The Contribution of Genetic Parameters to the Profitability of Canadian Holstein Cows

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ABSTRACT

Increase in profits corresponding to a one unit increase in Estimated Breeding Value (EBV) for 3 production traits and for 21 type traits were estimated from 31,123 merged "Official" first lactation records, type records and Estimated Breeding Value (EBVs) records of Canadian Holstein cows using multivariate REML and a mixed model accounting for herd and year of calving effects. The same regression model was used to estimate the same profit increases corresponding to a one unit change in EBVs from 336 merged "Non-Official" first lactation records, type records and EBV records of Canadian Holstein Cows to investigate whether purebred breeders are selecting their animals according to type and production performances while commercial producers are selecting animals that maximize their milk profits. Finally, the usefulness of DHAS cow records for increasing milk profits was investigated by comparing the average profit level of cows with "Official" milk records and their time of registration under the DHAS scheme.

Size had the largest negative impact on profits, with estimates ranging from -41.70 ± 6.60 to -26.62 ± 5.91. Chest width and fore attachment had the largest positive impact on profits, with estimates ranging from 4.30 ± 5.94 to 16.82 ± 6.00 and from 4.71 ± 3.52 to 14.57 ± 3.97 respectively. Grade cows were found to have on average lower EBVs for most type and production traits than purebred cows. However, grade and purebred cows generated similar milk profits. Finally, the efficiency of using information provided by DHAS to increase profits did not increase with the number of years of participation with DHAS.

RÉSUMÉ

L'augmentation des profits correspondant à une augmentation de une unité de la Valeur d'Élevage Estimée (VEE) pour 3 traits de production et pour 21 traits pour le type ont été estimés à partir de 31,123 dossiers fusionnés incluant des données de premières lactations "officielles", de pointages pour le type et de Valeurs d'Élevages Estimées (VEE) pour des vaches holsteins canadiennes en utilisant un modèle mixte selon la méthode de la multivariable de Maximum de Vraisemblance Restreinte (MVR) en tenant compte des effets de troupeaux et d'années de vêlage. Le même model de regression a été utilisé pour estimer la même augmentation de profits lorsque la VEE est augmentée de une unité à l'aide de 336 dossiers fusionnés "non-officiels" de premières lactations, de pointages pour le type et de VEEs pour des vaches holsteins canadiennes dans le but de déterminer si les éleveurs de vaches de race holstein pure selectionnent leurs animaux par rapport à leur type et à la quantité de lait ils produissent alors que les producteurs commerciaux selectionnent leurs animaux dans le but de maximiser les profits génèrés par la vente de lait produit par leurs troupeaux. Finalement, l'utilité des rapports de productions produient par le PATLQ a été éxaminé en comparant les nivaux moyens de profits générés par les vaches ayant des dossiers officiels de lactations avec leurs temps d'enregistrement avec le PATLQ.

La grosseur avait le plus grand impact negatif sur les profits, avec des estimés allant de -41.70 ± 6.60 à -26.62 ± 5.91. La largeur de pointrine et l'attache de pis avant avaient la plus grande impact positive sur les profits, avec des estimés allant de 4.30 ± 5.94 à 16.82 ± 6.00 et de 4.71 ± 3.52 à 14.57± 3.97 respectivement. Les vaches commerciales avaient généralement des VEEs inférieurs à la moyenne des vaches holsteins de race pure pour la plupart des traits. Cependant, les vaches commerciales et les vache pure-races généraient des profits laitiers similaires. Finalement, l'efficacité d'utilisation d'informations fournient par le PATLQ dans le but d'augmenter la profitabilité des troupeaux laitiers ne semblait augmenter avec le nombre d'années de participation avec le PATLQ.

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CHAPTER 1

INTRODUCTION

Dairy Production in Quebec

In 1995, 45% of the total number of Canadian dairy producers were situated in the Province of Quebec, where dairy production is considered the most important agricultural sector since it generates 36% of Quebec's total annual agricultural returns, amounting to $1.14 billion in 1995 (Roberge et al.,1995). Although the number of dairy producers in Quebec has been steadily declining over the years (363 producers left the industry from 1994 to 1995), production has increased by 4% from 1994 to 1995, reaching 2,654 millions liters of milk. This is in response to the increasing demand for milk products, especially fluid milk (Statistics Canada, 1995). This upward trend in demand indicates that farmers can increase their production volume in order to meet market demand and this would increase their gross revenues, thus increase their standard of living.

However, the rapid changes in Quebec's agricultural economic infrastructure, caused by the globalization of international markets will force dairy producers, in the near future, to modify the way in which they operate their business in order to survive (Daoust and Belzile, 1993). From a political standpoint, measures are being taken in that direction. For example, since August 1st 1995, Quebec's milk producers as well as Nova Scotia's, New Brunswick's, Prince Edward Island's, Ontario's and Manitoba's milk producers have been pooling all the milk they produce, which represents 80% of Canada's total milk production. Because of that change, composite pricing and milk classes will probably have to be renegotiated, possibly negatively affecting the profit level of milk producers if they do not adjust their production to this change (Dagenais, 1995). However, since the quota system is still in place at this date, dairy farmers can only expand their production subject to the outstanding quota available, which is limited and expensive (e.g.: $34/kg of fat in 1994) (Roberge et al., 1995).

Alternatively, profits can be increased without changing the volume of production by increasing the efficiency of production. Investing in assets such as pellet makers, round bail distributors or automatic silage and concentrate distributors can help increase feeding efficiency (Beauregard, 1995). However, a more sustainable and economical solution for dairy farmers could be to improve the genetic quality of their herd. Breeding superior animals producing higher amounts of milk, fat and protein, having a longer herdlife, higher feeding efficiency and better resistance to diseases related to milk production and parturition could lead to increased profits for the dairy producer. In this way, production is increased while operating costs such as feeding costs, veterinary expenses and replacement costs are decreased. Furthermore, since milk in Canada is priced according to its components: milk protein and fat, it makes sense for a farmer to breed cows that will yield the highest amount of milk, protein and fat possible, while consuming a large amount of good quality forage, thereby reducing the amount of grain required in the ration. Not only is it cheaper to feed an efficient ruminant, it also reduces their dependence on food that can be used for human consumption.

To increase the genetic quality of his herd, a dairy producer could either purchase dairy cattle that already possess superior productive qualities or select and breed his cows for desirable production qualities that will in turn increase his profits. However, it is very difficult to evaluate the impact these genetic improvements can bring to a dairy enterprise since they all interact one with another due to genetic[1] and phenotypic[2] correlations. Therefore, a straightforward method of measuring and of reporting the value of any genetic improvement in cows with respect to profit would be a useful tool for dairy producers to help them improve the genetic quality of their herd, and consequently improve their overall profitability.

Problem Statement

The initial objective of this study was to investigate the relationships between the market value of a pedigree dairy cow and its production and type traits so that it could be determined whether the value of the animal is a function of its production capacity, its type[3] or a mixture of both.

[1] Refers to the effect the genes of the animal have on its production or its physical appearance (Schmidt et al., 1988).

[2] Refers to the expression of the genetic and environmental effect for an animal's trait (Van Vleck et al., 1987).

[3] Refers to the physical appearance of an animal (Diggins et al, 1984)

Assuming the latter possibility is the answer, the level of contribution of the most significant traits to the value of dairy animals could then be determined by expressing it in terms of characteristics and by then regressing these characteristics against the price of the cow. This method, called hedonics, consists of generating implicit prices for studied characteristics of an heterogeneous class of goods within a defined market and is mostly used in studies that require information about price formation, which is of interest in this study.

However, data on purchase and/or market price of pedigree dairy cows is unavailable thus the primary objective of the study had to be restated. Since a large number of observations on the value of milk produced by cows under the milk recording program in Quebec (DHAS) was available, it was decided that the total value of the milk produced by each observed animal minus the cost of inputs to the production process (i.e. profit generated by each animal) for a first lactation could provide the closest measurable proxy to their actual market value. The Dairy Herd Analysis System (DHAS) has two main methods for its data collecting:

1) DHAS sends representatives on dairy farms to monitor the collection of milk samples and to record each cows performance level. This type of service is necessary to qualify as an "Official Herd".

2) The producer himself collects milk samples, records each cows performance level and sends it the DHAS for analysis. This type of herd qualifies as an "Owner-Sampler Herd".

Generally, "Official Herd" producers under DHAS also have their cows' conformation appraised by a breed association, while most "Owner Sampler Herd" producers do not. Knowing this we can make the following assumptions:

- "Official Herd" producers generally have purebred animals in their herd.
- "Owner Sampler Herd" producers generally are commercial dairy producers that have grade animals in their herd.

In the Canadian dairy industry, purebred breeders can generate revenues not only by selling the milk they produce but also by selling animals or by selling embryos from animals that are known to be superior with respect to their conformation, their production capacities or both. It is also a fact that most purebred breeders place an intrinsic value on the fulfillment they obtain from breeding good looking animals that could potentially perform well in dairy expositions. Conversely, commercial producers place very little value on this since grade cows usually are poorer with respect to conformation, they have less value on the market and they cannot be shown.

Therefore, we can assume the following:

- "Official Herd" producers breed animals for both type and production performances.
- "Owner Sampler" producers breed animals for profitability with respect to milk production only.

Therefore, the new objectives can be re-stated as follows:

1) To investigate the relationships of first lactation profit generation by a cow with type and production traits by calculating the weight of each type and production characteristics with respect to profit.
2) To investigate whether animals in commercial herds are selected to maximize milk production profits while animals in purebred herds are selected for production and type performances.

Justification for the Study

The main income of Quebec dairy producers generally originates from milk sales which have been priced according to milk, fat and protein yield since 1992. For this reason, the primary emphasis in dairy cattle selection is for production traits because cows that produce large amounts of milk produce more revenue (Bertrand et al., 1985). But in order to sustain high milk production over their lifetime, dairy cows also need to remain functionally sound because those that produce a lot in the short term can, in the long term be less profitable due to conformation defects, such as pendulous udders or sickle hocks[4], which limit herd life by having to cull (remove) cows from the herd earlier than they should in a better case. It is believed by most dairy producers that it is important to breed cows that not only produce a lot of milk but also possess a good conformation (type), which is essential to continue producing large quantities of milk for many years.

In order to provide dairy producers with an unbiased evaluation of the conformation of their animals, the Canadian Holstein Association initiated a classification program for type in 1925. As interest in artificial insemination increased in the 1950's, classification of sires' daughters became essential in order to analyze breeding values of bulls. These breeding values are used by dairy producers to make breeding decisions at the farm level (Canadian Holstein Association, 1995) The Canadian Holstein Association presently collects data on 21 types traits (12 coded and 9 measured) scored on a linear scale which yield a final conformation score where 100 is the optimal score. The weight allowed to each type trait over the final score is related to their genetic correlation with milk yield as computed by the breed association. In the dairy industry cows are currently being valued according to the value of their milk production, milk volume and its constituents, minus the cost of the inputs in the production process, resulting in the net economic value of the dairy cow. Input costs can be computed by adding feeding costs, insemination costs, labor, culling (removing an animal from the herd and replacing it with another), genetic gains, and constraints (such as quota and cash flow) (Groen, 1989). To increase their profits, dairy producers can genetically improve their herd by selecting for milk production, fat production, protein production, body weight, feed efficiency, disease resistance,

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[4] Crooked hind legs (Diggins et al., 1984)

mastitis resistance, milking speed, and other traits. Therefore, it is important for dairy producers to possess guidelines to help determine which attributes are most profitable to select for in a breeding scheme in order to make efficient decisions in the process of building a herd.

CHAPTER 2

LITERATURE REVIEW

The Profit Function

Profit generated by a dairy cow in her first lactation can be assumed to correspond to the total value of milk produced in that period minus the total costs of feeding the animal during that period (feed costs during lactation period + feed costs during dry period). A more accurate estimate of profits generated by a cow in her first lactation should also included veterinary expenses, and losses due to discarded milk, which may vary considerably from one animal to another and may be a good indication of the soundness of an animal. However, such data is unavailable, thus we assumed that health problems will be a factor reducing milk yield and its quality. Indeed, Deluyker et al. (1991) and Uribe et al. (1995) reported that the occurrence of clinical diseases, such as dystocia[5], stillbirth, twin births, milk fever, retained placenta, displaced abomasum, limping due to foot lesions, metritis[6], ketosis[7] and mastitis[8] were negatively correlated with milk yield. Thus it was decided that the profit generated by a cow should be a function of the estimated breeding values of production and type characteristics.

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[5] Difficult calving (Schmidt et al.,1988).
[6] Inflammation of the uterus (Schmidt et al., 1988).
[7] Decrease in blood glucose and increase in blood ketone bodies (Schmidt et al., 1988).
[8] Inflammation of the udder (Diggins et al., 1984).

