Breeding for Carcass Traits in Dairy Cattle

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Academic dissertation

To be presented, with the permission of the Faculty of Agriculture and Forestry of the University of Helsinki, for public criticism in Auditorium 2, Viikki Info Centre (Viikinkaari 11), on December 15th 2000, at 12 am.

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Abstract

Over 90% of beef produced in Finland is generated as a by-product of milk production with dairy breed animals, the majority of which are pure-bred Finnish Ayrshires. Some beef production traits have long been included in the breeding programs of dairy cattle breeds, but the selection pressure on these beef traits has remained weak. Consequently, the carcass quality of Finnish dairy cattle breeds is relatively poor, and the current income from beef for farmers is low.

Upon joining the European Union in 1995, Finland formally adopted a new national cattle identification system. When this new system is fully operating throughout the cattle production chain, it will be possible to routinely acquire large amounts of carcass data directly from slaughterhouses. This new source of data will offer many opportunities for animal breeders to improve beef production traits.

The objective of this study was to collect basic information on routinely collected field carcass data to see how it could best be used in genetic evaluation of dairy breeds for beef production traits. To this end, a data set of 122 000 carcasses was obtained from six slaughterhouses. From this data, the genetic parameters for carcass traits of bulls, heifers and cows were estimated, and non-genetic factors affecting the carcass traits of dairy breed animals were studied. Carcass data was further combined with milk recording data, and genetic correlations of carcass traits with milk production traits were estimated. Alternative strategies for combining carcass traits into breeding programs of dairy cattle were also studied. Effects of including carcass traits in breeding goals of dairy cattle were analysed, and different information sources for carcass traits in sire evaluations were compared. In addition, efficiency of simplified and multi-trait evaluations, and one-stage and multi-stage selection for carcass and milk traits in sire selection were compared.

Based on the analyses of selection strategies, it is feasible to expand the total merit index of Finnish dairy cattle breeds to include carcass traits. The inclusion of carcass traits in the breeding goal does not hinder progress of milk traits. It would also reflect the income sources of the farms better. Data for progeny testing young AI-sires for carcass traits is already available due to the evaluation system of AI-sires in Finland, which ensures close to 200 sons for each tested bull.

Results show that it is possible to breed for improved carcass weight and quality of young Finnish Ayrshire and Holstein-Friesian slaughter animals. The carcass traits are heritable, although the heritability estimates of bull and heifer carcass traits were relatively low. The genetic correlations of bull and heifer carcass traits are also generally favourable, both among themselves and between the carcass traits and milk production traits.

The relatively high heritability of carcass traits of cows suggest that it would be easy to breed for improved carcass quality and optimal body weight of dairy cows. Although dairy cows are not intended for beef production, improved carcass fatness and fleshiness, and thus, improved body condition, might help to reduce stress caused by lactation in high-yielding cows. Due to the negative genetic correlations estimated between the carcass quality and milk traits of dairy cows, their carcass fatness and fleshiness will continue to deteriorate as a result of selection on milk production traits unless some counteractive selection is practised.

Reliable breeding values for carcass traits can be estimated for young dairy AI-sires based solely on their male progeny, but inclusion of some carcass information on female progeny might also be of value, especially in predicting carcass fatness more accurately. If body
weight and condition of dairy cows are of interest, including some cow carcass data in selection decisions is necessary.

Young dairy AI-bulls have been tested in official testing stations for their own growth rates in Finland since the mid-1960s. The importance of sires’ own growth in selection of dairy breed sires has, however, been on the decline for years. In future, if all test sires get breeding values for carcass weight and carcass quality traits based on their progeny information, the need for an individual growth testing period for sires themselves will have to be reconsidered.

Large differences exist between proven sires with respect to carcass breeding values. Among Finnish Ayrshire, in particular, individual sires can be found that combine excellent milk production, health and fertility traits with good carcass weight and carcass quality traits. If animal breeding associations do not want to further expand the breeding goals of dairy cattle breeds, they could promote the use of sires with good carcass breeding values by, for example, annually naming some "dual-purpose" sires with both promising milk and beef traits.
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1 ORIGINAL ARTICLES

This thesis is based on the following original papers, which are referred to in the text by their Roman numerals, and on some unpublished results:


Contribution of the author to papers I to V:

I. The author participated in the planning of the study, participated in preparing the data for statistical analyses, participated in interpreting the results and participated in writing and is the corresponding author of paper I.

II. The author participated in the planning of the study, conducted the statistical analyses, interpreted the results and was the main writer of paper II.

III. The author participated in the planning of the study, conducted the statistical analyses, interpreted the results and was the main writer of paper III.

IV. The author participated in the planning of the study, conducted the simulations and statistical analyses, interpreted the results and was the main writer of paper IV.

V. The author participated in the planning of the study, conducted the simulations and statistical analyses, interpreted the results and was the main writer of paper V.
2 INTRODUCTION

2.1 Beef production in Finland

Beef production increased strongly in Finland in the 1950s and 1960s, when the practice of slaughtering calves was abandoned in favour of raising them to higher slaughter weights (Maijala 1983). Slaughter weights have also risen over time due to changes in beef-producing breeds, and direct or indirect selection for increased adult size of animals.

Beef production has increased up till the last few years, although the number of dairy cows has decreased considerably (Table 1). The total production numbers were highest in the mid-1980s, when approximately 130 million kg of beef was produced annually in Finland. Since then, beef production has been on the decline, and in the late 1990s, it dropped below domestic consumption levels. Currently the level of self-sufficiency in beef is only 85% in Finland. Since the number of slaughter animals continues to decrease, total beef production is expected to further decline in the coming years.

Due to declining domestic production, the need to import beef to Finland has increased. The imported beef consists mostly of the more expensive parts of carcass and is delivered to restaurants and the meat industry; very little imported beef is sold directly to the consumer. Traditionally, consumers prefer domestic beef, as most serious cattle diseases are very rare or non-existent in Finland. For example, to date (autumn 2000), no cases of Bovine Spongiform Encephalopathy have been reported in Finland.

Table 1: Beef production and consumption (million kg) and number of dairy cows (thousands) in Finland in 1960 - 1999 (Agrifacts 2000).

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<td>Production</td>
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<td>106</td>
<td>114</td>
<td>129</td>
<td>118</td>
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<tr>
<td>Total consumption</td>
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<td>96</td>
<td>111</td>
<td>103</td>
<td>109</td>
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<td>Import</td>
<td>–</td>
<td>–</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Consumption kg/capita</td>
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<td>21</td>
<td>23</td>
<td>21</td>
<td>22</td>
<td>19</td>
</tr>
<tr>
<td>Number of dairy cows</td>
<td>1153</td>
<td>889</td>
<td>720</td>
<td>628</td>
<td>490</td>
<td>372</td>
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</tbody>
</table>

2.1.1 Breeds

The native Finnish cattle breed is Finncattle, which is divided to three subtypes: Western, Eastern and Northern. Until the 1960s, Finncattle was the most common cattle breed in Finland, but its numbers have since decreased rapidly (Maijala 1999). Today only 1% of dairy cows are Finncattle (MKL 2000). Finncattle is small in size and very well adapted to local conditions, but its production levels are lower than those of the current major dairy breeds. In 1999, the average annual milk production of Finncattle was 5 921 kg per cow, with average fat and protein percentages of 4.41 and 3.43, respectively (MKL 2000). The average live weight of Finncattle cows was 500 kg.

