1998.** Genetic parameter estimates in the South African Jersey breed. *S. Afr. J. Anim. Sci.* 28: 146- 152.

- DZAMA, K., WALTER, J.P., RUVUNA, F., SANDERS, J.O. & CHIMONYO, M., 2001.** Index selection of beef cattle for growth and milk production using computer simulation modeling. *S. Afr. J. Anim. Sci.* 31(2): 65-75.
- ERASMUS, G.J., 2000.** Review of Holstein breed development in South Africa. *Proc. of the 10<sup>th</sup> World Holstein-Friesian Confer.* Sydney, Australia. 133 –135.
- EVERETT, R.W. & PEARSON, R.W., 1992.** Economics of dairy cattle breeding. Genetic improvement, Univ. of Ohio.
- FALCONER, D.S. & MACKAY, F.C., 1996.** Introduction to quantitative genetics. 4<sup>th</sup> edition, Longman, England. 325 - 330.
- GERTENBACH, W.D., 1991.** Breeds of dairy cattle. Dairying, in Kwazulu-Natal, Publications. Cedara Agricultural Development Institute.
- GIBSON, J.P., 1987.** Options and prospects for genetically altering milk composition. *Anim. Breed. Abstr.* 55: 231- 243.
- GIBSON, J.P., 1989a.** Selection on the major component of milk: Alternative methods of deriving economic weights. *J. Dairy Sci.* 72 (12): 3176 –3189.
- GIBSON, J.P., 1989b.** The effect of pricing systems, economic weights, and population parameters on economic response to selection in milk components. *J. Dairy Sci.* 72 (12): 3314 - 3326.
- GIBSON, J.P., GRAHAM, N. & BURNRSIDE, E.B., 1992.** Selection indices for production traits of Canadian dairy sires. *Can. J. Anim. Sci.* 72: 477-491.
- GILMOUR, A.R., CULLIS, B.R., WELHAM, S.J. & THOMPSON, R., 2000.** ASREML. Reference-Manual. NSW Agriculture, ORANGE, 2800, Australia.

**GODDARD, M.E., 1998.** Consensus and debate in the definition of breeding objectives. *J. Dairy Sci.* 81 (2): 6 -18.

**GROEN, A.F., 1988.** Derivation of economic values in cattle breeding. A model at farm level. *Agricultural Systems* 27: 195-213.

**GROEN, A.F., 1989a.** Economic values in cattle breeding. I. Influence of production circumstances in situation without output limitations. *Livest. Prod. Sci.* 22: 1-16.

**GROEN, A.F., 1989b.** Economic values in cattle breeding. II. Influence of production circumstances in situation with output limitations. *Livest. Prod. Sci.* 22: 17-30.

**GROEN, A.F., STEINE, T., COLLEAU, J.J., PEDERSEN, J., PRIBYL, J., REINSCH, N., 1997.** Economic values in dairy cattle breeding with special reference to functional traits. Report of an EAAP working group. *Livest. Prod. Sic.* 49: 1-21.

**GUO, Z., LUND, M.S., MADSEN, P., KORSGAARD, I. & JENSEN, J., 2002.** Genetic parameter estimation for milk yield over multiple parities and various lengths of lactation in Danish Jerseys by random regression models. *J. Dairy Sci.* 85 (6): 1596-1606.

**HALLOWELL, G.J., VAN DER WESTHUIZEN, J. & VAN WYK, J.B., 1998.** Variance component and heritability estimates for first and second lactation milk traits in the South African Ayrshire breed. *S. Afr. J. Anim. Sci.* 28(1): 46-49.

**HALLOWELL, G.J. & MOSTERT, B.E., 2001.** Genetic progress. In: *South African National Dairy Animal Improvement Scheme. Agricultural Research Council, Irene, South Africa, Annual Report.* 21: 4-7.

HARDING, F., 1995. Milk quality. 1<sup>st</sup> edition, Chapman & Hall, London, UK.

HAZEL, L.N., 1943. The genetic bases for constructing selection indices. *Genetics*. 28: 476-490.

HAZEL, L.N., DICKERSON, G.E. & FREEMAN, A.E., 1994. Symposium: Selection index theory. The selection index- Then, Now, and for the Future. *J. Dairy Sci.* 77(10): 3236- 3251.

HENDERSON, C.R., 1984. Application of linear models in animal breeding. Univ. of Guelph, Guelph, Ontario, Canada.

HILLERS, J.K., YOUNG, J.W., FREEMAN, A.E. & DOMMERHOLT, J., 1979. Effects of milk composition and production on the feed cost of producing cow. *J. Dairy Sci.* 62 (10): 1662 - 1664.