Characteristics

For selection purposes in breeding schemes, the evaluation of genetic value of dairy cattle is a key factor in the decision process. For that reason, research in breeding is often oriented toward finding the genetic merit of a cow which is determined by its ability to produce high quantities of milk, fat and protein, while maintaining this level of production over several lactations. In practice, breeders have observed that high production along with longevity could only by achieved by developing a cow that would not only produce a lot, but would also possess the necessary physical attributes (type) that would allow for sustained high milk production. Very few studies exist in the literature on the relationships between milk, fat and protein yield with production and type traits.

Norman and Van Vleck (1972) used a random effects model which included herd, year, sire and sire x herd effects to estimate phenotypic and genetic correlations between 48 type appraisal traits and first lactation milk production. They reported that strength of fore udder attachment had the highest genetic correlation with lifetime performance (2.23).

Norman et al. (1981) also used a random effects model including herd and year effects to estimate relationships between profit (income from milk, calves and costs) and first lactation production and type characteristics. It was found that dairy character had the highest correlation with relative net income per day of productive life (.34).

Meyer et al. (1987) reported genetic correlations ranging from -.52 to .24 between linear type score and first lactation British Fresians. Udder depth had the most negative correlation with milk yield (-.52).

Norman et al. (1988) calculated genetic correlations between first lactation milk yields and linear type traits for Jerseys and Guernseys. Similarly to previous research, udder depth and fore udder had the largest negative genetic correlation with milk yield (-.59 and -.56) while the largest positive genetic correlation with milk yield was for dairy character.

Finally, Misztal et al. (1992) investigated relationships between milk yield and type traits, using a multitrait Restricted Maximum Likelihood (REML) procedure with an animal model. Again, negative relationships between type traits such as udder depth, fore udder attachment and front teat placement were found.

Production Traits

The following section consists of a summary of the relationships existing between production traits and yield, which are directly linked to the profit function.

MILK YIELD

Milk is the primary product of a dairy enterprise and as it increases, milk sales increase, thus milk producers' net returns (profits) should also increase. For that reason, it is reasonable to state that the overall genetic value of a cow is determined by her lifetime production (Harris, 1992). The lifetime production of a cow is 50% determined by the cow's real producing ability, which includes the genetic value and 50% to a permanent environmental effect that remains with the cow throughout its lifetime (Schmidt et al., 1988). Although milk production is positively related to both protein and fat production, it appears to be more related to protein yield. (Harris, 1992)

PROTEIN YIELD

Since 1992 in Canada, protein yield has been included in the composite pricing of milk and is therefore positively related with milk sales. In the literature, it has been reported that milk yield and protein yield are highly correlated genetically (.79-.83) (Albuquerque et al,. 1995, Chauhan and Hayes, 1991) as well as fat and protein yields (.68) (Chauhan and Hayes, 1991).

FAT YIELD

As with protein yield, fat yield is also included in the composite pricing of milk, thus the amount of fat in milk is positively related to the income generated from milk sales. Fat yield can be increased to a certain degree by providing dairy animals with feed high in fat such as linseed oil, cottonseed oil or tallow. This alternative is not popular among dairy producers because it is temporary and known to cause a decrease in the casein content of milk which is related to the protein content of milk (Schmidt et al., 1988). Fat yield is also known to change according to the cow's age (fat percentage production tends to decline in cows from first through fifth lactation) and environment, but more importantly, the amount of fat produced by a dairy animal will depend on its genetic value (effect the genes of the animal have on its production). Albuquerque et al. (1995) and Chauhan and Hayes (1991) reported moderate genetic correlations of respectively .52 and .42 between milk and fat yield in Holstein cows.

Type Characteristics

Type characteristics in dairy cattle refer to an ideal or standard of perfection that combines all the body characteristics that contribute to the utility of a cow. These characteristics are based only on the appearance of the animal and do not include any production performances. They are related to milk production because cows that have a good functional type will tend to stand up longer under high production than cows with a mediocre body type (Trimberger et al, 1987). To demonstrate this point, and as mentioned by Trimberger et al. (1987), Kliewer found that when milk yield alone is used in selection (top ten percent), herd life is decreased by 153 days in five generations and by 306 days in ten generations. However, when both production and type classification scores are considered in selection decisions, herd life is increased by 255 days in five generations and by 510 days in ten generations. Further, Norman and Van Vleck (1972) reported that 35 type traits of Holsteins in first lactation were as useful as production variables in predicting the herd life of a dairy animal. Table 1 illustrates the traits to be considered in the analysis along with their method of measurement.

Table 1. Type Characteristics

(7) TRAITS ON THE POINTAGE CARD	(21) DESCRIPTIVE TRAITS	(12) CODED/ (9) MESURED
FRAME/CAPACITY (20 points)	Stature	measured
	Front-end	coded
	Size	measured
	Chest width	coded
	Body depth	coded
	Loin strength	coded
RUMP (10 points)	Rump angle	measured
	Pin width	measured
FEET AND LEGS (16 points)	Foot angle	coded
	Bone quality	coded
	Rear leg side view	coded
FORE-UDDER (13 points)	Fore-attachment	coded
	Fore teat placement	coded
	Fore teat length	measured
REAR-UDDER (17 points)	Rear attach height	measured
	Rear attach width	measured
	Rear teat placement	coded
MAMMARY SYSTEM (40 points) -includes: Fore-udder (13 points) Rear-Udder (17 points)	Udder depth	measured
	Udder texture	coded
	Median suspensory	measured
	(Fore-udder)	
	(Rear-udder)	
DAIRY CHARACTER (14 points)	Dairy form	coded

(Canadian Holstein Association, 1995)

FRAME/CAPACITY

This trait appears to be weakly correlated genetically with profits generated by a dairy animal (.12), as reported by Norman et al. (1981). However, it represents 20 % of the final linear type score of a cow (Canadian Holstein Association, 1995)

STATURE

This characteristic refers to the height of a cow at the rump (Canadian Holstein Association, 1995). A taller cow will score higher since its udder will tend to be cleaner and less prone to injury because it is higher above the ground. Cows with high udders also tend to incur less veterinary expenses and milk production drop by avoiding the chance of mastitis (Trimberger et al., 1987) Norman et al. (1981) found a low correlation coefficient of .10 between stature and relative net income per day of the productive life in Jerseys, while Klassen et al. (1992) reported low to moderate genetic correlations between lifetime milk production and milk yield (.14 to .25). This trait is measured, 9 being the optimal score (Canadian Holstein Association, 1995)

FRONT END

This characteristic refers to the height of the animal at the wither, which determine its upstandingness (Canadian Holstein Association, 1995). Similar to possessing height at the rump, a tall cow at the wither will generally be cleaner, less prone to udder injuries and mastitis, thus with a longer herdlife. This results in decreased veterinary expenses and lower risk of a drop in milk production due to injury or infection (Trimberger et al., 1987). Research has shown that the genetic correlation between lifetime production and upstandingness is high (.71), thus it may be of importance in milk production selection schemes (Norman and Van Vleck, 1972). This trait is coded, 9 being the optimal score (Canadian Holstein Association, 1995).

SIZE

Size refers to the space occupied by the cow and is measured in terms of her weight (Canadian Holstein Association, 1995). For this characteristic, a cow that is functional by being neither too big nor too small will be preferred since it will allow for smooth and efficient use while occupying a reasonable space in the barn. Larger, heavier cows generally eat more, thus produce more milk in total and have a greater slaughter (salvage value) than small cows. However, small individuals can produce comparable amounts of milk by eating less feed, thus reducing the costs of production (Trimberger et al., 1987). It has been initially reported by Norman and Van Vleck (1972) that the genetic correlation between lifetime production and body weight was moderate (.56). However, in a more recent study, Klassen et al. (1992) derived much lower correlation estimates with a REML algorithm for the same traits (.07 to .18). This trait is measured, 9 being the optimal score (Canadian Holstein Association, 1995).

CHEST WIDTH

A desirable chest in dairy animals should be deep and full with ample distance across the front legs. Wide chests are a good indication of larger capacity, which is associated with larger feed intake by the animal, thus higher milk yield while narrow chests are associated with occurrence of lameness in dairy animals which generally results in increased veterinary expenses and often results in a decrease in milk production (Trimberger et al., 1987). This trait is coded, 9 being the optimal score (Canadian Holstein Association, 1995).

BODY DEPTH

Body depth is a measure of the size of a cow's rib cage compared to the rest of its body. An ideal cow displays long, deep, wide, strong and arched ribs, which are good indications of feed efficiency in an animal (i.e. the animal can consume a higher quantity of high-quality forage versus less grain, which is the primary utility in ruminants) (Trimberger et al., 1987). However, a field study by Norman and Van Vleck (1972) shows a negative genetic correlation between lifetime production and body depth (-.02) This trait is coded, 9 being the optimal score (Canadian Holstein Association, 1995).

LOIN STRENGTH

This characteristic corresponds to the strength between the back and the rump of the animal (Canadian Holstein Association, 1995). In practice, it is believed that loin strength is not directly related to milk production itself but is often associated with general strength and conformation, especially the condition of feet and legs. Strong backs in dairy animals will generally result in a well supported udder, better reproductive characteristics and more effective digestion, which is crucial in milk production. The preferred appearance for the loin is broad, strong and nearly leveled (Trimberger et al., 1987). However, Norman and Van Vleck (1972) showed that genetic correlation between lifetime production and loin strength is negative (-.28), which contradicts the common belief that one should select for strong backs in dairy cattle. This characteristic is coded, 9 being the optimal score (Canadian Holstein Association, 1995).

RUMP

The rump is closely related to milk production performance in a dairy animal since it supports the udder (Trimberger et al., 1987). A cow displaying a wide rump is preferable since it will generally have lower risk of dystocia and all the economic losses associated with it, such as veterinary expenses, decreased milk production and replacement costs. This characteristic has a 10% weight with respect to the overall type score (Canadian Holstein Association, 1995).

RUMP ANGLE

This characteristic corresponds to the placement of pin bones relative to the placement of hip bones (Canadian Holstein Association, 1995). In dairy cows, pin bones are preferably placed slightly lower than the hips to facilitate uterine drainage and to reduce the occurrence of genital tract and calving complications. These problems can lead to increased veterinary expenses, a lowering of potential milk yield and a decrease in herd life implying an increased replacement cost (Trimberger et al., 1987). Accordingly, research shows low (.06) to moderate (.10 to .16) genetic correlation between lifetime production and rump angle (Norman and Van Vleck, 1972, Klassen et al., 1992). This characteristic is measured and the optimal score is an intermediate five over a one to nine scale (Canadian Holstein Association, 1995).

PIN WIDTH

This characteristic corresponds to the distance between the two pin bones (Canadian Holstein Association, 1995). A large distance between pin bones is preferable and associated with calving ease, which results in lower veterinary costs and lower postpartum complications, which are known to decrease milk yield and often lead to culling the animal, implying increased replacement costs (Trimberger et al., 1987). This characteristic is measured and scoring 9 is ideal (Canadian Holstein Association, 1995).

FEET & LEGS

Along with the udder, feet and legs are considered in type classification as the most important functional type characteristic for a dairy cow. A good type for feet and legs is known to be both under the influence of heritability and the environment, especially when the animals are confined (Trimberger et al., 1987). Costs associated with feet problems can appear in the form of veterinary expenses, a reduction of feed intake resulting in lower milk yield, lower reproductive performance and additional replacement costs. However, research shows a very low correlation level (.08) between relative net income generated per day of productive life and feet and legs (Norman et al.,1981). In a linear type evaluation, rear legs receive more emphasis than front legs since they are judged more important than front legs in production performance. The total weight assigned to this trait represents 16% of the total classification score of the animal (Canadian Holstein Association, 1995)

FOOT ANGLE

This characteristic corresponds to the angle of the cow's hooves (Canadian Holstein Association, 1995). Extremely steep hooves reduce the risk of lameness due to bruised heels and are therefore the ideal type for this trait. Lameness caused by weaknesses of the trait could incur supplementary veterinary expenses, a decrease in milk production and increased replacement costs (Trimberger et al., 1987). However, research contradicts this affirmation by reporting notable negative correlations between rear heel angle and lifetime production, ranging from -.16 to -.31 (Norman and Van

Vleck, 1972, Choi and McDaniel, 1993). This trait is coded, 9 being the optimal score (Canadian Holstein Association, 1995).