The first Ayrshire animals were imported to Finland already in the late 19th century, mainly from Scotland and Sweden (Maijala 1999). Its numbers have steadily increased since, and from the 1960s onward, it has been the predominant cattle breed in Finland. These days, approximately 75% of dairy cows are Finnish Ayrshires (FAy) (MKL 2000). The FAy is one of
the best red breeds in the world for protein production \cite{FABA2000}, and it continues to hold
its ground in Finland despite the dominance of the Holstein for dairy production elsewhere.
In 1999, the average annual milk production of FAy cows was 7 381 kg per cow, with average
fat and protein percentages of 4.36 and 3.36, respectively \cite{MKL2000}. The average live
weight of FAy cows was 531 kg.

Importation of Friesian animals to Finland started in the 1960s, and initially they were
mainly used for upgrading herds from Finncattle to Friesian \cite{Maijala1999}. The Finnish
Friesian originated from black and white animals mostly from Sweden, and it was con-
sidered to be more of a dual-purpose type than the FAy. However, from the 1980s onward,
Finnish Friesian has actively been upgraded with imported Holstein semen, with the fre-
cuency of Holstein genes already at 37\% in Finnish Friesian cows born in 1995 \cite{Lidauer
andMäntysaari1996}. Despite the Holsteinization, the proportion of the Holstein-Friesian (HFr)
of all dairy breed animals has remained the same in Finland since the mid-1980s; currently
24\% of dairy cows are HFr \cite{MKL2000}. In 1999, the average annual milk production of
the HFr was 7 716 kg per cow, with average fat and protein percentages of 4.02 and 3.29,
respectively \cite{MKL2000}. The average live weight of HFr cows was 562 kg.

Eight beef cattle breeds currently exist in Finland \cite{Maijala1999}. The oldest and most
common are the British breeds Aberdeen Angus and Hereford, and the continental breeds
Charolais and Limousin. Simmental is also starting to grow in popularity. Furthermore,
some Piemontese and Highland Cattle breed animals can be found, and in the late 1990s,
Blonde d’Aquitane was introduced to Finland \cite{Maijala1999}.

In 1999, there were approximately 372 000 dairy cows in Finland, and only 27 500 mother
cows \cite{Kallinen2000}. Consequently, only 2\% of beef produced in Finland originates from
beef breed herds \cite{Korhonen and Toivonen1994}. Crossing of dairy cows with beef bulls has
not gained in popularity, the number of first inseminations with beef bulls remaining between
5 to 10\% for the past 20 years despite active campaigning by slaughterhouses and animal
breeding organizations \cite{Korhonen1994; Holmström2000}. As a result, over 90\% of beef is
produced as a by-product of milk production with dairy breed animals, the majority of which
are pure-bred FAy.

\subsection{Dairy cattle farms}

The number of dairy cattle farms has declined over the years; while in 1990 over 40 000
dairy farms and 11 500 beef farms existed, in 1999 only 27 000 dairy farms and 6 700 beef
farms were left \cite{Agrifacts2000}. However, cattle production remains economically the most
important agricultural production form in Finland. In 1999, income from milk, beef and
veal production formed 52\% of total agricultural gross return (subsidies excluded) \cite{Agrifacts
2000}.

As the number of dairy cattle farms has decreased, the average size of farms has increased.
However, the cattle farms in Finland are still very small compared with those of many other
countries. The average number of dairy cows per dairy farm was 16.5, and the average
number of fattening bulls per beef farm was 27 in 1999 \cite{Kallinen2000}. Of all dairy farms,
over half also fatten at least some of their bull calves and surplus heifers, while the other half
sell the surplus calves to specialized fattening farms.

\subsection{Carcass classification}

Since Finland joined the EU in 1995, Finnish cattle carcasses have been classified according
to the European SEUROP classification system. All cattle carcasses are routinely classified at
slaughterhouses for pricing purposes and for guiding the material within the slaughterhouses.

The carcass classification is done within two hours of stunning to prevent drip loss from affecting measurement of carcass weight. After slaughter, the head, hide and intestines are removed from carcasses. The cleaned carcasses are then halved, and a trained classifier weighs and evaluates them with respect to fatness and fleshiness. The official carcass weight is the measured weight of the hot carcass minus a 2% hot carcass deduction.

There are officially five fatness and six fleshiness grades in the SEUROP system (Appendices 1 and 2), in addition to which the grades can be further divided to subclasses if needed. In Finland, fatness is classified according to the original SEUROP grades, but fleshiness is classified in 11 grades. No fleshiness grade S exists because there are no double-muscled breeds in Finland except for a few recent Piemontese imports. On the other hand, grades R, O and P are divided to three subclasses, each of which is marked with + and - symbols; e.g., R+, R and R-.

In general, Finnish cattle carcasses grade well for fatness (Figure 1), but poorly for fleshiness (Figure 2). The main reason for the overall poor fleshiness grade is the small number of pure beef breed animals and beef-dairy breed crosses compared with the large number of pure dairy breed slaughter animals.

![Fatness grade distribution](image)

Figure 1: Distribution of cattle carcasses for EUROP-fatness grades in Finland in 1996 (TIKE 1997).

### 2.1.4 Carcass pricing

Over ten individual slaughter companies in Finland slaughter cattle. All companies decide on their own pricing policies for cattle carcasses, but in practice, pricing is very similar for all companies. The base price of beef is different for calves, bulls, heifers and cows, and may differ within each of the forementioned classes based on the weight of carcasses.

The base price per kg of carcass is defined for a reference carcass type with regard to fatness and fleshiness grades; for example, fatness grade 2 and fleshiness grade O for bulls. The final price per kg of carcass is formed by either giving premiums for better fleshiness classification or by deductions from base price for poorer fatness or fleshiness classification. Some slaughter companies also give an extra premium for cross-bred or pure beef breed
carcasses. The final price that a farmer gets for a carcass is formed by multiplying the final price per kg of carcass by the carcass weight of the animal.

Base beef prices have declined drastically after Finland joined the EU in 1995, and are currently very low (Agrifacts 2000). For example, thus far in 2000 the producer price for a bull in reference class O2 has been 1 FIM lower per kg in Finland than the European Union average (Kallinen 2000). In addition, more and more cattle carcasses do not reach the reference fatness and fleshiness grades for pricing. As a result, the income for farmers from beef is substantially reduced these days.

2.2 Beef traits in breeding programs of dairy cattle in Finland

Increased beef consumption and production in the 1950s and 1960s led to increased importance of traits, such as growth rate, in dairy cattle breeding (Lindström and Maijala 1970). As a consequence, interest arose in developing the Finnish dairy cattle breeds into dual-purpose breeds, and some beef production traits were introduced into breeding programs of dairy cattle.