HILLERS, J.K., 1984. Sire selection under alternative systems of milk pricing. *J. Dairy Sci.* 67 (2): 444-449.

KELLER, D.S. & ALLAIRE, F.R., 1990. Economic weights for genetic changes in milk component yields at the herd level. *J. Dairy Sci.* 73 (6): 1631-1643.

KINGHORN, 2000. Desire software programm. <http://www-personal.une.edu.au/~bkinghor/desire.htm> .

LEGATES, J.E. & MYERS, R.M., 1972. Genetic change in a dairy herd using a control population. *J. Dairy Sci.* 55 (5): 681- 682.

LIU, Z., REINHARDT, F. & REENTS, R., 2002. Genetic correlation estimates of multiple lactation multiple country models for milk production traits based on

- performance records. *Proc. of the InterBull Meetings*. Interlaaken, Switzerland. *Interbull Bulletin* 29: 12-17.
- LOBO, R.N.B., MADALENA, F.E. & VIEIRA, A.R., 2000.** Average estimates of genetic parameters for beef and dairy cattle in tropical regions. *Anim. Breed. Abstr.* 68: 433 - 462.
- MAHER, J., 1997.** Cattle breeds: history and origin of Holstein-Friesian. <http://www.agric.nsw.gov.au/reader/1826>. Accessed 06/12/2001.
- MANDIZHA, S., MAKUZA, S.M. & MHLANGA, F.N., 2000.** Selection response for milk, fat and protein yields in Zimbabwean Holstein cattle. *Asian-Australasian J. Anim. Sci.* 13 (7): 883-887, CAB Abstr.
- MONTGOMERIE, B., 2000.** Breeding for profit in New Zealand- the breeding worth index. *Proc. of the 10<sup>th</sup> World Holstein-Friesian Confer.* Sydney, Australia. 99-102.
- MOORE, R.K., KENNEDY, B.W., SCHAEFFER, L.R. & MOXLEY, J.E., 1992.** Relationship between age and body weight at calving, feed intake, production day open, and selection indices in Ayrshires and Holsteins. *J. Dairy Sci.* 75: 294-306.
- MOSTERT, B.E., THERON, H.E., KANFER, F.H.J., 2001.** The effect of calving season and age at calving on production traits of South African dairy cattle. *S. Afr. J. Anim. Sci.* 31 (3): 205-214.
- OJANGO, J.M.K. & POLLOTT, G.E., 2001.** Genetic of milk yield and fertility traits in Holstein-Friesian cattle on large-scale Kenyan farms. *J. Anim. Sci.* 79(7): 1742-1750.

- OJANGO, J.M.K. & POLLOTT, G.E., 2002.** The relationship between Holstein bull breeding values for milk yield derived in both UK and Kenya. *Livest. Prod. Sci.* 74 (1): 1-12.
- ONGE, S.T.A., HAYES, J.F. & CUE, R.I., 2002.** Economic values of traits for dairy cattle improvement estimated using field-recorded data. *Can. J. Anim. Sci.* 82: 29-39.
- PANDER, B.L., HILL, W.G. & THOMPSON, R., 1992.** Genetic parameters of test day records of British Holstein-Friesian heifers. *Anim. Prod.* 55: 11- 21.
- PEARSON, R.E. & MILLER, R.E., 1979.** Economic definition of total performance, breeding goals and breeding values for dairy cattle. *J. Dairy Sci.* 64: 857-869.
- PEREIRA, J.A.C., SUZUKI, M., HAGIYA, K., YOSHEZAWA, T., TSURUTA, S. & MISZTAL, I., 2001.** Method R estimates of heritability and repeatability for milk, fat and protein yields of Japanese Holstein. *J. Anim. Sci.* 72 (5): 372-377, CAB Abstr.
- PHILIPSSON, J., BANOS, G. & ARNASON, T., 1994.** Present and future uses of selection index methodology in dairy cattle. *J. Dairy Sci.* 77(10): 3252-3261.
- PIETERS, T., CANAVESI, F., CASSANDRO, M., DADATI, E., ARENDONK, J.V. & VAN ARENDONK, J., 1997.** Consequence of difference in pricing systems between regions on economic values and revenues of a national dairy cattle breeding scheme in Italy. *Livest. Prod. Sci.* 49 (1): 23-32.
- PIRLO, G., MIGLIOR, F. & SPERONI, M., 2000.** Effect of age at first calving on production traits and on difference between milk yield returns and rearing costs in Italian Holstein. *J. Dairy Sci.* 83 (3): 603-608.