BONE QUALITY

This characteristic refers to the bone structure of the cow's legs (Canadian Holstein Association, 1995). A strong, smooth, substantial and refined leg bone is ideal since it indicates an animal with the right combination of bone, tendon, ligament and muscle built to provide a good foundation for the entire body, allowing smooth and easy movements. Ideal bone structure is positively associated with longer herd life under sustained high milk production (Trimberger et al., 1987). This characteristic is coded, 9 being the optimal score (Canadian Holstein Association, 1995).

REAR LEG SIDE VIEW

This characteristic corresponds to the setting of hind legs, ranging from extremely strait to extremely sickled (Canadian Holstein Association, 1995). A correct rear set of legs is an important characteristic since it denotes an animal that is coordinated and carries its weight properly. A cow that has legs too close at the hocks will carry her weight at a bad angle on the hocks and pastern, causing uneven wear of hooves which can deteriorate further and cause lameness in the animal (Trimberger et al., 1987). Accordingly, Norman and Van Vleck (1972) reported a moderate genetic correlation of .31 between lifetime production and rear leg side view. This trait is coded, scoring an intermediate five over a one to nine scale is ideal (Canadian Holstein Association, 1995).

UDDER

The udder is the characteristic that receives the most attention in a linear type evaluation of dairy cows since it is the most closely related to milk production. An animal with a good udder type will have lower risks of injury, of mastitis, and will stand up better under high production than an animal with a weak udder. A positive relationship (phenotypic) was found between the mammary system with milk production in Jerseys, and herdlife and production in Holsteins (.15) (Norman et al., 1981).

FORE UDDER

The fore udder corresponds to the two quarters situated in the front part of the udder (Canadian Holstein Association, 1995). A desirable fore udder, according to type appraisal, should have a moderate capacity and length, with a floor at the same level as the rear udder (Trimberger et al., 1987). Klassen et al. (1992) found a notable negative genetic correlation between fore udder and lifetime production (-.05 to -.11). However, it was reported by Norman et al. (1981) that relative net income per day of productive life and fore udder had a positive correlation coefficient of .12. The total weight associated with this characteristic represents 13% of the total type score of a cow (Canadian Holstein Association, 1995).

FORE ATTACHMENT

An udder that is strongly attached is preferred for that characteristic because it is associated with lower risks of formation of abnormal tissue and edema[9] in the udder. A strong attachment will also hold the udder in place for more lactations than a weak attachment (Trimberger et al., 1987). Research by Norman and Van Vleck (1972) shows that fore attachment and lifetime milk production are highly correlated (2.23). This characteristic is coded, 9 being the optimal score (Canadian Holstein Association, 1995).

FORE TEAT PLACEMENT

This characteristic corresponds to the position of the teat on each fore quarter (Canadian Holstein Association, 1995). For easy milkout, teats are preferably of average size, pointing straight down from the udder floor, placed uniformly and not too widely spaced (Trimberger et al., 1987). This trait is coded, 5 being the optimal score over a one to nine scale (Canadian Holstein Association, 1995).

FORE TEAT LENGTH

This characteristic corresponds to the length of the fore teats (Canadian Holstein Association, 1995). Cows with round teat ends are associated with higher somatic cell count, but will score higher than cows with pointed teat-ends because the length of their milkout is generally shorter (Trimberger et al., 1987). However, it was shown by

[9] Swelling of the udder that occurs either shortly before, at the time of, or shortly after calving (Schmidt et al., 1988).

Monardes and Hayes (1985) that high somatic cell count was positively associated with the incidence of mastitis. According to Short et al. (1991), teat length is an important type trait with respect to milk production by being genetically distinct from other type traits and by having moderate heritability. This trait is measured, 5 being the optimal score over a one to nine scale (Canadian Holstein Association, 1995).

REAR UDDER

This trait corresponds to the two back quarters of the udder (Canadian Holstein Association, 1995). Rear udder conformation is believed by dairy producers to be highly related to milk production because a well proportioned rear udder will wear better under high production lactations than a weak udder (Trimberger et al., 1987). According to research, rear udder conformation has a moderate genetic correlation with lifetime production, ranging from .19 to .25 (Klassen et al., 1992). A slightly lower genetic correlation of .12 was found between relative income per day of productive life and rear udder by Norman et al. (1981). This characteristic represents 17% of the total type score of a dairy animal (Canadian Holstein Association, 1995).

REAR ATTACH HEIGHT

This trait is the distance between the inferior part of the cow's vulva and the superior part of the milk secreting tissue (Canadian Holstein Association, 1995). According to type evaluation, the rear attachment is preferably high, strong and smooth since it supports 60% of the total milk produced by the udder (Trimberger et al., 1987). This affirmation is supported by research, reporting a moderate genetic correlation between lifetime production and rear attach height (.10 to .25) (Norman et al., 1981) (Klassen et al., 1992). This trait is measured, 9 being the optimal score (Canadian Holstein Association, 1995).

REAR ATTACH WIDTH

This characteristic corresponds to the width of the udder at the superior part of the rear attachment (Canadian Holstein Association, 1995). According to a linear type evaluation, the rear attachment is preferably extremely wide and strong, displaying a well balanced udder that will wear better under numerous high milk yield lactations (Trimberger et al., 1987). However, research shows a negative genetic correlation (-.02) between lifetime production and the width of rear attachment (Norman and Van Vleck, 1972). This trait is measured, 9 being the optimal score (Canadian Holstein Association, 1995).

MAMMARY SYSTEM

This characteristic includes the score for the fore udder (13 points) and the score for the rear udder (17 points). Norman et al. (1981) reported a moderate genetic correlation between relative net income per day of productive life and mammary system in Jersey cows (.17). The pointage for this trait corresponds to 40% of the overall type score (Canadian Holstein Association, 1995).

UDDER DEPTH

Udder depth corresponds to the distance between the bottom part of the udder and the hocks (Canadian Holstein Association, 1995). A good type for this trait is displayed by having the bottom part of the udder as far as possible from the hocks. A shallow, well shaped udder will be less susceptible to mastitis and injury, which are known to increase veterinary costs and/or reduce milk yield (Trimberger et al., 1987). However, research by Norman and Van Vleck (1972) shows a negative genetic correlation between udder depth and lifetime production. This characteristic is measured, 9 being the optimal score (Canadian Holstein Association, 1995).

UDDER TEXTURE

Udder texture refers to the general appearance and texture of the tissue enveloping the mammary system (Canadian Holstein Association, 1995). A healthy, high quality udder is generally prominently veined, soft, pliable and spongy to the touch with no edema or firm fatty tissue. Edema will hamper milk production by congesting the udder at calving time and by persisting after the cow is further in her lactation cycle (Trimberger et al., 1987). Accordingly, Klassen et al (1992) reported a moderate positive genetic correlation between udder texture and lifetime milk production (.19 to .26). This characteristic is coded, 9 being the optimal score (Canadian Holstein Association, 1995).

MEDIAN SUSPENSORY LIGAMENT

This trait corresponds to the depth of the cleft between the right side and the left side of the udder (Canadian Holstein Association, 1995). A strong medial ligament is positively related to sustained high milk production (2.23) and longer herd life (Norman and Van Vleck, 1972), (Trimberger et al., 1987). This characteristic is measured, 9 being the optimal score (Canadian Holstein Association, 1995).

DAIRY CHARACTER

Dairy character or "dairyness" refers to the general appearance of the cow (Canadian Holstein Association, 1995). Dairy character of a cow and milk production have been shown to be highly correlated (from .45 to .60) (Trimberger et al., 1987). Further, Norman et al. (1981) reported an important correlation between relative net income per day of productive life and dairy character in Jerseys (.34). This trait represents 14% of the total type score for a cow (Canadian Holstein Association, 1995).

DAIRY FORM

This trait refers to the angularity, the evidence of milk production capacity of the animal (Canadian Holstein Association, 1995). A cow with good dairy form will display a clean cut, angular conformation (angularity), while being strong but of a refined appearance. The evidence of dairyness and milk yield has been shown to be strongly correlated (.44 to .68) (Klassen et al., 1992, Misztal et al., 1992). Misztal et al.(1992) reported a high genetic correlation between fat yield and dairy form. It was also shown that a cow that displays good dairy form will generally be more feed efficient by turning just about all of the feed consumed above maintenance requirements into milk rather than into body fat (Trimberger et al., 1987). This characteristic is coded, 9 being the optimal score (Canadian Holstein Association, 1995).

Dairy Cattle Valuation Techniques

In livestock improvement schemes, the most straightforward method used to select animals consists of determining their genetic value. To achieve this task, field data on production and conformation performances are collected by breed associations and dairy herd analysis services. However, most dairy producers will only keep in production animals that are believed to be the best in their herd, and thus the data collected has already been subject to selection. Further, since management and climatic conditions are different from one herd to another, data are subject to systematic environmental effects and often are considerably unbalanced. Because of the unbalanced nature of the data, one has to use a mixed model, which will account for environmental random effects in order to accurately estimate genetic parameters of dairy cattle.

Originally, Henderson's methods I, II and III (Henderson 1953), which relied on least squares estimation, were used to estimate genetic parameters in most studies related to milk production performance. However, the major assumption behind least squares and ANOVA type estimators is random sampling, which is not the case since the population of cows that is producing milk has already been selected to stay in the herd (Robertson 1977). Further, correlations were obtained using univariate analysis, creating a bias in parameter estimates because it ignores the effect that correlated traits may have on one another. In order to avoid selection or correlated trait bias, it is essential to use a multivariate approach (Meyer and Thompson 1984). As computers became more sophisticated and powerful, interest in Maximum Likelihood (ML) has grown since this procedure is known to yield estimators with much more desirable properties (Harville 1977). The use of ML procedures over ANOVA type procedures is now preferred and has become the standard procedure for assessing the genetic merit of dairy animals for various reasons: 1) it accounts for selection, if all the information on which the selection decisions were based are included in the model (Meyer and Thompson 1984, Cue et al. 1987). 2) it is flexible, and 3)constraints on the parameter space can be imposed (Jairath 1992). However, ML estimators do not account for the loss in degrees of freedom due to the fixed effects in the mixed model. That is why a more sophisticated version of the general ML procedure, called Restricted Maximum Likelihood (REML), was developed by Patterson and Thompson (1971) to overcome this problem by maximizing only the part of the likelihood which is independent of the fixed effects.

REML Theory

Restricted Maximum likelihood is now the method of choice in animal breeding for estimating variation components of Gaussian linear mixed models. In general terms, it consists of finding the set of parameter estimates that are the most likely to generate the observed sample data, providing that the estimates are representative of the population. More precisely, it finds the likelihood of drawing, for a set of N sample observations, the sample observations y_1, y_2, ..., y_n, on the random variable y, from the observed population, given a certain set of population parameters. In order to accomplish this, many iterations of different possible values of the population parameters will be required before the set that maximizes this likelihood can be found (Breen, 1996). REML is more widely used in dairy genetics studies than a simple Maximum Likelihood procedure since it overcomes the bias of ignoring the loss in degrees of freedom, due to fitting the fixed effects, by maximizing only the part of the likelihood independent of the fixed effects (Meyer, 1989).

Mixed Model Theory

Multiple-trait REML procedures with mixed models are preferred over the Generalized Least Squares method (GLS) in animal breeding research because it extracts more information from the data by considering fixed and random effects in the analysis (Milliken and Johnson 1994). Factors or effects are considered "fixed" when the levels of the study represent all possible levels of the factors and "random" when the levels of the factor that are used in the study represent only a random sample of a larger set of potential levels. In most studies involving the genetic evaluation of a cow, year of calving and herd represent random treatment effects while the traits observed represent the fixed effects. This type of experiment is called a "randomized block design" where the herd-year effect has random block effects. Blocking is useful in genetics since it helps to diminish the effects of variation among experimental units by randomly assigning treatments to units within the blocks. Blocks consist of small subsets of a larger set of blocks and are for this reason considered random so that they adequately represent the entire population studied. Further, a randomized block design that applies each treatment in each block is more specifically called a randomized complete block design (Littel et al., 1996).

Mixed Model For a Randomized Complete Block Design

Assuming that:

1) The block effects are independently and normally distributed, with mean 0 and variance σ^2, and

2) Errors ε_{ij} are independently and normally distributed

The general equation for a mixed model is:

$$Y_{ij} = \mu + \tau_i + b_j + \varepsilon_{ij}$$

Where

Y_{ij}= Proxy for profit

i= 1,..., t (treatment)

j= 1,..., r (block)

μ and τ_i = fixed parameter such that the mean for the ith treatment is $\mu + \tau_i$

b_j= random effect associated with the j^{th} block

ε_{ij}= random error associated with the experimental unit in block j that received treatment i.