2.2.1 Growth

The first testing stations for future artificial insemination (AI) bulls were founded in the mid-1960s (Lindström and Maijala 1970), and in 1974 all bull testing for growth was centralized to one station (Maijala 1999). In this station, the growth capacity of bull calves intended for use in AI service is measured under controlled conditions, after which breeding values are estimated for the bulls based on their growth during this testing period. In the beginning, only the bull’s own growth was used, but from 1974 onward, the breeding values were estimated with a selection index for deviation of bulls’ growth from the corresponding breed average for contemporary bulls in test station (Maijala 1999). From 1996 onward, the breeding values have been estimated with the Best Linear Unbiased Prediction (BLUP) method using an animal model (Korhonen 1996).
The testing period has shortened considerably over the years. Originally, the testing period took place while the bull was 60 to 365 days of age (Lindström and Maijala 1970), but today bulls start the test at the age of 210 days and finish at the age of 330 days (Finnish Animal Breeding Association (FABA), personal communication). The bulls are weighed at the beginning and at the end of the test, and breeding values for growth are estimated based on these two weights. Conformation and character of the bulls are also evaluated at the end of the test, and heart girth circumference and wither height are measured. In the 1999 growth test, the average daily growth was 1 406 g/day for FAy bulls, 1 194 g/day for Finncattle bulls and 1 439 g/day for HFr bulls (Kiljunen 2000).

The aim has been to yearly cull around 20% of the tested bulls at the end of the testing period, with approximately 80% of culling being due to weak growth and 20% due to poor conformation (Maijala 1999). However, these days, conformation and other culling reasons are more important than growth. For example, in 1999, 37% of bulls were culled after the test, of which 17% due to poor growth, 54% due to poor conformation and 28% for other reasons such as accidents and illness (Kiljunen 2000). There is, however, some pre-selection of bull calves for normal size and development on their home farms before they are sent for growth testing at the age of six months (Haltia et al. 1999).

2.2.2 Daughter live weight and conformation

A live weight breeding value has been estimated for AI-bulls since the beginning of progeny testing in Finland, based on the estimated live weight of bulls’ milking daughters. Initially, the breeding value was the mean of the estimated live weights of the daughters (e.g., Varo 1954). However, from the beginning of the 1970s, a selection index based on live weight deviations of daughters from the herd average was used instead (Maijala 1972), and from the 1980s onward, the live weight breeding value has been estimated for sires using the BLUP methods (Hietanen 1992). From 1990, live weight indices have been estimated using the animal model BLUP so that cows also get estimated live weight breeding values (FABA, personal communication).

The live weight of daughters of an AI-bull is estimated based on heart girth circumference, which is measured at the same time as their conformation traits are assessed. The live weight is estimated for the first time during the first lactation ("heifer weight") and again during the second or possibly even later lactation ("mature weight"). At present breeding value evaluations are run with a repeatability model so that all measurements of a cow’s live weight during her first three lactations are included in the evaluations (FABA, personal communication).

Currently, AI-bulls also get estimated breeding value (EBV) for some other traits that are related to the size of their milking daughters. In addition to using heart girth circumference for estimating live weight, a breeding value is predicted for heart girth circumference itself as well. Breeding values are also estimated for wither height of cows. Finally, a body index is obtained as a mean of heart girth circumference and wither height EBVs. The genetic evaluation for these conformation traits is carried out with animal model BLUP, using a repeatability model for each individual trait (FABA, personal communication).

2.2.3 Selection for beef traits in dairy cattle

The first total merit index for dairy breed AI-bulls was developed in Finland in 1981 (Hellman 1981). As both the FAy and the HFr were considered to be dual-purpose breeds at the time, the bull’s own growth breeding value was included in the total merit index together with
other production, fertility, health and conformation traits. At its widest, the total merit index included 12 traits, most of which had small economic weight. The most important trait with an economic weight of 1.0 was protein yield, while growth had an economic weight of 0.075.

In 1993, the total merit index was reformatted by dropping most of the original traits with small economic weight, and including only the economically most important traits (Juga 1993). At this point, growth was also left out of the total merit index, and it has not been included since. The traits currently included in the total merit index for all dairy breeds in Finland are protein yield, fertility, udder health, fat yield and udder conformation, listed in declining order of importance with respect to economic value (FABA, personal communication).

The EBVs for growth are still published for all progeny-tested bulls so that interested farmers can use them in choosing suitable sires with regard to the breeding goals at the farm. Considerable variation exists in the growth EBVs of top proven bulls; for example, in the breeding evaluation of spring 2000, the FAy bull with the fourth highest total merit index had a growth EBV of 123, whereas the second best bull with only a slightly higher total merit index had a growth EBV of 88 (Anonymous 2000).

Live weight or other body measurements, such as wither height, have never been included in the total merit index of Finnish dairy breeds. However, these breeding values are available for consultants of the Finnish Animal Breeding Association when they design breeding plans for individual farms. Some breeding values, such as for live weight and more recently for wither height, are also published for all proven bulls together with other production, health and conformation indices. The live weight EBVs are also published for all cows, and the conformation EBVs for all stud-book cows.

Some proven dairy breed bulls with exceptionally good growth EBVs were marketed to farmers as special "beef-power bulls" in 1970s (e.g., Lindström 1975b). The marketing target group was those farmers who fatten their own surplus calves, but do not want to use beef bull semen in their herds. Use of these special bulls resulted, however, in increased calving difficulties and calf mortality, and thus was eventually given up.

Today, selection for meat production traits in Finnish dairy cattle breeds is mainly done on the farms whose breeding goal includes beef. However, the selection direction is already determined by the selection of bulls in the national population breeding scheme. The weak selection pressure on beef traits, combined with possible negative relations with other traits under selection and the ongoing Holsteinization of the HFr, have lead to deteriorating carcass conformation. Consequently, in particular those fattening farms have suffered economically that specialize in growing bull calves and surplus heifers originating from dairy farms.

### 2.2.4 Milk-beef program

In 1975, a milk-beef program was developed to improve the efficiency of both milk and beef production in Finland (e.g., Lindström 1975a). The program focuses on creating an individual mating plan for each dairy farm participating in the program, by taking into consideration the planned use of calves before the actual insemination.

The program divides the dairy cows of a farm to the following three classes based on cow indices: high, medium and low (Haltia et al. 1999). Moreover, conformation and non-dairy traits of the animals are taken into account when assigning the cows to different classes. The best class contains approximately 45 to 50% of the cows, the average class 40 to 45% of the cows and the poor class the remaining 5 to 15% of cows. Heifers are assigned to the average class.
The best class of cows is recommended for insemination with the top proven dairy breed bulls, and the poor class with beef breed bulls. Thus, the pure-bred progeny of the best cows will remain in dairy production, and the cross-bred progeny of the poorest cows will be used for beef production. The average class of cows and most heifers are recommended for insemination with young unproven dairy breed bulls to ensure that test bulls will get enough progeny for genetic evaluation.