- RAUW, W.M., KANIS, E., NOORDHUIZEN STASSEN, E.N. & GROMMERS, F.J., 1998.** Undesirable side effects of selection for high production efficiency in farm animals: a review. *Livest. Prod. Sci.* 56: 15-33.
- REGE, J.E.O., 1991.** Genetic analysis of reproductive and productive performance of Friesian cattle in Kenya. 1. Genetic and phenotypic parameters. *J. Anim. Breed. Genet.* 108: 412-423.
- RENSING, S., PASMAN, E., REINHARDT, F. & FEDDERSEN, F., 2002.** New total merit index RZG for Holstein in Germany with more emphasis on herd life. *Proc. of the Interbull Meeting*. Interlaaken, Switzerland. *Interbull Bulletin* 29: 147-149.
- ROMAN, R.M. & WILCOX, C.J., 2000.** Bivariate animal model estimates of genetic, phenotypic, and environmental correlations for production, reproduction, and somatic cells in Jerseys. *J. Dairy Sci.* 83 (4): 829-835.
- ROSATI, A. & VAN VLECK, L.D., 2002.** Estimation of genetic parameters for milk, fat, protein and mozzarella cheese production for the Italian river buffalo *Bubalis bubalis* population. *Livest. Prod. Sci.* 74 (2): 185-190.
- SAS, 1996.** SAS. User's Guide. SAS Institute Inc, Cary, Nc, USA.
- SCHMIDT, G.H. & VAN VLECK, L.D., 1974.** Principles of dairy science. Freeman, San Francisco. 75- 82.
- SIVANADIAN, B., LOHUIS, M.M. & DEKKERS, J.C.M., 1998:** Expected genetic responses from selection indices for Canadian dairy cattle under present and future milk pricing systems. *Can. J. Anim. Sci.* 78 (2): 157-165.
- SMITH, H.F., 1936.** A discriminant function for plant selection. *Annals of Eugenics* 7: 240-250.

- SMITH, C., 1983.** Effects of changes in economic weights on the efficiency of index selection. *J. Anim. Sci.* 56: 1057-1064.
- SMITH, C., JAMES, J.W. & BRASCAMP, E.W., 1986.** On the derivation of economic weights in livestock improvement. *Anim. Prod.* 43: 545-551.
- SPELMAN, R.J. & GARRICK, D.J., 1997.** Effect of live weight and differing economic values on response to selection for milk fat, protein, volume, and live weight. *J. Dairy Sci.* 80 (10): 2557-2562.
- STRABEL, T. & SZWACZKOWSKI, T., 1997.** Additive genetic and permanent environmental variance components for test day milk traits in Black White Cattle. *Livest. Prod. Sci.* 48 (2): 91-98.
- THERON, H.E., VAN DER WESTHUIZEN, J. & RAUTENBACH, L. 2001.** The use of breeding values in the South African dairy industry. In: *Dairy Herd Improvement in South Africa, Agricultural Research Council Animal Improvement Institute, South Africa, Irene.* Edited by Loubser, L.F.B., Banga, C.B., Scholtz, M.M. & Hallowell, G.J. 25-28.
- VAN TASSELL, C.P., WIGGANS, G.R. & NORMAN, H.G., 1999.** Method R. estimations of heritability for milk, fat and protein yields of United States Dairy Cattle. *J. Dairy Sci.* 82: 2231-2237.
- VAN VLECK, L.D., POLLAK, E.J. & OLTENCHU, E.A., 1987.** Genetics for Animal Science. W. H. Freeman & Company, New York. 326-332.
- VARGAS, B., HERRERO, M., & VAN ARENDONK, J.A.M., 2001.** Interaction between optimal replacement policies and feeding strategies in dairy herds. *Livest. Prod. Sci.* 69: 17-31.

- VARGAS, B., GROEN, A.B.F., HERRERO, M. & VAN ARENDONK, J.A.M.,**  
2002. Economic values for production and functional traits in Holstein cattle of Costa Rica. *Livest. Prod. Sci.* 75: 101-116.
- VEERKAMP, R.F., DILLON, P., KELLY, E., CROMIE, A.R. & GROEN, A.F.,**  
2002. Dairy cattle breeding objectives combining yield, survival and calving interval for pasture based systems in Ireland under different milk quota scenarios. *Livest. Prod. Sci.* 76: 137-151.
- VISSCHER, P.M. & THOMPSON, R., 1992.** Comparison of genetic variance from different types of relatives in dairy cattle. *Anim. Prod.* 55: 315-320.
- WATTIAUX, M.A., 1995.** Dairy Essentials. 5<sup>th</sup> edition, Babcock Institute for International Dairy Research and Development. Univ. of Wisconsin, Madison.
- WELLER, J.L., 1994.** Economic Aspects of Animal breeding. 1<sup>st</sup> edition, Chapman & Hall, London, UK. 118-131.