Mixed Models and Genetic Parameters

Estimating genetic parameters using REML with a mixed model procedure has been a very popular method in research related to animal production, especially dairy production. Indeed, since the beginning of the 90's, most studies on genetics related to production, type, fertility, health, and survival traits of dairy animal include regression analysis solved with a REML methodology and a linear mixed model.

For instance, Boettcher et al. (1996), investigated the effects of maternal lineage on production traits by using a mixed model and REML methodology where herd, year and season of calving, parity and maternal lineage were treated as fixed effects while the animals, the environment and the residual were treated as random effects.

Dimov et al. (1995) examined variance of interaction effects of sire and herd on yield traits, while Swalve (1995) conducted the same type of research but took test days into consideration instead of sire and herd. Relationships between first lactation and lifetime performance traits have been investigated by Jairath et al. (1995 a,b) as well as Albuquerque et al. (1995) using multitrait REML methodology and a mixed model, again treating herd, year and season of calving as fixed effects. Chauhan and Hayes (1991) also estimated genetic parameters related to first lactation milk production traits but treated proven sires as fixed effects instead. REML methodology has also been useful for investigating the effects on production of milking first lactation cows three times daily. In their study, Campos et al. (1994) used derivative-free REML and a mixed animal model to estimate effects on milk, fat and protein yield of milking three times daily.

With relation to survival and herd life, mixed models have been used by Vischer and Goddard (1995) to estimate heritabilities and genetic correlations of milk yield, survival, workability and type traits for Australian Holstein and Jersey cattle. Similarly, Rogers et al. (1991b) investigated relationships among survival and linear type traits in

Jerseys by using the same regression method, while Harris (1992) focused his research by estimating heritabilities, genetic and phenotypic correlations for 48 and 72 months of herd life with a multiple-trait REML.

Finally, a mixed model regressed with REML methodology is widely used in dairy science for investigating health related issues. This method was used by Uribe et al (1995) as well as Lyons et al. (1991) to analyze the genetics of common health disorders of Holstein cattle. But since mastitis is one of the most common and costly diseases in a dairy herd, extensive research is conducted in this area of genetics. Poso and Mantysaari (1996), Rogers et al. (1995), Miglior et al. (1995), Schutz et al. (1994), and Da et al. (1992), have used regression analysis with REML and a mixed model procedure to study genetic and phenotypic correlations of clinical mastitis and somatic cell score. Finally, some research as been conducted by Rogers et al (1991a) with relation to correlations among linear type traits and somatic cell counts.

Relationships between type traits and production traits have been somewhat less investigated with this method to this date. Most recently, Norman et al. (1996) studied the relationships between herd life and profitability, defining the profits generated by a cow as the value of milk, value of calves and the cow's salvage value minus fixed costs, operating costs and cow depreciation costs. REML methodology with a mixed model has also been used by Klassen et al. (1992), Harris (1992b) and Misztal et al.

(1992) to estimate heritabilities, genetic and phenotypic correlations for milk, fat and protein productions and linear type traits.

Mixed models with REML methodology have also been useful for conducting studies that investigated reproductive capacities and fertility of dairy animals. Hayes et al. (1992) calculated repeatabilities and heritabilities of days to first service, days open and number of services per conception by REML, with a mixed model including herd, year and season of calving as fixed effects, and sire and cow as random effects. Boldman et al. (1992) investigated the use of sire linear type traits transmitting abilities as predictors of herd life transmitting abilities. More closely related to the work of Hayes et al. (1992) relationships between production and days open at different levels of herd production were investigated by Marti and Funk (1994). Further, research using derivative-free REML with an animal model has been conducted by Becerril et al (1993) to estimate the effects of percentage of white coat color on Holstein production and reproduction performances in subtropical environments.

CHAPTER 3

DATA & PROCEDURES

Sample Population

In Quebec, the Holstein breed is the most popular, as 92% of the herds under the Dairy Herd Analysis System (DHAS) are either made up of purebred[10] or grade[11] Holstein cows. Of all these Holstein herds, 94% are at least made up of 75% purebred Holstein cows, while 6% of these herds contain at least 75% grade animals. This study was designed to investigate the relationships between the profit generated by a dairy animal and its production and type traits as well as to investigate breeding decision differences between purebred and commercial producers. Because of the importance of the Holstein Breed in Quebec, and attributes and performances tend to differ among breeds, the sample was extracted from data on Holstein cows only, gathered by DHAS, the Canadian Holstein Association and the Canadian Dairy Network (CDN). Since our second objective was to investigate whether animals were bred according to the purpose of their herd or not (i.e. pedigree breeding versus production oriented herd), data on both types of herd are separately analyzed. In order to do so, it was assumed that "Official Herd" producers generally have purebred animals in their herd while

[10] A purebred is defined as an animal whose ancestry can be traced back through all lines to the foundation animals of the breed (Schmidt et al., 1988).

[11] A grade animal is defined as a nonpurebred animal that possesses the major characteristics of a breed. In many cases, a grade is a descendant of purebred animals that has not been registered with the breed association (Schmidt et al., 1988).

"Owner Sampler Herd" producers generally are commercial dairy producers that have grade animals in their herd .

Our second assumption was that "Official Herd' producers breed animals for both type and production performances while "Owner Sampler" producers breed animals primarily for profitability, with respect to milk production only. The rationale behind these assumptions is that it is thought that dairy producers owning mostly grade cows would care less about the type of the animals and be more interested in the milk they produce. However, dairy producers that breed purebred animals are thought to put more emphasis on the type of the animals for their selection criteria, since breed associations tend to value registered animals according to their final conformation score. In addition, even though there is a general belief among dairy producers that selecting dairy animals on the basis of their first lactation will decrease their length of productive life and lifetime production, only records of primiparous[12] cows were used in the sample since first lactation production is highly correlated genetically with subsequent lactations (Maijala and Hanna, 1974, Meyer, 1983a,b). Indeed, various researchers show that positive genetic and phenotypic correlations exist between first lactation yield and lifetime production (Gill and Allaire 1976, Hoque and Hodges, 1980).

Finally, only cows that calved from 1992 and on were accepted in the sample since multiple component pricing, including protein yield was made effective as of January 1992 (Erwing, 1994).

[12] Cows on their first lactation cycle (Diggins et al., 1984)

The observations were a mixture of actual field data, such as milk yield, milk value and costs of feeding, and calculated values for each production and type trait. These traits are measured in terms of "Estimated Breeding Values" (EBVs), which are a measure of an animal's expected progeny performance relative to the population mean for specific production or type traits (Van Vleck et al., 1987). Each production and type EBV is estimated using multivariate REML and a mixed model procedure. The dependent variable, based on milk value and costs of feeding originated both from the actual price the producer would get for the milk produced by cow X during its first lactation, and from the calculated value of feed needed by the same animal during its first lactation, according to its weight. All the data on feed costs and milk value were already adjusted for constant 1996 dollars and since EBVs consist of genetic evaluation index numbers with no monetary values attached to them, no further modification needed to be made to render prices constant.

Finally, SAS V. 6.11 was use as a regression software. It was the only statistical tool that was able to handle a data set of this size, as well as a mixed procedure function.

Data

A total of 159,479 lactation and genetic evaluation records of Holstein cows freshened between January 1992 and July 1996 were created from test-day records gathered by DHAS, genetic evaluations computed by the Canadian Dairy Network and linear type evaluations conducted by the Canadian Holstein Association. Test-day records issued by DHAS contained information on dollar value of milk, milk yield, its percentage of fat and protein and the cost of feeding the animal during the lactating and dry periods. This information was used to compute the profit generated by each cow during their first lactation by subtracting the total estimated feeding costs from the value of milk produced in that period. Genetic evaluations issued by the CDN contained information on EBVs for milk, fat, protein and EBVs for 29 type traits issued by the Canadian Holstein Association corresponded to the production and type traits regressed to investigate the nature of the dairy cow's profit function.

Data Editing

All the cows in the data set were required to be registered under DHAS, Canadian Holstein Association and CDN simultaneously in order to have records containing complete information. Secondly, only records of primiparous cows were kept. Finally, the data set was partitioned in two: 1) Official Herds, and 2) Owner Sampler Herds under DHAS in order to investigate the potential difference between breeding and production oriented animals. The edited data set for official herds contained records on 31,123 cows, while the edited data set for the owner-sampler herds contained records on 336 cows.

Traits

In order to investigate relationships between the profit generated by a cow and its production and conformation, both production and type traits had to be examined in this study. Production traits consisted of milk fat and protein yield, while type traits consisted of the 7 traits figuring on the pointage card for final type classification score, or the 21 descriptive traits that are evaluated by breed association classifiers. (See Table 1.) All traits were measured in terms of Estimated Breeding Values. EBVs for milk, protein and fat yield are computed by the Canadian Dairy Network, while EBVs for type traits are calculated by the Canadian Holstein Association. The EBVs are regressed values originating from actual field data gathered by DHAS for yield estimates and by the Canadian Holstein Association for type estimates.

The Statistical Model

Genetic parameters of production and type traits with relation to profit were estimated in a 10-trait (or 24-trait) analysis using multivariate REML and a mixed model where herd and calving year are treated as random effects. The multivariate mixed linear model used to estimate the genetic parameters was:

$$Y = (Iq * X)\beta + (Iq * Z)W + e$$

Where:

Y= Vector of observations for each trait in the model

Iq= Identity matrix of the order of the number of traits (q= 10) or (q= 24)

X= Incidence matrix relating β to Y

β= Vector of unknown fixed effects of regression

Z= Incidence matrix relating W to Y

W= Vector of unknown random herd and year effects

e= Vector of random residual effects

* = Direct product operator (Searle, 1966)

Choice of Variable

In the Canadian dairy industry, the producers' main tool to make breeding decisions concerning their cows is a cow index. A cow index is an estimation of a cow's transmitting ability, which corresponds to one-half of the breeding value, since an animal can pass on only one-half of its genes to its offspring. Therefore, the initial choice of variables corresponding to the type and production traits present in a cow index, since it is precisely these traits that are looked at for selection purposes. The final model was to only include variables that had a 5% significance level.

Confidence Interval

To test the significance of the regression coefficients, the confidence interval method was used. This consists of verifying the truth or falsity of a null hypothesis by looking at the standard error of the parameter estimate. A parameter estimate will be considered significant at a 95% confidence interval whenever it is larger than twice its standard error. Therefore, all parameter estimates corresponding to this description are the independent variables that have a significant impact on the dependent(s) variable(s) (Gujarati, 1995).

T-Statistics

To test the significance of the regression coefficient, the test-of-significance approach is an alternative but complementary approach to the confidence interval method of testing statistical hypotheses. It uses sample results to verify whether $H_0: \beta_x = 0$ or not. The null hypothesis, H_0 will then be accepted or rejected depending on the value of the test statistic obtained from the data at hand. A coefficient will be significant at a 5% level if the critical region of the test is smaller than five percent (Gujarati, 1995).

Autoccorelation

The existence of autocorrelated errors is always a possibility and is worth investigating when the regression involves a sample of time-series observations. However, this study involves regressions of cross-sectional data, thus testing for autocorrelated errors, which occur when the elements of the error vector are autocorrelated, is irrelevant.

Heteroscedasticity

This phenomenon occurs when the residuals do not have a common variance. Under this circumstance, the error covariance matrix can no longer be written as a scalar times the identity matrix since all the elements in the covariance matrix will not be equal. In this study, it is assumed that the error variance is caused by management practices (herd effect) and year of calving (year effect) i.e. from one dairy farm to another, producers may make better or worse management decisions concerning breeding, feeding and medical care, which all have a considerable impact on the quantity and quality of milk produced. Further, the year of calving affects production since milk yield fluctuates with the air temperature and the quality and quantity of feed grown is related to the weather. To avoid this type of problem, herd and year effects amongst the observations have to be accounted for, which a mixed model accomplishes. For this reason, heteroskedasticity is assumed to be nonexistent in our regression.

Multicollinearity

This problem arises in nonexperimental data when the model's explanatory variables are such that their individual effects cannot be determined with the desired degree of precision. There are two main methods to test for multicollinearity:

1) *Insignificant coefficients*: the occurrence of multicollinearity is usually suspected when an independent variable known to influence the dependent variable has an estimated coefficient that is insignificantly different from zero.
2) *Correlation matrix:* when a simple correlation coefficient matrix between all pairs of independent variable is used, multicollinearity can be suspected when one pair, or more than one pair, of two independent variables are highly correlated (Kennedy, 1979)

To solve this problem, variables that are insignificant or correlated can be either omitted, combined or redefined (Kmenta, 1986). In our case, the presence of high multicollinearity can be assumed since type and production traits have been shown to be genetically related amongst each other (Short et al., 1991).

For this reason, it was decided to accept the presence of multicollinearity and to conduct the research without trying to solve this problem.