The use of young and proven bulls has approximately followed the forementioned plan, but the number of beef breed inseminations has failed to reach recommended levels. The best year was in 1989, when 8.9% of first inseminations were done with beef breed bulls (Korhonen 1994). However, since then, the proportion of beef breed semen used in all first inseminations has declined, being only 4.2% in 1999 (Holmström 2000). The most used beef breed in inseminations has varied over the years, but is currently Limousin (35.2% of beef breed inseminations), followed by Aberdeen Angus (17.2%), Charolais (15.1%), Hereford (11.2%), Simmental (9.3%) and other breeds (12.0%), mainly Blonde d’Aquitane.

In 1991 to 1992, dairy cattle farmers were questioned with respect to their opinions on using beef breed bulls for insemination in their herds (Korhonen 1994). Sixty percent of the interviewed farmers said they had had a good experience with beef breed crosses on their farm, with 25% and 12% having had fair and negative experiences, respectively. The most important benefits of using beef breed bulls were:

1. Progeny of the poorest cows will cease to remain in dairy production;
2. Cross-bred calves are more valuable when sold to fattening farms; and
3. Cross-bred calves have better beef production qualities.

The greatest obstacles reported for increasing the number of beef breed inseminations were:

1. Small herd size, so that all cow calves are needed for dairy production;
2. Level of the herd is so good that they do not want to use beef breed inseminations; and
3. Fear of calving difficulties.

2.3 New alternatives for breeding for beef traits

Data on carcass weight and carcass quality traits have not been used routinely in cattle breeding in Finland thus far. Each slaughterhouse has had its own carcass identification system, which has not been compatible with animal breeding cattle registers such as milk-recording data. Another problem has been the cattle identification system, where identification number of an animal was unique only during a certain time period within its farm of origin. This system was especially ambiguous for animals that changed farms during their lifetime such as a large proportion of dairy breed bulls that were fattened outside their birth farms.

Upon joining the European Union in 1995, Finland formally adopted a new national cattle identification system. The main reason behind the change was to make it easier to follow movements of animals, especially for disease control. In this new system, each animal gets a nationally unique identification number at birth. The same number follows an animal throughout its lifetime and even after death at slaughterhouse in carcasses. Therefore, in theory, it should even be possible to trace the meat sold to consumers to a certain animal.
Slaughter companies have gradually changed their own systems to the new identification system. The first large company began using the new identification numbering in some of their slaughterhouses already in the beginning of 1996. When the majority of big slaughter companies have instigated this identification system, it will be possible to routinely acquire large amounts of carcass data from slaughterhouses and combine it with other cattle registers. This new source of data will offer many opportunities for animal breeders to improve beef production traits of Finnish cattle breeds.

Approximately 40 to 45% of dairy cows are inseminated with young bulls in Finland (Haltia et al. 1999). This procedure ensures that all of the approximately 160 FAy, 40 HFr and 4 to 8 Finncattle young bulls tested each year get enough daughters to be evaluated with adequate accuracy in genetic evaluation. The aim is to produce approximately 140 to 150 daughters for each FAy and HFr young bull, which requires around 1 500 inseminations per young bull.

Since sexing of semen is not yet available for routine use, half of the calves born from test inseminations are males that will be fattened for beef production. The carcass information from these bulls is currently not utilized in genetic evaluations of their sires, but it could well be used to progeny test the test sires for their sons’ beef production traits.
3 OBJECTIVES OF THE STUDY

The objective of this study was to assess opportunities to use routinely collected field carcass data in genetic evaluation of dairy breeds for beef production traits. Alternative strategies for utilizing carcass traits in breeding programs of dairy cattle were also studied. To this end, the following subjects were studied:

- Non-genetic factors affecting the variation in carcass traits of dairy breed bulls, heifers and cows;
- The genetic (co)variation of carcass traits and their relationship with milk traits;
- The prediction of breeding values for AI-sires with respect to carcass traits;
- Construction of economic index for dual-purpose selection objective in dairy cattle;
- Selection strategies for improving beef traits in dairy cattle; and
- Different information sources for carcass traits in sire evaluations.
4 MATERIALS AND METHODS

4.1 Materials

Carcass data that were used in papers I, II and III were collected in slaughterhouses of Lihakunta Oyj in Northern and Central Finland. The data collection period began in January 1996 and ended in June 1998. During this period, almost 180 000 heads of cattle were slaughtered in the six slaughterhouses participating in data collection.

As the aim of this thesis was to study the possibilities of breeding for improved carcass traits within pure dairy breeds, all beef breed and cross-bred animals were excluded from the analyses. Animals originating from farms not participating in the milk-recording system were excluded as well because it was not possible to trace their pedigrees in the genetic analyses. After data editing, 122 275 animals remained in the dairy breed carcass data set.

Fattened bulls formed the largest part of the carcass data set (48%), with the rest of the slaughtered animals being culled cows (39%), heifers (11%) or calves of under 10 months of age (2%). In this study, a heifer is defined as a female animal that is over 10 months old and has not calved, while a cow is an animal that calved at least once before slaughter.

The majority of the animals were Finnish Ayrshire (72%), with Holstein-Friesian animals forming 27% and Finncattle animals 1% of the data set. Finncattle was left out of the final data set since the population is very small, and therefore its economic influence in beef production in Finland is negligible. The calves under 10 months were also excluded as veal production is not commonly practised in Finland.

For all of the animals included in the carcass data, information was available on carcass weight, and for almost all, on the official SEUROP-scores for carcass conformation traits (fatness and fleshiness). The 1 436 animals that lacked information for carcass conformation had their carcasses rejected in health inspection, after which, carcass conformation was not evaluated; however, their carcass weight was recorded as for the rest of the animals.

Carcass weight was measured according to standard slaughter procedures, and fatness and fleshiness were evaluated subjectively according to the routinely used European Union SEUROP classification system (EUR-OP 1995; Appendices 1 and 2). For this study, the original fleshiness classification was transformed into numbers such that numbers from 1 to 9 replaced grades from P- to R+. Due to the lack of subclasses in U and E, they were numbered as 11 and 14, respectively. Figures 3 and 4 illustrate the frequency distributions of the fatness and fleshiness grades in the carcass data for bulls, heifers and cows.

For papers II and III, additional data on slaughtered cows’ first lactation milk production traits were obtained from the database of the Agricultural Data Processing Centre. Information on cows’ estimated live weight based on heart girth circumference was also included if it had been recorded. The information on milk traits included 305-d milk, fat and protein yield, and fat and protein content. The structure of the complete carcass and milk data set is presented in Figure 5.

Pedigrees were obtained for the slaughtered animals from the database of Agricultural Data Processing Centre. The pedigree information included parents and grandparents when available, and the slaughtered animals were required to have at least one known parent to be included in the analyses.
Paper I

The data set in paper I comprised information collected on FAY and HFR bulls and heifers that had been slaughtered in the two biggest collaborating slaughterhouses between 1 January 1996 and 31 August 1997 (Figure 5). Only bulls and heifers that were slaughtered at the age of 300 through 899 days and with carcass weight of at least 130 kg were included. Altogether 38,188 animals were included in the analyses.