Akaïke's Information Criterion

In econometric studies, it is essential to verify whether the model regressors offer a good fit for the regression or not. In the case where least squares methodology is used, the coefficient of determination, R^2, is a useful tool for determining how well the least-squares line fits the observed data. It can be defined as the explained sum of squares over the total sum of squares:

$$r^2 = \frac{\text{Explained sum of squares}}{\text{Total sum of squares}}$$

where the explained sum of squares corresponds to the explained deviation from the least squares line (squared), and the total sum of squares corresponds to the summation of the explained and the unexplained deviation (squared) from the least squares regression line. The coefficient of determination yields a number less than 1 that correspond to the percentage of the total variation of the dependent variable that is explained by its relationship with the dependent variable(s). The closer to one the r^2 is, the better the fit (Hoshmand, 1988).

However, with REML methodology, the explained and unexplained sum of squares cannot be computed since unlike least squares estimation, the basic idea of Maximum Likelihood is to find the set of estimates of parameters that, if these parameter estimates were true of the population, would have generated the observed sample most often (Breen, 1996). Thus, for a study using REML methodology, the most appropriate test for verifying the goodness of fit of the model is Akaïke's Information Criterion. This test does not indicate how well, in percentage terms, the independent variable(s) explain the variation of the dependent variable(s), but it can be used to compare models with the same fixed effects but different variance structures. The model having the largest AIC is considered the best. Akaïke's Information Criterion (AIC) is computed as follow:

$$AIC = p\ (\theta) - q$$

were p (θ) is the REML log likelihood and q is the number of covariance parameters (SAS Institute Inc., 1992).

CHAPTER 4

RESULTS AND DISCUSSION

Data Setup

The initial procedure for solving the model consisted of dividing the data set into two different samples: "Owner-Samplers" and "Official Herds". However, the computing memory necessary to run the model with the "official herds" data set was insufficient. Therefore, the "official herds" data set, which consisted of 31,123 random observations, was further divided into 3 data sets. The herds included in the three new data sets appeared in the order they were registered under DHAS, i.e. from the first herd that registered under DHAS to the last.

Official Herds

Because these three data sets were random and relatively large, they would be expected to yield similar results. However, this was not the case, and it was then hypothesized that it might be caused by the fact that the three samples were built with observations that were random with respect to type and production records but not with their date of registration under DHAS. Dairy producers can use DHAS records to evaluate the merits of a cow in terms of culling[13], breeding and as a replacement animal. The individual cow record is produced when a cow completes her lactation record. In addition to cow records, DHAS produces monthly herd summaries for

[13] Removing a cow from a herd.

producers that are registered under their scheme. This summary is designed to help producers evaluate the present status of their dairy herd by providing information on: test day milk production on all cows, extrapolated 305-day mature equivalent milk production, average age of cows at first calving, average age of cows at last calving, average days dry, days in milk at first breeding, average calving interval, services per conception, days open, percent of cows with low somatic cell counts, and percentage of cows culled. Dairy producers can then adjust their management scheme by comparing each of these measures with their goals. Using these measures to make good herd management decisions probably requires that the producer goes through a learning process that has a certain time frame. It can therefore be assumed that the longer a dairy producer has been registered under DHAS, the better use of the information provided is made for herd management decisions For this reason, the final "official herds" data set was divided as followed:

- Group 1 (herd number from 1 to 2000)= 5,464 observations
- Group 2 (herd number from 2001 to 4000)= 6,050 observations
- Group 3 (herd number from 4001 to 6000)= 5,478 observations
- Group 4 (herd number from 6001 to 7500)= 7,458 observations
- Group 5 (herd number from 7501 to 11000)= 6,673 observations

where herd number 1 was the first herd to register under DHAS, herd number 2 the second,..., herd number 11000 the last. These groups were chosen to result in approximately the same number of observations (cows).

This new data set thus allowed us to verify the impact of the production information provided by DHAS on profits generated by Canadian Holstein cows. Therefore, the new objectives for this study may be stated as follows:

1) To investigate the relationship between first lactation profit generation per cow in the first lactation with type and production traits, by calculating the weight of each type and production characteristic with respect to profit.
2) To investigate whether animals in commercial herds are selected for maximizing milk production profits while animals in purebred herds are selected for production and type performances.
3) To verify if the information on production levels and milk quality provided to dairy producers by DHAS has an impact on the level of profits generated by Canadian Holsteins cows.

Choice of Model

Normally, a regression model should include only variables that are significant since the significance level of a variable indicates the importance that this variable has on the dependent variable. For a variable to be non-significant does not mean that it does not have any effect on certain observations in the sample, but it does mean that these variables do not affect the studied population as a whole, and we can thus say nothing statistical about the effect. Thus, we would retain only the variables that are significant, indicated by a Student t-test.

However, in the case of dairy genetics, to develop the best model possible by dropping non-significant variables may be difficult since type and/or production traits are known to be genetically correlated. For example, stature, which refers to the height of an animal can be assumed to be correlated with size, which refers to the weight of an animal, since taller animals generally weigh more than shorter ones. Further, a trait such as fore udder is possibly correlated with traits such as fore attachment, fore teat placement, and fore teat length since the final score of a cow for the trait "fore udder" is determined by the individual score it gets for fore attachment, fore teat placement, and fore teat length (see Table 1).

Therefore, it can be assumed that the chosen regression model, which involves dairy genetics, presents a multicollinearity problem that cannot be completely solved, since it investigates traits that belong to the same animal, with respect to the profits generated by the animal. In order to avoid the multicollinearity problem as much as possible, the regression model was run in the two following forms:

1) the "Long Model"
2) the "Short Model"

where the "Long model" included all production traits with the 21 descriptive traits, and the "Short Model" included all production traits with the 7 traits appearing on the pointage cards (see Table 1).

According to Akaïke's Information Criterion, the model which provided the best explanation of the profit function was the "Long Model". Normally, multicollinearity can be solved by combining or omitting one of the collinear variables or by redefining the set of variables. However, it cannot be completely solved in this study since it would yield a final model that would include very few variables. Hayes and Hill (1980, 1981) developed a technique for decorrelating variables, and it could be used to solve this type of problem in our study. However, it is outside the scope of our study, and will not be applied in our case. Although this model would provide the "best" relationship of traits to profit, it would provide no information as to the effect of each trait on profit. Further, Akaïke's Information Criterion (Tables 12 and 13) was higher when the "Long Model" was used then when the "Short Model" was used. This indicates that the "Long Model" was the most appropriate. For this reason, results that originated from the "Long Model" will be more thoroughly discussed in the next section.

Effects of Production and Type Traits on Profits

A description of the data used in the estimation of the effects of production and type traits on profits in "official herds" is presented in Table 2. Arithmetic means, standard deviations, minima and maxima of profits, milk, fat and protein EBVs as well as of type trait EBVs are presented in Tables 3 to 7. In these tables, the variable profit represents the profit per first lactation that is generated by each observation (cow) in the sample. Across the five groups (samples), mean profits are similar, thus it gives no indication that the date of registration under DHAS affects the profitability of dairy producers.

Table 2. Description of "Official Herds" Data.

	Group1	Group 2	Group 3	Group4	Group 5
No. of records	5464	6050	5478	7458	6673
No. of herds	198	242	228	306	239
No. of subclasses (herd/year)	792	968	912	1224	956

The other remaining variables such as milk, fat protein and frame/capacity are all measured in terms of EBVs. The EBV of a cow for a trait represents her comparative capacity with respect to the entire Canadian Holstein cow population to pass on the effects of genes for that trait to her progeny. For example, a cow that has an EBV for milk of 0 is considered average, a cow that has a negative EBV is considered below average and a cow above average is considered above average for transmitting the effects of genes for a particuliar trait. In this study, the mean EBVs for milk are similar and positive across the five groups although highest in group 1, and declining through group 4, meaning that most cows in these sample have above average capacities to pass on the effects of genes for milk yield. The mean EBVs for fat and protein were also similar and positive across the five groups, meaning that most cows in these 5 samples are above average for transmitting genes for fat and protein yield. For type traits, most mean EBVs are also positive across the 5 samples, however, EBVs for rump angle, rear legs side view, udder depth and fore teat length are all below average across the 5 groups. These results indicate that the cows in the 5 samples will transmit genes for these traits that are inferior to the average population. However, since the standard deviations for all traits are large, it can be concluded that most cows in these samples have production and type EBVs that are close to those of the average population.

Table 3. **Means, standard deviations, minima and maxima of official herd profits and EBVs, group 1.**

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM
Profit ($)	2107.00	946.96	57.60	6385.00
Milk	310.56	594.75	-1636.00	2959.00
Fat	10.15	22.47	-70.00	113.00
Protein	10.07	17.66	-48.00	101.00
Frame/Capacity	1.92	4.05	-14.41	15.28
Rump	1.33	3.67	-13.50	15.46
Feet and Legs	2.24	3.92	-14.09	13.52
Fore Udder	1.32	3.28	-10.16	13.39
Rear Udder	2.71	3.64	-12.01	15.07
Mammary System	2.24	3.48	-10.87	13.32
Dairy Character	2.38	3.13	-9.45	12.75
Stature	1.69	3.66	-13.86	12.65
Front End	1.12	4.14	-17.91	15.10
Size	1.55	3.79	-12.56	14.24
Chest Width	1 .49	3.70	-11.10	13.93
Body Depth	0.57	4.15	-13.51	12.77
Loin Strength	1.47	3.72	-13.32	14.70
Rump Angle	-0.44	3.72	-11.93	12.20
Pin Width	0.38	3.57	-12.24	12.60
Foot Angle	2.19	3.75	-13.01	13.33
Bone Quality	1.43	3.77	-13.08	13.20
Rear Legs Side View	-0.81	3.43	-14.46	12.44
Udder Depth	-0.44	3.55	-14.26	13.80
Udder Texture	2.14	3.75	-11.86	13.38
Medial Suspensory	1.60	3.30	-12.61	13.14
Fore Attachment	0.77	3.33	-10.43	12.87
Fore Teat Placement	0.99	3.42	-13.57	13.70
Fore Teat Length	-0.66	4.21	-19.91	15.29
Rear Attach Height	2.68	3.66	-10.91	13.70
Rear Attach Width	2.15	3.83	-12.54	16.44
Rear Teat Placement	1.14	3.37	-16.11	11.91
Dairy Form	1.82	3.83	-16.25	14.73

Table 4. **Means, standard deviations, minima and maxima of official herds profits and EBVs, group 2.**

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM
Profit ($)	2064.00	928.27	-825.50	7463.00
Milk	277.96	584.90	-1630.00	2801.00
Fat	8.95	22.28	-77.00	111.00
Protein	9.10	17.44	-47.00	101.00
Frame/Capacity	1.97	4.18	-15.18	15.28
Rump	1.34	3.74	-14..79	14.68
Feet and Legs	2.19	3.88	-12.77	14.69
Fore Udder	1.40	3.37	-12.93	13.53
Rear Udder	2.52	3.69	-9.96	14.26
Mammary System	2.17	3.54	-11.66	12.93
Dairy Character	2.19	3.12	-11.34	15.59
Stature	1.73	3.69	-13.25	12.35
Front End	1.13	4.25	-18.85	16.67
Size	1.62	3.90	-12.47	13.62
Chest Width	1.57	3.83	-13.07	14.67
Body Depth	0.60	4.20	-16.63	17.10
Loin Strength	1.47	3.76	-13.45	14.17
Rump Angle	-0.45	3.66	-14.04	13.64
Pin Width	0.40	3.60	-12.91	12.51
Foot Angle	2.15	3.71	-12.79	13.11
Bone Quality	1.37	3.74	-11.96	12.98
Rear Legs Side View	-0.78	3.46	-14.75	13.58
Udder Depth	-0.39	3.50	-14.14	11.89
Udder Texture	1.93	3.70	-10.75	14.86
Medial Suspensory	1.64	3.33	-11.64	11.35
Fore Attachment	0.88	3.41	-12.45	13.89
Fore Teat Placement	0.99	3.48	-12.38	17.94
Fore teat Length	-0.68	4.17	-17.20	18.01
Rear Attach Height	2.49	3.70	-10.54	12.14
Rear Attach Width	1.96	3.95	-12.07	14.88
Rear Teat Placement	1.08	3.42	-14.19	13.18
Dairy Form	1.63	3.81	-16.88	13.85

Table 5. **Means, standard deviations, minima and maxima of official herds profits and EBVs, group 3.**

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM
Profit	2086.00	919.91	56.20	6132.00
Milk	257.02	594.23	-1584.00	2373.00
Fat	8.32	22.47	-67.00	113.00
Protein	8.55	17.66	-54.00	86.00
Frame/Capacity	1.94	4.16	-12.29	17.39
Rump	1.41	3.71	-13.76	14.94
Feet and Legs	2.16	3.85	-12.47	14.40
Fore Udder	1.37	3.32	-12.51	15.06
Rear Udder	2.53	3.75	-10.78	15.20
Mammary System	2.15	3.54	-12.72	13.99
Dairy Character	2.23	3.23	-12.38	14.17
Stature	1.68	3.71	-11.88	13.79
Front End	1.12	4.19	-15.55	14.31
Size	1.55	3.92	-12.47	13.80
Chest Width	1.50	3.82	-11.59	14.67
Body Depth	0.64	4.18	-17.71	15.34
Loin Strength	1.58	3.78	-14.52	14.57
Rump Angle	-0.44	3.65	-15.09	14.40
Pin Width	0.37	3.57	-13.49	13.96
Foot Angle	2.15	3.70	-11.03	14.87
Bone Quality	1.37	3.69	-13.75	13.09
Rear Legs Side View	-0.71	3.44	-14.60	11.59
Udder Depth	-0.36	3.55	-15.21	11.18
Udder Texture	1.91	3.76	-11.12	12.83
Medial Suspensory	1.64	3.36	-10.54	11.49
Fore Attachment	0.86	3.38	-14.62	14.18
Fore Teat Placement	1.03	3.48	-11.29	15.66
Fore Teat Length	-0.65	4.22	-18.75	20.86
Rear Attach Height	2.52	3.74	-9.82	12.86
Rear Attach Width	2.02	3.99	-12.22	17.53
Rear Teat Placement	1.18	3.48	-12.81	12.54
Dairy Form	1.73	3.94	-18.64	16.11

Table 6. **Means, standard deviations, minima and maxima of official herds profits and EBVs, group 4.**

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM
Profit	2058.00	945.63	-1031.00	6456.00
Milk	249.97	604.97	-1967.00	2842.00
Fat	8.59	22.88	-74.00	98.00
Protein	8.31	18.17	-56.00	86.00
Frame/Capacity	2.34	4.09	-12.10	15.38
Rump	1.80	3.73	-11.82	15.20
Feet and Legs	2.50	3.87	-12.77	14.54
Fore Udder	1.71	3.37	-11.82	14.64
Rear Udder	2.94	3.70	-10.78	14.79
Mammary System	2.57	3.55	-12.32	14.12
Dairy Character	2.46	3.20	-12.10	13.22
Stature	2.05	3.65	-11.96	12.43
Front End	1.38	4.16	-17.28	15.57
Size	1.95	3.81	-11.22	13.26
Chest Width	1.87	3.77	-12.46	14.67
Body Depth	0.80	4.16	-17.98	14.53
Loin Strength	1.79	3.71	-12.52	14.57
Rump Angle	-0.51	3.61	-12.12	13.83
Pin Width	0.73	3.57	-11.37	12.89
Foot Angle	2.49	3.78	-11.91	15.53
Bone Quality	1.51	3.73	-12.30	13.31
Rear Legs Side View	-0.80	3.38	-13.75	13.01
Udder Depth	-0.28	3.50	-17.35	13.32
Udder Texture	2.30	3.81	-12.60	13.01
Medial Suspensory	2.01	3.34	-13.43	12.04
Fore Attachment	1.15	3.44	-11.73	14.18
Fore Teat Placement	1.16	3.43	-14.88	15.44
Fore Teat Length	-0.68	4.19	-17.07	16.20
Rear Attach Height	2.83	3.68	-11.27	13.34
Rear Attach Width	2.33	3.87	-13.63	16.75
Rear Teat Placement	1.28	3.40	-16.11	11.59
Dairy Form	1.87	3.85	-16.25	15.86

Table 7. **Means, standard deviations, minima and maxima of official herds profits and EBVs, group 5.**

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM
Profit	2112.00	1021.00	-145.40	6931.00
Milk	261.18	597.52	-1780.00	2665.00
Fat	8.72	22.97	-65.00	101.00
Protein	8.53	17.94	-51.00	82.00
Frame/Capacity	2.29	4.10	-14.89	18.07
Rump	1.74	3.67	-13.11	15.33
Feet and Legs	2.40	3.84	-15.26	15.42
Fore Udder	1.75	3.40	-12.79	14.50
Rear Udder	2.87	3.69	-12.56	14.79
Mammary System	2.57	3.54	-12.19	13.99
Dairy Character	2.35	3.21	-10.87	14.26
Stature	2.00	3.64	-11.81	13.79
Front End	1.47	4.18	-22.62	16.67
Size	1.90	3.82	-11.85	14.33
Chest Width	1.83	3.73	-11.84	14.18
Body Depth	0.70	4.11	-19.20	14.93
Loin Strength	1.77	3.76	-12.65	14.44
Rump Angle	-0.51	3.55	-14.81	12.11
Pin Width	0.64	3.56	-12.91	13.18
Foot Angle	2.34	3.77	-14.98	12.89
Bone Quality	1.51	3.66	-12.52	13.09
Rear Legs Side View	-0.75	3.36	-13.89	11.31
Udder Depth	-0.10	3.48	-15.45	12.01
Udder Texture	2.23	3.77	-12.04	12.64
Medial Suspensory	1.92	3.36	-9.72	12.45
Fore Attachment	1.21	3.45	-12.45	14.32
Fore Teat Placement	1.21	3.41	-13.46	14.46
Fore Teat Length	-0.84	4.17	-20.69	21.64
Rear Attach Height	2.75	3.70	-12.84	14.43
Rear Attach Width	2.21	3.84	-13.31	16.29
Rear Teat Placement	1.28	3.40	-12.38	12.22
Dairy Form	1.76	3.84	-16.25	15.23

Long Model Results

REML analysis results are presented in table 8 and they show that parameter estimates for milk, fat and protein ranged from .11 ± .04 to .18 ± .03, from 5.43 ± 0.67 to 7.37 ± 0.67, and from 4.14 ± 1.60 to 8.04 ± 1.57 respectively. Since many of the standard errors are large, the confidence intervals are also large, thus it is difficult to determine precisionly what would be the impact on profits of increasing the EBVs of these production traits. For example, breeding a dam that has an EBV for milk of 31 with a bull with an EBV for milk of 33 should yield an offspring with an EBV for milk of 32. This would represent a 1 unit increase for the production trait "milk yield" in the dam's next generation, but it would result in a 1 unit decrease for the same trait in the bull's next generation. Since the data only included cows' EBVs (dams), the parameter estimates representing unit increases or decreases in EBVs, that are found with our regression model, from a cow's standpoint. According to this model, each one unit increase in EBV for milk represents a first lactation profit increase ranging from $0.07 to $0.21 per total lactation for the dam's next generation. In other words, since you cannot change a cow's EBV for milk, it will be it's offspring's EBV for milk that will increase by one unit (see example above), resulting in a first lactation that will yield profits that will be $.03 to $.21 higher than its dam's. That interval is too wide to make any reliable predictions, however the range is positive, which means that selecting for milk does increase profits for the next generation. However, our initial reaction to this result may be to wonder why dairy producers should bother to select for milk in their

Table 8. **Parameter Estimates of Increase in Profits Corresponding to a One Unit Increase in EBV Using the "Long Model". (Official Herds)**

	GROUP 1		GROUP 2		GROUP 3		GROUP 4		GROUP 5	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
Milk	0.14	0.04	0.11	.04	0.07	0.04	0.18	0.03	0.17	0.04
Fat	6.05	0.68	6.57	0.64	5.43	0.67	6.94	0.59	7.37	0.67
Protein	6.84	1.55	5.43	1.48	8.04	1.57	2.08	1.36	4.14	1.60
Stature	2.22	4.97	6.53	4.59	4.93	4.88	-3.41	4.39	9.42	4.99
Front end	9.72	3.05	7.33	2.81	11.87	2.99	7.31	2.66	9.07	3.05
Size	-31.20	6.95	-36.91	6.25	-41.70	6.60	-26.62	5.91	-39.01	6.84
Chest width	4.30	5.94	15.94	5.41	13.30	5.66	16.27	4.97	16.82	6.00
Body depth	6.38	4.07	9.50	3.83	7.30	3.99	0.45	3.49	-0.31	4.13
Loin strength	-11.85	3.83	-11.84	3.65	-13.43	3.69	-4.32	3.29	-9.83	3.78
Rump angle	8.99	3.54	5.36	3.33	4.39	3.50	3.12	3.11	0.79	3.62
Pin width	-8.50	3.37	-11.59	3.15	-6.98	3.36	-3.53	2.98	-6.43	3.44
Foot angle	4.11	3.78	9.33	3.60	6.22	3.74	5.09	3.31	1.20	3.79
Bone Quality	-1.91	3.57	0.21	3.32	-1.47	3.52	2.63	3.10	3.33	3.64
Rear legs side view	-0.99	3.29	0.39	3.13	0.01	3.28	0.00	2.92	-2.06	3.40
Udder depth	-4.26	3.82	-7.02	3.64	-15.80	3.81	-9.04	3.40	-4.03	3.96
Udder texture	-3.21	5.04	-17.17	4.64	-12.47	4.94	-2.16	4.33	-12.37	5.07
Medial suspensory	-16.61	5.61	-18.13	5.18	-14.52	5.48	-21.35	4.92	-13.12	5.69
Fore attachment	13.90	4.14	14.57	3.97	13.03	4.12	4.71	3.52	13.13	4.16
Fore teat placement	2.63	3.88	-1.20	3.72	-1.40	3.84	-5.70	3.41	-4.95	4.07
Fore teat length	-3.47	2.42	-8.09	2.34	-6.07	2.43	-7.06	2.13	-4.77	2.47
Rear attach height	-21.18	4.49	-6.64	4.23	-10.21	4.33	-9.48	3.95	-13.07	4.55
Rear attach width	7.26	4.23	3.12	3.84	-1.54	4.02	0.67	3.67	4.30	4.19
Rear teat placement	9.32	4.10	12.00	3.77	3.49	3.91	13.61	3.56	9.38	4.18
Dairy form	1.82	3.83	6.32	3.89	8.04	4.05	3.61	3.60	11.32	4.19
Statistical Test:	Akaike's Criterion * -43870 ** -43897.9		Akaike's Criterion * -48531.5 ** -48554.4		Akaike's Criterion * -43915.2 ** -43934.3		Akaike's Criterion * -59986.6 ** -60019.2		Akaike's Criterion * -54163.7 ** -54196.9	

Estimates that are significant at a 5% significance level. (2 times the standard error).

* Akaike's Information Criterion for the model including all the variables.

** Akaike's Information Criterion for the model including only the significant variables herd after all if it only increases their profits by such a small amount? However, the following should be kept in mind when reading the parameter estimates in our study: when a producer wishes to increase a dam's next generation EBV for a certain trait, it is usually increased by more than one unit. Thus in reality, a breeder may very well decide to increase the EBV for milk of a dam's next generation by as much as 1000 units (e.g. the dam has an EBV for milk of -1000 and the bull has an EBV for milk of 3000, resulting in an offspring with an EBV for milk of 1000). With our estimate for "milk", this increase of 1000 units for the EBV for milk would represent an increase in profits ranging from $70.00 to $180.00 from the dam's first lactation profits to its offspring's first lactation profits, only for increasing the EBV for milk. Looking at the estimates for type traits, we can see that across the five groups, the following traits were found to have no significant impact on first lactation profits: stature, bone quality, rear legs side view, fore teat placement, and rear attach width.

Body depth was found to be significant only for group 2, having an impact of 9.50 ± 3.83 on profits for each unit increase of EBV for this trait. Foot angle only had a significant impact of 9.33 ± 3.60 also for group 2, while rump angle was found to be significant only for group 1, having an impact of 8.99 ± 3.54 on profits. These results indicate that selecting dairy animals for stature, bone quality, rear legs side view, fore teat placement, rear attach width, body depth, foot angle, and rump angle does not generally lead to increased or decreased first lactation profits since these traits were found to be nonsignificant in most cases.

With respect to ranking, it was found that size and medial suspensory ligament had the greatest negative impacts on first lactation profits, ranging from -41.70 ± 6.60 to -26.62 ± 5.91, and -21 .35 ± 4.92 to -13.12 ± 5.69 respectively. These results indicate that selecting for heavy animals as well as selecting dairy cows that possess strong medial suspensory ligaments would substantially decrease profits. It suggests that smaller animals with weaker medial suspensory ligaments are preferable when the goal is to maximize profits. The first result can be easily explained: heavier animals generally eat more, thus can be more expensive to feed than smaller animals. A heavier animal might produce more milk but the difference between the value of milk produced and the feed costs (i.e. profits) might be actually smaller than the difference between the lower milk yield of a lighter animal and the cost of feeding it. In other words, smaller animals that might produce less milk but are also cheaper to feed might generate greater profits. However, for the case of the medial suspensory ligament, a sound explanation is hard to find since common sense tells us that a stronger medial suspensory ligament should allow an animal to sustain higher milk yield through a longer herd life than one with a weaker ligament would.