The data were divided to subsets to study whether fixed effects and genetic variation for carcass traits differ between breeds and sexes. The primary subsets were FAY bulls with 22,231, HFR bulls with 8,711, FAY heifers with 5,328 and HFR heifers with 1,918 observations. Primary data subsets were further combined within sexes and breeds, and all animals were also analysed together as one data set.
HFr bulls and heifers:
- Carcass fleshiness
- Carcass fatness
- Carcass weight

FAy bulls and heifers:
- Carcass weight
- Carcass fatness
- Carcass fleshiness

FAy cows:
- Estimated heifer weight
- Estimated mature weight
- Milk yield
- Fat yield
- Protein yield
- Fat content
- Protein content

Date of slaughter:

Date of slaughter:

Milk recording system

Figure 5: Structure of field data.
Paper II

The data set in paper II consisted of information collected on FAy cows slaughtered in the six participating slaughterhouses between 1 January 1996 and 30 June 1998 (Figure 5). Data on slaughtered cows’ first lactation milk production traits and cows’ estimated live weight based on heart girth circumference were also included.

The oldest cows that were included in the data had calved for the first time in September 1987. Furthermore, it was required that cows had completed their first lactation, and had a known birth date and last calving date. These requirements reduced the size of the final data set used in the analyses to 28 362 cows, 22 944 of which had at least one measure of estimated live weight.

Paper III

The data set in paper III comprised information gathered on FAy bulls, heifers and cows slaughtered in the six participating slaughterhouses between 1 January 1996 and 30 June 1998 (Figure 5). The cow data were exactly the same as described in paper II, and all FAy animals in paper I were also included in this data set. For animals slaughtered after 31 August 1997, which was the final slaughter date covered by data of paper I, the restrictions imposed on the bull and heifer data were the same as outlined in paper I. After restrictions, the final data set included 41 834 bulls, 9 018 heifers and 28 362 cows.

To study the relationships between carcass and milk production traits, the data were divided to two subsets, with bulls and heifers in one subset and cows in the other. Altogether 67% of animals had paternal half-sibs and 10% had maternal half-sibs in both data sets. Furthermore, 32% of bulls and heifers had their dams included in the cow data set.

4.2 Methods

4.2.1 Statistical analyses

The model used in paper I for analysing the data subsets within breeds and sexes included the fixed effects of

- slaughterhouse,
- year-month of slaughter and
- age class,

and random effects of

- herd,
- animal or sire or maternal grand-sire and
- residual.

When analysing combined data sets and in paper III, fixed effects of breed and/or sex were also included.

The model assumed for carcass traits of cows in papers II and III included the fixed effects of

- slaughterhouse,
• year-month of slaughter and
• age class,
regression on
• number of days from last calving to slaughter,
and random effects of
• herd,
• animal and
• residual.

For estimated live weight and milk production traits, the model included the fixed effects of
• calving year-season class at first calving and
• age at first calving,
and random effects of
• herd,
• animal and
• residual.

In paper I, the Restricted Maximum Likelihood (REML) method was used for estimating variance components from animal models and sire models, by VCE4.0 software (Groeneveld 1997). Sire maternal grand-sire models could not be solved using VCE4.0, so the variance and covariance components from these models were estimated using the Gibbs sampling (GS) method and MTGSAM software (Van Tassell and Van Vleck 1995). For comparison of the methods, sire model estimates were obtained also with the GS method. In paper II, variance and covariance components for the traits were estimated with the REML method and the program package VCE4.0 (Groeneveld 1997), and in paper III with the program package VCE4.2 (Neumaier and Groeneveld 1998).

4.2.2 Construction of selection index

The genetic and phenotypic parameters for carcass and milk traits for calculations in paper IV were obtained from literature. Parameters for carcass traits were taken from de Jong (1997), and parameters for milk production traits from van Veldhuizen et al. (1991). The genetic correlations between carcass and milk traits were adapted from van Veldhuizen et al. (1991). The animals in both the aforementioned studies of were all either Dutch Black and White or Dutch Red and White dairy breeds, and did not include any beef crosses.

The economic weights for carcass and milk traits were derived to represent the Finnish economic situation by using product prices and production circumstances in Finland in 1997.

Selection index theory (Hazel 1943) was used to evaluate the expected first generation response to selection in the aggregate breeding goal as well as in the individual traits. Interest was in selection of bulls at the time they received the first breeding value predictions based
on the milk production data of their daughters. At that point, carcass data were assumed to be available for 100 sons and 10 daughters, and milk production data for 100 daughters.

Six alternative selection indices were constructed to compare different strategies to improve carcass quality, body weight and milk production in dairy cattle. Reduction of variances due to selection (Bulmer effect) was not taken into account, as its effect on the ranking of the different alternatives was assumed to be small.

4.2.3 Analytical comparison of breeding strategies

The genetic, phenotypic and economic parameters for carcass and milk traits for calculations in paper V were obtained from other parts of the study. The genetic and phenotypic parameters for carcass traits in bulls and heifers were obtained from paper I, and the genetic and phenotypic parameters for carcass and milk traits in dairy cows from paper II. The genetic and phenotypic correlations between carcass traits of bulls and heifers, carcass and body weight traits of dairy cows, and milk production traits were obtained from paper III. The economic weights of carcass and milk production traits were obtained from paper IV.

Asymptotic response in aggregate genotype and its component traits to selection on multivariate predictions was calculated with a selection index that approximates animal model BLUP selection with a deterministic method (Villanueva et al. 1993). Changes in genetic parameters due to linkage disequilibrium generated by selection were accounted for (Bulmer 1971). Reduction in selection intensity due to finite population size and correlated breeding values of selection candidates was also taken into account (Meuwissen 1991). Calculations were done using the program MSSEL (Rutten et al. 2000).

Population structure assumed in the predictions was chosen to resemble the current selection scheme of young dairy breed AI-bulls in Finland (Haltia et al. 1999). Three different breeding goals were assessed in the study: including only milk traits, including only carcass traits and including both milk and carcass traits. Information sources for genetic evaluation of carcass traits were animal’s own record, records of male and female half-sibs, records of male and female progeny and/or parent EBVs. Information sources in evaluating sires for milk traits included female half-sibs, female progeny and parent EBVs, and for dams own record, female half-sibs and parent EBVs.
5 RESULTS AND DISCUSSION

5.1 Non-genetic factors

5.1.1 Breed

The carcasses of HFr bulls were on average 10 kg heavier than those of FAy bulls, while in heifers the corresponding difference was 8 kg in favour of HFr heifers (I). The HFr heifer carcasses were slightly fatter than the FAy heifer carcasses, but no difference was found between the breeds in bulls. The HFr bull and heifer carcasses classified 0.3 EUROP grades higher for fleshiness than the FAy bull and heifer carcasses.

Traditionally, the Finnish Friesian has been considered to have superior carcass quality traits to the FAy (Kenttämies 1983). However, the importation of Holstein to Finnish Friesian has weakened the carcass quality of the HFr relative to the FAy (Liinamo 1997). In the data of this thesis, the HFr carcasses were still heavier and had better grades in fleshiness than FAy carcasses, but the difference between breeds was smaller than in Kenttämies. The average proportion of Holstein genes in the Finnish Friesian was 10% in the early 1980s, whereas by the mid-1990s it was close to 40% and rising rapidly (Lidauer and Mäntysaari 1996). As a result, it is to be expected that with the continued importation of Holstein material the Finnish HFr will eventually lose its superiority in carcass quality traits over the FAy.

5.1.2 Sex

The average carcass weights for bulls and heifers were 273 kg and 203 kg, respectively (I). Heifer carcasses were on average 0.5 grades fatter than bull carcasses (Figure 3), while bull carcasses were classified on average one fleshiness grade higher than heifer carcasses (Figure 4). Heifers were more susceptible to gaining fat with age, and differences in carcass quality between sexes increased with age. The different development of the sexes is in agreement with earlier reports (e.g., Berg and Butterfield 1976; Kenttämies 1983).

5.1.3 Age

On average, bulls and heifers were slaughtered at the age of 18.5 months (I). Heifers were 1.5 months older than bulls at slaughter, and HFr animals were slaughtered 0.5 months younger than FAy animals. Carcass weight increased from the youngest (< 12 mo) to the oldest bull and heifer age class (> 26 mo), by 115 kg in bulls and by 90 kg in heifers. Fatness and fleshiness also increased with age, but change in fatness classification was faster in heifers, while improvement of fleshiness was faster in bulls.

The youngest FAy cows in the data had been slaughtered at under 3 years and the oldest at 13 years of age, with an average slaughter age of 5.4 years (II). The FAy cow carcasses weighed on average 41 kg more than the FAy heifer carcasses, but their fatness grades were similar (I, II). Heifer carcasses classified on average one grade higher than cow carcasses for fleshiness. The poorer average fleshiness grades of cow carcasses relative to heifer carcasses could be partly due to ageing and the stress caused by lactation. It is also likely that many of the animals culled already as heifers were culled because they had shown more capacity towards beef production than milk production.
5.1.4 Production environment

The effect of herd on carcass traits of FAy and HFr bulls and heifers was considerable (I). In carcass weight, the variation between herds was approximately one-half of the phenotypic variance. The effect of herd was somewhat smaller on fatness, where it explained 23 to 47% of the total variance, and on fleshiness, where herd effect explained 20 to 26% of the phenotypic variance of fleshiness grades. These results agree closely with those of Kenttämies (1983). In FAy cows, the herd effect was less pronounced than in bulls and heifers, both on carcass and milk traits (II).

The herd correlations ($r_c$) between different carcass traits of the FAy and HFr bulls and heifers were positive and high, implying that management and feeding have a key position in the production of young slaughter animals of high carcass quality (I). In the FAy cows, $r_c$ were also positive and moderate to high between carcass traits and milk production traits, except for correlations with milk fat content, which were low and negative (II). The $r_c$ between carcass traits of the FAy bulls/heifers and carcass traits of the FAy cows were all positive and moderate, suggesting a common favourable effect on all animals reared in the same herd regardless of their intended use (III). The positive $r_c$ between bull and heifer carcass traits and cow milk production traits also suggest some common favourable environmental effects for both growing and lactating animals in the same herd (III).

Other environmental factors that had an effect on carcass traits of bulls, heifers and cows included slaughterhouse and slaughter month-year (I, II, III), and in cows the number of days from last calving until slaughter (II, III).

5.2 Genetic factors

An overview on the magnitudes of the estimates of heritabilities and genetic correlations for carcass, body weight and milk production traits in Finnish Ayrshire (I, II, III) is presented in Table 2.

5.2.1 Heritabilities

Estimates of heritability ($h^2$) for carcass quality traits of FAy and HFr bulls and heifers were relatively low in all breed and sex data subsets, with fleshiness having the highest $h^2$ estimates varying from 0.16 to 0.31 (I). For carcass weight, heritabilities in the HFr data subsets were somewhat lower than in the FAy data subsets, while the opposite was true for fleshiness. The estimated heritabilities and herd effects were almost the same in all studied data subsets for the different models and methods of analysis (animal model vs. sire model vs. sire maternal grand-sire model; REML vs. GS). Observed differences all fell within the bounds of standard errors of estimates (I).

Estimated heritabilities from the FAy and HFr bull and heifer data sets were relatively low compared with literature (e.g., Wilson et al. 1976; Koch 1978; Lamb et al. 1990; Robinson et al. 1990; Arnold et al. 1991; Gregory et al. 1994; Wheeler et al. 1996; de Jong 1997; van der Werf et al. 1998). However, the previously mentioned studies assumed herd as a fixed effect, whereas herd was treated as a random effect in this study. Estimated within-herd heritabilities in study I, which were obtained by leaving herd variance out of the denominator, were within the range of the heritabilities reported in literature.

Estimates of heritability for different body weight measures of the FAy cows were moderate to high, with carcass weight having the highest $h^2$ of 0.40 (II). Moreover, the estimates of $h^2$ for their fatness and fleshiness grades were somewhat higher than for FAy bulls and
Table 2: Overview\(^1\) of estimates of heritabilities (on diagonal) and genetic correlations (above diagonal) for carcass, body weight and milk production traits of Finnish Ayrshire.

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<th>Trait</th>
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<td>Fatness</td>
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<td>Heifer live weight</td>
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<td>Mature live weight</td>
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<td>Carcass weight</td>
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<td>Milk yield</td>
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\(^1\)Key: 0 = -0.1 – +0.1; + = +0.1 – +0.2; ++ = +0.2 – +0.6; +++ = +0.6 – +1.0; - = -0.1 – -0.2; --- = -0.2 – -0.6

heifers. Heritability estimates for milk production traits were in the low end of the usual range.

The high estimates of heritability of carcass traits of FAy cows as compared with FAy bulls and heifers were somewhat surprising. This result is in contrast with de Jong (1997), who found that heritability estimates for most carcass traits were much lower for dairy cows than for dairy bulls. This discrepancy might be due to the different breeds examined in the two studies, the Dutch bulls being fattened under more uniform conditions, or to the Dutch cows having considerably higher carcass weight, higher fatness and better fleshiness to begin with. The FAy data suggests that additive genetic differences are expressed more clearly in mature animals.

5.2.2 Genetic correlations

In FAy and HFr bulls and heifers, estimates of genetic correlations \( r_g \) between carcass traits were in general favourable (I). The genetic correlation between carcass weight and fleshiness was positive and moderate to high, while \( r_g \) between carcass weight and fatness, and fleshiness and fatness were low. On the other hand, in FAy cows all \( r_g \) between body weight and carcass traits as well as between carcass weight and fatness were positive and moderate to high (II). This difference in \( r_g \) between fatness and other carcass traits in bulls/heifers vs. cows may be due to bulls and heifers being slaughtered at a different point in the growth curve than cows.

Genetic correlations between the analogous carcass traits in the FAy bull/heifer data set and the FAy cow data set were positive and moderate, especially between carcass weight and fleshiness grades (III). The other \( r_g \) between the bull/heifer and the cow carcass traits were mostly positive and low. Thus, it would seem that, at least in FAy, the carcass traits of young
and growing animals, in contrast to fully mature animals, can be considered as partly different traits. The $r_g$ between the carcass traits of the FAy bulls/heifers and the cows estimated in this study are generally consistent with those estimated for Dutch Black and White and Dutch Red and White populations (De Jong 1997).