Conversely, chest width and fore attachment were found to have the greatest positive impact on profits, ranging from 13.30 ± 5.60 to 16.82 ± 6.00, and from 13.03 ± 4.12 to 14.57 ± 3.97 respectively. These results suggest that in order to increase profits, dairy producers should select for animals with large chests and with strongly attached fore udders. The importance of chest width with respect to profit is hard to rationalize, although dairy animals with large chests may be able to produce more milk because this physical attribute allows them to better support their weight. A strong attachment of the fore udder can be explained more easily: healthy cows with strong udders are expected to have fewer health related problems, thus having a more regular as well as a higher overall milk yield. Surprisingly, the result showed that selecting for milk has the smallest positive impact on profits, followed by protein and fat. These results suggest that dairy farmers wanting to maximize their profits should select for milk, protein and fat less intensively than for other traits such as size and chest width.

Short Model Results

Although it was found that the "Short Model" was inferior to the "Long Model" in terms of making predictions in profit changes when selecting for production and type traits of Canadian Holsteins, the following can be observed: at a 5% significance level, the trait "Fore Udder" was found to be nonsignificant across the five groups (See Table 9). The estimate for the trait "Feet and Legs" was found to be significant only for group 4. The estimate for the trait "mammary system" was found to be significant only for group 1, while the estimate for the trait "dairy character" was found to be significant only for group 3. These results indicate that selecting for the traits "feet and legs", "fore udder", "mammary system", and "dairy character" does not have a significant impact on

Table 9. **Parameter Estimates of Increase in Profits Corresponding to a One Unit Increase in EBV Using the "Short Model". (Official Herds)**

	GROUP 1		GROUP 2		GROUP 3		GROUP 4		GROUP 5	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E	Estimate	S.E.
Milk	0.17	0.04	0.15	0.04	0.11	0.04	0.21	0.03	0.19	0.04
Fat	5.93	0.66	6.59	0.62	5.44	0.65	6.97	0.57	6.84	0.66
Protein	5.14	1.50	3.37	1.45	5.78	1.52	0.47	1.32	3.23	1.55
Frame/Capacity	-14.86	3.03	-5.64	2.83	-13.58	2.93	-10.38	2.62	-10.15	3.06
Rump angle	-7.26	3.15	-6.84	2.98	-7.09	3.09	1.07	2.72	-6.92	3.17
Feet and legs	-2.33	2.86	4.52	2.79	-0.03	2.88	5.12	2.57	0.33	2.94
Fore udder	-9.91	11.06	-7.64	10.54	15.25	11.14	-5.25	9.91	8.54	11.32
Rear udder	-45.87	12.12	-36.00	11.64	-4.94	12.17	-19.72	10.76	-25.68	12.44
Mammary system	48.46	20.01	36.08	19.26	-21.55	20.29	12.20	18.02	12.91	20.82
Dairy character	4.75	4.44	-1.35	4.28	8.88	4.29	2.16	3.76	8.05	4.43
Statistical test:	Akaike's Criterion		Akaike's Criterion		Akaike's Criterion		Akaike's Criterion		Akaike's Criterion	
	* -43947.7		* -48644.3		* -44020.7		* -60077.3		* -54239.2	
	** -43956.5		** -48653.5		** -44026.2		** -60089.2		** -54245.4	

Estimates that are significant at a 5% significance level (2 times the standard error).

* Akaike's Information Criterion for the model including all the variables.

** Akaike's Information Criterion for the model including only the sigificant variables

milk production profits. This suggests that dairy producers should put less emphasis on these traits when they develop their breeding scheme. Estimates for the trait "milk yield" were found to be slightly smaller with the long model than with the short model. Estimates for the trait "fat yield" were found to be similar with both models, while estimates for the trait "protein yield" were found to be slightly lower with the short model than with the long model.

With respect to ranking, the trait "rear udder" was found to have the highest negative impact on profits, with estimates ranging from -45.87 ± 12.12 to -25.68 ± 12.44, followed by the trait "frame/capacity", with estimates ranging from -14.86 ± 3.03 to -5.64 ± 2.83. These suggest that dairy producers should select cows in a way to decrease their offspring's EBVs for rear udder and frame/capacity as much as possible in order to increase their profits. In other words, these results indicate that animals that posses a weaker rear udder, and that are generally smaller, are more profitable than taller and bigger cows, possessing a stronger rear udder. Also with respect to ranking, it was found that the trait "protein yield" had the highest positive impact on profits, with estimates ranging from 3.23 ± 1.55 to 5.78 ± 1.52, followed closely by the trait "fat yield", with estimates ranging from 5.44 ± 0.65 to 6.97 ± 0.57. These results indicate that dairy breeders should select their cows for protein yield as well as for fat yield before all other traits in order to increase their profits. However, it is important to keep in mind that these results were estimated with the "Short Model", which was found, with Akaïke's Information Criterion, to offer a worse fit than the "Long Model" for explaining profit generation.

Owner Sampler Herds

A description of the data used in the estimation of the effects of production and type traits on "owner sampler herds" profits is presented in Table 10. Arithmetic means, standard deviations, minima and maxima of profits, milk, fat and protein EBVs as well as of type traits EBVs are presented in Table 11. In the "Owner Sampler" herd sample, most cows had an EBV that was inferior to the average Canadian Holstein cow population for the following traits: stature, size, loin strength, pin width, bone quality, rear legs side view, udder depth, udder texture, medial suspensory ligament, fore teat placement, fore teat length, and rear attach height, while most cows in the "Official Herd" sample had an EBV that was inferior to average only for the traits "rump angle", "rear legs side view", "udder depth", and "fore teat length". Thus in general, purebred Canadian Holstein cows had higher EBVs than Canadian Holstein grade cows. However, if we look at the mean profits generated by both type of cows, we can consider them equivalent if their respective standard deviations are taken into account.

Table 10 . Description of data for analysis of owner-sampler herds

No. of records	336
No. of herds	88
No. of subclasses (herd-year)	352

Table 11. **Means, standard deviations, minima and maxima of owner sampler herds profits and EBVs.**

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM
Profit	1,923	787.63	172.00	5023.00
Milk	156.42	560.15	-1442.00	1596.00
Fat	1.75	21.62	-68.00	62.00
Protein	3.63	16.34	-48.00	45.00
Frame/Capacity	0.83	4.22	-9.80	13.74
Rump	0.95	3.65	-9.10	12.75
Feet and legs	1.50	3.82	-12.33	11.75
Fore udder	0.69	3.24	-9.74	9.93
Rear udder	1.47	3.67	-12.42	12.61
Mammary system	1.26	3.47	-11.40	10.15
Dairy character	1.31	3.17	-9.64	8.69
Stature	-14.42	18.31	-0.79	0.43
Front end	13.45	10.70	1.26	0.21
Size	-33.86	25.35	-1.34	0.18
Chest width	19.55	21.60	0.91	0.37
Body depth	24.60	14.16	1.74	0.08
Loin strength	-5.90	14.63	-0.40	0.69
Rump angle	12.13	12.74	0.95	0.34
Pin width	-1.56	11.70	-0.13	0.89
Foot angle	27.17	14.91	1.82	0.07
Bone quality	-25.39	14.52	-1.75	0.08
Rear legs side view	-15.52	11.98	-1.30	0.20
Udder depth	-1.32	12.81	-0.10	0.92
Udder texture	-15.94	17.91	-0.89	0.37
Medial suspensory	-4.81	20.17	-0.24	0.81
Fore attachment	10.69	15.46	0.69	0.49
Fore teat placement	-7.60	15.22	-0.50	0.62
Fore teat length	-6.34	9.58	-0.66	0.51
Rear attach height	-21.96	15.57	-1.41	0.16
Rear attach width	2.28	15.10	0.15	0.88
Rear teat placement	22.14	15.31	1.45	0.15
Dairy form	2.60	14.81	0.18	0.86

REML analysis showed that only the estimates for body depth, foot angle and bone quality were significant at a 10% significance level (See Table 12). Parameter estimates for body depth, foot angle and bone quality were of 24.60 ± 14.16, 27.17 ± 14.91, and -25.39 ± 14.52 respectively. The estimates for the same three traits were much larger, except for bone quality which was smaller, for official herds. However, they were not considered in the study of official herds since they were found to be not significant at a 5% significance level. These results indicate that in the case of an owner sampler herd, profits can be increased by selecting animals with deep bodies, possessing hooves that are set at a steep angle, and with a finer or coarser bone structure for their legs when compared to what the Canadian Holstein Association considers to be the ideal bone structure for dairy cows. The estimate for body depth seems sensible since this attribute is known to be related to the feed efficiency of the dairy cow, i.e. a cow that is more feed efficient will be able to produce adequately under a diet comprising a minimal amount of grain compared to the amount of high quality forage needed. Because the price of forages is generally lower than the price of grains for equivalent nutrition, the costs of feeding such an animal will be lower, and it could lead to higher profits assuming it also produces high quantities of milk. However, with respect to the ranking of the estimates, it was found that selecting for foot angle would contribute the most to increased profits.

Table 12. **Parameter Estimates of Increase in Profits Corresponding to a One Unit Increase in EBV Using the "Long Model". (Owner Sampler Herds)**

	ESTIMATE	STANDARD ERROR
Milk	0.11	0.15
Fat	3.72	2.49
Protein	8.71	5.59
Stature	-14.42	18.31
Front end	13.45	10.70
Size	-33.86	25.35
Chest width	19.55	21.60
Body depth	$\boxed{24.60}$	$\boxed{14.16}$
Loin strength	-5.90	14.63
Rump angle	12.13	12.74
Pin width	-1.56	11.70
Foot angle	$\boxed{27.17}$	$\boxed{14.91}$
Bone quality	$\boxed{-25.39}$	$\boxed{14.52}$
Rear legs side view	-15.52	11.98
Udder depth	-1.32	12.81
Udder texture	-15.94	17.91
Medial suspensory	-4.81	20.17
Fore attachment	10.69	15.46
Fore teat placement	-7.60	15.22
Fore teat length	-6.34	9.58
Rear attach height	-21.96	15.57
Rear attach width	2.28	15.10
Rear teat placement	22.14	15.31
Dairy form	2.60	14.81
Statistical test:	Akaike's Information Criterion	
	* -2572.20	
	** -2644.53	

Estimates that are significant at a 10% significance level (2 times the standard error).

* Akaike's Information Criterion for the model including all the variables.

** Akaike's Information Criterion for the model including only the sigificant variables

This result is more difficult to rationalize since it was found by previous research that there is a notable negative relationship between lifetime production and rear heel angle (Norman and Van Vleck, 1972, Choi and McDaniel, 1993). The second trait that was found to have the most important impact on profits was bone quality. Since the optimal score for this trait, when a cow is being appraised for its type, will be an intermediate 5 over a scale from 1 to 9, cows scoring less or more than five will have a bone structure that is not considered ideal by the Canadian Holstein Association. Thus for this trait, a cow will have a negative EBV if it possesses a finer or coarser leg bone than the average Canadian Holstein cow population. A negative estimate does not indicate whether a producer should select for finer or coarser bone in order to increase profits. However, common sense tells us that a coarser bone structure might be associated with a heavier, taller animal, which was found to be less profitable in the previous section.

Even though EBVs for milk fat and protein were found to be smaller for owner sampler herds than for official herds, their profits were not found to be significantly different (Table 11). If we refer to our assumption that owner sampler herds are grade animals, and that the main goal of owner samplers is to maximize profits, it is reasonable to conclude from these estimates that animals are indeed being bred according to the stated goal of profit. That is, purebred breeders are probably less concerned with profits, their main goal being to breed superior looking animals with above average producing abilities since their profit levels are no different than those of commercial producers utilizing grade animals, which generally have a conformation score that is less than that of purebred animals. Conversely, commercial producers are probably less concerned by the type or only the production performance than they are by the overall profitability of their animals since their main goal is to maximize profits by producing the most revenue at the lowest cost possible.