The genetic correlations between body weight measures of the FAy cows and their first lactation milk production traits were low (II). By contrast, $r_g$ between the carcass quality traits and milk traits were mostly negative and had higher absolute values than those between body weight and milk production traits. These results generally agree with earlier studies, although none of them had simultaneously analyzed all the traits included in this study (e.g., van Veldhuizen et al. 1991; Hietanen and Ojala 1995; Veerkamp and Brotherstone 1997).

The genetic correlations between the FAy bull/heifer carcass traits and the FAy cows’ first lactation milk production traits were either positive and low (yield traits) or close to zero (composition traits). These results were mostly in agreement with previous studies (e.g., Mason 1962, 1964; Langlet 1965; Calo et al. 1973; Alps and Averdunk 1984). In some studies, however, also much higher genetic correlations between milk and beef traits of dairy cattle have been obtained (e.g., Mason et al. 1972; Colleau et al. 1982; van Veldhuizen et al. 1991), but in most of these the standard errors of the estimates were very large.

5.3 Breeding values of sires

Based on the results of papers I and III, breeding values were estimated for carcass weight, carcass fatness and carcass fleshiness for those FAy and HFr sires that had progeny in these data sets. The evaluation was based on animal model BLUP methodology, using program package PEST (Groeneveld 1990). Only bull and heifer progeny were used in the breeding value estimation. The fixed effects in the model were sex, breed, slaughter age, slaughter month, slaughterhouse and herd, as presented in papers I and III. There were altogether 883 and 360 HFr sires, for which breeding values were estimated. To facilitate the comparison of sires, the EBVs were standardized within breeds (mean 100 and standard deviation 10) in such a way that for all traits figures above 100 were favourable.

Sires that were accepted as proven bulls in the national breeding value estimation of spring 1999 (minimum total merit index +12) were more closely inspected with respect to their carcass indices. Only those sires that had carcass indices based on data of at least 20 progeny were included in the study, resulting in a total of 91 FAy and 41 HFr sires.

Even though sires had already been strongly selected for the total merit index (protein yield, fertility, udder health, fat yield, udder conformation), considerable genetic variation was present in their carcass traits. For example, the difference between the best and the poorest FAy sire was 62 index points in carcass weight, 41 index points in fatness and 57 index points in fleshiness (Table 3). In practice, this corresponds to a difference of 21 kg in carcass weight, 0.2 EUROP fatness grades and 0.8 EUROP fleshiness grades between the two extreme sires. Marked differences also existed between the best and the poorest HFr sires with respect to their carcass EBVs (Table 4).

The breeding values demonstrated that among the FAy sires bulls could be found with both a good total merit index and excellent carcass EBVs (Table 3). For example, the FAy sire "A" not only had a total merit index of +20, but also a carcass weight EBV of 137 and a fleshiness EBV of 130. Its progeny did not have a tendency for excessive fatness either. In contrast, FAy sire "I" had an equally high total merit index but very poor carcass weight and
Table 3: Proven Finnish Ayrshire sires with the best and the poorest carcass indices based on at least 20 progeny (spring 1999).

<table>
<thead>
<tr>
<th>Sire</th>
<th>Total merit index</th>
<th>Carcass weight EBV</th>
<th>Fatness EBV</th>
<th>Fleshiness EBV</th>
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<tr>
<td><strong>Best sires</strong></td>
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<tr>
<td>A</td>
<td>20</td>
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<td>B</td>
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EBVs. For a dairy farmer, it does not matter which of the two sires is chosen for use in the herd, but from a beef producer’s point of view, there is a considerable difference.

In HFr less choice was evident in the list of best and poorest sires (Table 4). Some sires had relatively good carcass weight EBVs, but good fleshiness EBVs were less common. Especially poor in this respect was HFr sire "F", which had a total merit index of +30, but a carcass weight EBV of 84 and an exceptionally poor fleshiness EBV of 59. In addition, even those HFr sires that had reasonably good carcass weight and fleshiness EBVs, such as sire "B", the carcasses of their progeny showed a tendency to gain too much fat. It would seem that the importation of Holstein into the Finnish Friesian has weakened the carcass quality traits of the HFr, although the effect on carcass weight has not been as great.

5.4 Selection index and different selection strategies

5.4.1 Simplified vs. multiple-trait indices

Ignoring some or even all genetic and phenotypic correlations between carcass and milk traits affected total predicted response only slightly compared with a full multiple-trait index (IV). This result, mainly due to the dominating effect of protein yield in the breeding goal, agrees with findings reported by e.g. Spelman and Garrick (1997).

Theoretically, a multiple-trait evaluation is the optimal methodology to evaluate and rank animals when selection is for a combination of traits (e.g., Thompson and Meyer 1986). In practice, however, multivariate indices can be computationally expensive when predicting...
Table 4: Proven Holstein-Friesian sires with the best and the poorest carcass indices based on at least 20 progeny (spring 1999).

<table>
<thead>
<tr>
<th>Sire</th>
<th>Total merit index</th>
<th>Carcass weight EBV</th>
<th>Fatness EBV</th>
<th>Fleshiness EBV</th>
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<tr>
<td><strong>Best sires</strong></td>
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<td>A</td>
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1 Estimated breeding value; standardized with mean 100 and standard deviation 10

breeding values of young dairy bulls from large data sets. Based on these results, simplified evaluations can be used for the prediction of breeding values of dairy bulls for carcass and milk production traits without fear of reduced total selection response.

Proportional gain resulting from carcass and milk traits differed somewhat between simplified and multiple-trait indices. Using wrong index weights which were derived for having only milk traits in the breeding goal when the true breeding goal also included carcass traits, reduced the response in carcass traits. These aspects should be considered especially in situations where a balanced profit is sought for the whole dairy cattle production sector.

5.4.2 Restriction of body weight of cows

The desired gain constraint set for body weight of cows resulted in considerable loss of predicted total response (IV). The main cause was a reduced response in protein yield, accounting for over 50% of the total loss in monetary units. The reduction of monetary response in carcass weight of bulls was larger than the monetary gain achieved by maintaining body weight of cows at the same level. This result is in line with Gibson and Kennedy (1990), who concluded that constrained indices should be avoided for economic genetic selection.

Interestingly, in paper V of the study, for several index variants, the asymptotic genetic gain in the carcass weight of cows was close to zero and in some cases even negative, i.e., as desired. At the same time, the response in protein yield and carcass weight of bulls was affected very little. The genetic parameters between carcass and milk traits were estimated from different populations in papers IV and V, which may account for the observed discrepancy between these studies. Thus, the possibility of constraining body weight increase of dairy cows while simultaneously breeding for improved carcass and milk production traits seems to some extent be dependent on the population in question. However, in paper V, setting the economic weight of carcass weight of cows to zero, increasing the economic weights
of carcass traits of bulls, or extensively using bull carcass data as an information source in indices resulted also in a negative economic response in the carcass weight of cows.

5.4.3 Sensitivity to product price changes
Changes in milk prices had the largest effect on both predicted total monetary response and relative contributions of different trait groups (IV). Changes in average beef price also had a notable effect on predicted responses, but changes in price differences between carcass quality categories affected predicted results only marginally. The efficiency of the index, with index weight factors derived for having only milk traits in the breeding goal when the true breeding goal did include also carcass traits, was especially sensitive for changes in milk and beef prices.