DHAS Information

The third objective was to verify whether the information provided by DHAS is helping dairy producers to make breeding decisions that will result in higher profits. A decreasing trend in profits across the five groups would have indicated that the number of years producers are registered under DHAS is positively related to profits. This would indicate that complete information on herd performance levels enables dairy producers to make better management decisions which will increase their profits overtime. In this study, profits are similar across the five groups and no increasing or decreasing trend could be observed. Therefore, these results give no indication that profits increase as the number of years the information is provided by DHAS to producers also increases. Further, because owner sampler profits are similar with those for official herds, it indicates that being under the non official scheme of DHAS is as useful for increasing profits as being under the official scheme, which is more expensive to producers.

CHAPTER 5

CONCLUSION AND DISCUSSIONS

The Nature of the Study

The two initial objectives of this study were:

1) To investigate the relationships of first lactation profit generation by a cow with type and production traits by calculating the weight of each type and production characteristics with respect to profit.

2) To investigate whether animals in commercial herds are selected to maximize milk production profits while animals in purebred herds are selected for production and type performances.

To accomplish these objectives, complete cow records from DHAS, the Canadian Dairy Network and the Canadian Holstein Association were merged by matching the cows' registration number of each record, resulting in 159,479 lactation and genetic evaluation records of Holstein cows. By selecting only "official" cow records, it resulted in a sample of 31,123 observations, including production records and type and production trait EBVs for each cow in the sample. This sample, was divided in three because the computing memory necessary to run the model with all the "Official Herds" records simultaneously was insufficient. Additionally for the second objective, only cow records from "Owner-Sampler Herds" were selected from the initial sample of merged records, which resulted in a sample of 336 observations. Furthermore, the cows included in both samples had to be at their first lactation, since first lactation production is highly correlated genetically with subsequent lactations.

The periodicity of this data occurs from January 1st, 1992 since multiple component pricing, including protein yield, was made effective as of January 1992. Priliminary results from "Official Herds" were not similar across the three samples, which should have been the case. Since the three samples were random with respect to type and production records but not with their date of registration under DHAS, it was hypothesized that the longer a dairy producer has been registered under DHAS, the better use of the provided information is made for herd management decisions. This led us to formulate a third objective for the study, as follows:

3) To test if the information on production levels and milk quality provided to dairy producers by DHAS has an impact on the level of profits generated by Canadian Holsteins cows.

Most sample observations in both "Official Herds" and "Owner Sampler Herds" had average first lactation profits ranging from $1,923 ± 787.63 to $2,112 ± 1021. Mean EBVs of cows in "Official Herds" were positive for all traits except for "rump angle", "rear legs side view", "udder depth", and "fore teat length", which indicate that most purebred cows have the ability to transmit genes that are superior when compared to those of the general Canadian Holstein cow population for all type and production traits, with the exception of those mentioned above. Mean EBVs of cows in "Owner-Sampler Herds" were mostly negative, except for the traits "milk", "fat", and "protein". This indicates that with respect to type, grade cows are genetically inferior to the average Canadian Holstein cow population, but genetically above average for production traits. REML methodology with a mixed model was used to regress type and production EBVs of cows on the profit they generated to determine what is the impact of selecting for these traits on profits.

Study Conclusions

In this study, only profits from milk sales were considered. However, dairy producers can also generate income from selling breeding stock, replacement stock, and embryos. This segment of the industry is important to consider since in some cases it represents the major source of income for purebred breeders. Thus, while commercial producers are usually focusing most of their selection effort to breed cows that are profitable with respect to their production of milk, most purebred breeders are also interested building the market value of their herds. To do so, these producers have to gain a good reputation as breeders. Breeders' reputations are determined by the producing ability of their animals and their success in the show ring. The success of animals in expositions should be in principle only linked to their aesthetic qualities. However, it is a well known fact that judging decisions are often biased on the reputation of the breeder. For these reasons, purebred breeders have in their best interest to breed animals that will be aesthetically superior while breaking production records since this is how breeders are presently being appraised in the dairy industry. Thus, even though they might very well be aware that their animals are not necessarily profitable with respect to their milk production, they have no incentive to change that fact since the market value of their cows is mostly based on their reputation and the milk production potential of the cows.

In accordance with this, this study has shown that size (i.e. the weight) had the greatest negative impact on first lactation profits (-41.70 ± 6.60 to -26.62 ± 5.91) for official herds. This result indicates that producers should primarily select for lighter animals in order to increase their profits. This result is easily explained by the fact that heavier animals generally eat more, thus can be more expensive to feed than smaller animals. However, purebred producers will very rarely make that kind of breeding decision in real life since taller, thus heavier animals will more easily break production records and will also have more value in the show ring which is precisely what purebred breeders are after. In the case of commercial producers, breeding for smaller animals might however make a lot of sense since most of their income originates from profits of milk sales.

Further, it was found that chest width and fore attachment had the greatest positive effect on profits, ranging from 13.30 ± 5.66 to 16.82 ± 6.00, and from 13.03 ± 4.12 to 14.57 ± 3.97 respectively. Thus producers should select for cows with large chests and strongly attached fore udders if their primary goal is to maximize their profits. For purebred breeders, this type of selecting is more feasible since large chests and strong udders are well appraised in show animals and are highly positively correlated with lifetime production (Norman and Van Vleck, 1972).

When EBVs of cows in purebred herds were compared with EBVs of cows in commercial herds, it was found that although the average commercial cow had production and type characteristics that were inferior to the average Canadian Holstein population, it generated an equivalent amount of profits to those generated by purebred animals. Further, our model showed that in a commercial herd, profits could be increased by selecting animals with deeper bodies, steeper hooves and inferior bone structure than what is deemed by the Canadian Holstein Association to be ideal. Parameter estimates for these traits in respective order are: 24.60 ± 14.16, 27.17 ± 14.91 and -25.39 ± 14.52. Based on our assumption that "owner sampler herds" consist of grade animals, and that the main goal of "owner samplers" is to maximize profits, our data showed quite clearly evidence that although purebred cows in our sample had greater EBVs for type and production traits than grade cows, both types of animals nonetheless generated similar profits. This result may seem hard to rationalize at first glance. However, if we consider that purebred cows in the sample had greater

EBVs for frame/capacity than grade cows, and that in the first part of the results, it was found that breeding for large animals decreased profits substantially, it can be concluded that even though purebred cows have superior milk producing abilities than grade cows, they are larger, thus expensive to feed. Therefore, both purebred and grade cows are generating equivalent profits. It can further be concluded that purebred cows are indeed bred to reach type and production excellence, so that the breeder can gain recognition from this, while grade cows are being bred to reach a profit maximizing goal, and not necessarily record breaking production levels or for outstanding type.

Finally, no particular trend in profits across the five groups of "Official Herds" was detected, which indicates that there did not seem to be any connections between milk production profits and the number of years that producers have been under DHAS. These results do not however indicate that DHAS information is not linked to increased profits. They merely suggest that producers that have been registered and receiving information, from DHAS longer do not seem to make superior use of this information with respect to their profit levels, when compared to producers that have been registered under the scheme for a shorter period of time.

This might indicate the following:

1) Either the information provided by DHAS is so user-friendly that dairy producers do not really have to go through a learning period to maximize it use, or
2) Information provided by DHAS is not a useful tool to help increase dairy producers' profits.

To determine which is the case, a study including profit levels of producers that are not registered under DHAS would need to be conducted. However, results from this study confirm that being registered under the non official scheme of DHAS ("Owner Sampler") is as useful for increasing profits as being under the "Official Herd" scheme. Thus it can be concluded that producers that have the goal to maximize their profits from milk production should register under the "Owner Sampler" scheme since it is less expensive and as efficient for increasing profits as the "Official Herd" status.

Recommendations for Future Studies

Studies in dairy genetics often involve multicollinearity problems in regression analysis since most production and type traits that are estimated are genetically correlated. This problem can be solved by decorrelating the variables studied with the method developed by Hayes and Hill (1980, 1981). This would allow one to predict the increase in profit by increasing the EBV of a trait by one unit with more confidence. Further, this study included only first lactation records. It would be interesting to perform the same study on a sample of older cows to see how type and production traits might have a different impact on profits due to wear and tear of the animals. There is also a need to study more thoroughly the effect that DHAS information has on profits generated by cows.

Finally, since there is definite evidence that purebred producers are breeding their animals for production and type but not for efficiency (i.e. profits), it would be interesting to investigate whether they are doing it for personal reasons, or to increase the value of their herd by gaining a better reputation from higher recorded yields and success in the show ring. The latter possibility raises questions concerning the way dairy cows are appraised: is the infrastructure of the Canadian dairy industry preventing producers from becoming profitable with respect to milk production by appraising cows according to yield and type traits without considering profitability ?

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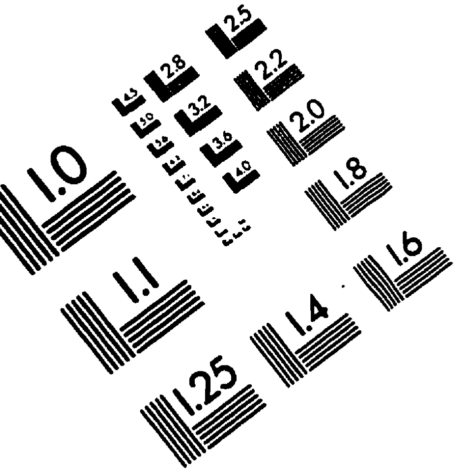
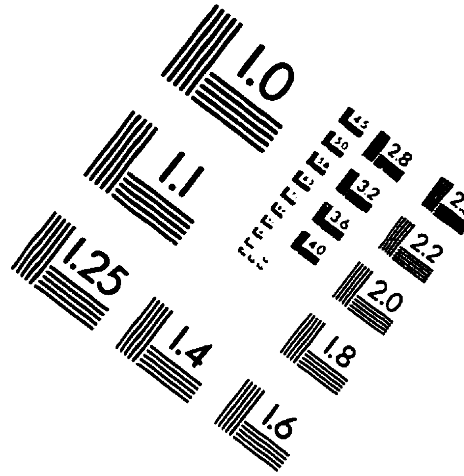
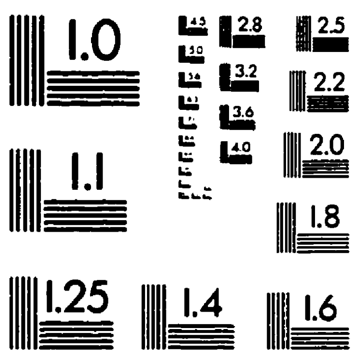
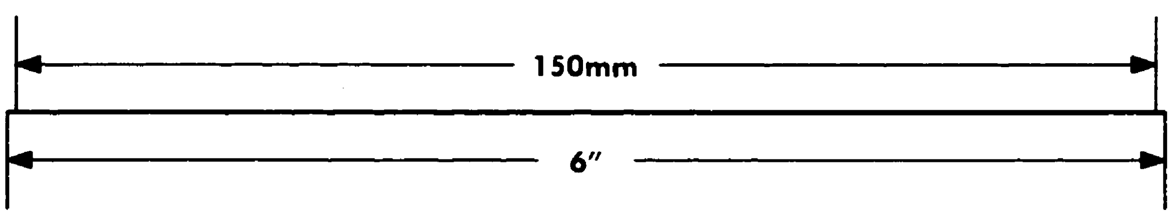
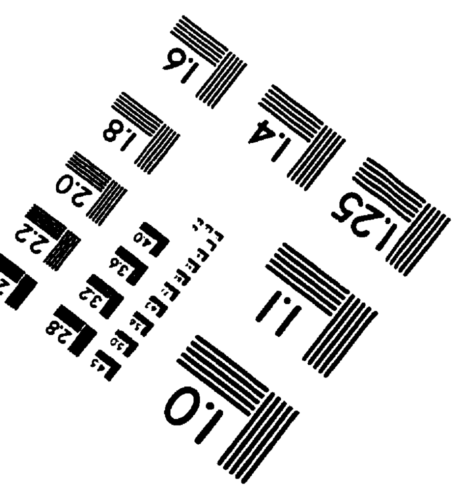
IMAGE EVALUATION TEST TARGET (QA-3)

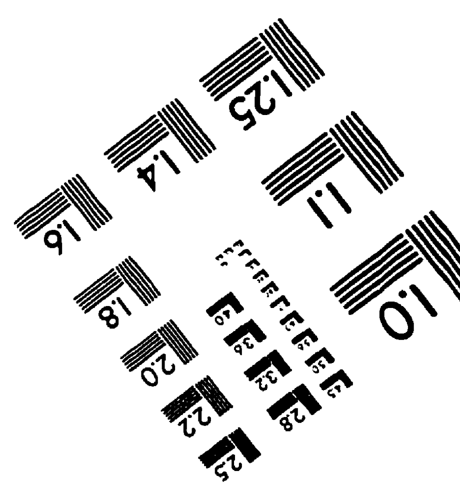












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