These results illustrate that the estimated total monetary responses are not robust for a wide range of product price situations. However, the relative contribution of milk traits to overall economic gain is much more stable.

5.4.4 Breeding goals
The asymptotic response in milk traits was very little affected whether the breeding goal included only milk traits or both milk and carcass traits (V). When the breeding goal included only beef traits, response in milk traits was reduced considerably, but the correlated response in milk traits was still positive. Overall, protein yield gave the highest economic response under all studied breeding goals.

Substantially more variation existed between the asymptotic response in carcass traits for the different breeding goals. In general, the breeding goal including both carcass and milk traits resulted in better response, particularly in bull carcass traits, than the breeding goal including only milk traits. As the response in milk production traits was equal in both options, the total economic response was improved under the breeding goal including both carcass and milk traits. While the largest responses in carcass traits were achieved in the extreme case of the breeding goal including only the carcass traits, the profitability was reduced due to the reduced response in milk production traits.

All breeding goals showed some positive response in carcass traits of bulls, but corresponding response in cows was either negligible or even negative irrespective of the breeding goal. The negative economic response in cow carcass traits was mostly due to decreased carcass fleshiness, and in some cases, due to increased carcass weight.

5.4.5 Information sources for carcass traits
Including information on carcass traits had little impact on response in milk traits (V). This result reflects that information on beef traits does not improve response when breeding only for milk. However, using information on carcass traits alone reduced response in milk traits, although a considerable positive response in milk traits remained. This result indicates the favourable genetic relationship between milk traits and carcass traits (III), and the dominant economic weight of milk traits in the breeding goal (IV).

In carcass traits, somewhat more variation was present in asymptotic response between indices containing different information sources (V). The response in cow carcass traits was especially sensitive to the information sources used in the selection index. In general, a favourable response in cow carcass traits was only observed when some cow carcass information was included in the index. The highest response in bull carcass traits was obtained
with a selection index that utilized information on the carcass traits of male progeny of sires, whereas the predicted carcass traits of sires themselves had only a minor effect. Based on these results, the need for individual growth testing for future AI-sires should be reconsidered, especially since progeny data on carcass traits is readily available for the sires.

5.4.6 Multi-stage selection of sires

The multi-stage selection schemes resulted in equal or lower total economic response as compared with the equivalent one-stage selection schemes (V). The relative proportions of response from different trait groups in multi-stage selection schemes were slightly different from those of one-stage selection. The asymptotic response in milk traits was somewhat reduced, while the response in carcass traits of bulls was, in most cases, either equal or slightly higher than the response obtained with one-stage selection. All studied multi-stage selection schemes resulted in an unfavourable response in carcass traits of cows due to decreased carcass fleshiness and, in some cases, also increased carcass weight.

Overall, the best multi-stage selection scheme was a three-stage scheme where 10% of sires were culled at the age of 1.5 years based on their own carcass traits. Further, 22% of sires were culled at the age of 3.5 years based on the previously available information plus information on their sons’ carcass traits. The final culling of sires was done at the age of 5.5 years based on all previously available information plus information on their daughters’ carcass and milk traits. At this final stage, the top 3% of sire candidates were selected. The scheme resulted in approximately equal total economic response to the one-stage scheme that utilized the same information, but its costs are expected to be somewhat lower due to need to maintain fewer bulls. There is still room for further optimisation of the selected proportion in different stages and selection schemes.
6 CONCLUSIONS

Based on the analyses of selection strategies, it is feasible to expand the total merit index of Finnish dairy cattle breeds to include carcass traits (IV, V). The inclusion of carcass traits in the breeding goal for both bulls and cows does not hinder progress in milk traits. It would also reflect the income sources of the farms better. The carcass weight and carcass quality traits of bulls in particular would benefit from being included in the breeding goal.

Results show that it is possible to breed for improved carcass weight and quality of young FAy and HFr slaughter animals. The carcass traits are heritable, although the heritability for the bull and heifer traits is relatively low (I). However, heritability of carcass traits of bulls and heifers is higher than, for example, the fertility and health traits that are currently included in breeding goals of dairy cattle. The genetic correlations of bull and heifer carcass traits are generally favourable, both between the carcass traits themselves (I) and between the carcass traits and milk production traits (III).

The relatively high heritability of carcass traits of FAy cows suggest that it would be easy to breed for improved carcass quality and optimal body weight of dairy cows (II). Although dairy cows are not intended as beef-producing animals, improved carcass fatness and fleshiness, and thus, improved body condition might help to reduce stress caused by lactation in high-yielding cows. This could, in turn, reduce problems related to negative energy balance during early lactation, such as weakened fertility.

Due to the negative genetic correlation between carcass quality and milk traits of dairy cows, their fatness and fleshiness will continue to deteriorate as a result of selection on milk production traits unless some counteractive selection is practised (II, V). The high positive genetic correlation between carcass traits of bulls/heifers and carcass traits of dairy cows might help to reduce the deterioration of cow carcass quality if improved carcass traits of young slaughter animals are selected for (III, V).

The data for progeny testing young AI-sires for carcass traits is already available due to the evaluation system of AI-sires in Finland. The progeny carcass data can be collected at a fraction of the cost of the data needed for progeny testing of sires for milk production traits. Furthermore, simplified evaluations that ignore genetic and phenotypic correlations between carcass and milk traits can be used for the prediction of breeding values of dairy sires without fear of reduced total selection response (IV).

Because bull and heifer progeny of young sires are slaughtered approximately 1.5 years before sires’ daughters finish their first lactation, it would be possible to select young sires on carcass traits over a year earlier than for milk. According to the results of this study, however, selection of sires for their carcass and milk traits could be done in one stage at the age of 5.5 years, since multi-stage selection of sires does not yield extra profit over one-stage selection with respect to the total selection response (V). It should be noted that in this study the selection intensity of sires was fixed at each stage, and thus, was not necessarily optimal. In future, the intensities should be optimized between the stages to maximize total selection response. Furthermore, the costs of maintaining the candidate sires were not considered in this study.

Reliable EBVs for carcass traits can be estimated for young dairy AI-sires based solely on their male progeny, which form the majority of the carcass data (V). For most sires, some daughters will also be slaughtered before they begin lactation. Including the carcass traits of these heifers in breeding evaluation might be of value in predicting fatness more accurately, as heifers provide additional information on variation in fatness, while most bulls classify in
fatness grade 2 (I, Figure 3). Combining bull and heifer data might also reduce the number of herds that provide only few carcasses, thereby improving the overall structure of data (I).

If body weight and condition of dairy cows are of interest, including some cow carcass data in selection decisions is necessary (V). Collecting carcass data on mature half-sisters and/or daughters of AI-sires would offer an easy and inexpensive way to obtain objective information on these traits. According to data of this study, approximately 10% of dairy cows were culled after the first lactation, and altogether one-third of dairy cows were culled before the third lactation. The culled half-sisters and possibly also daughters would enable an earlier genetic evaluation of cow carcass traits for the proven bulls that continue in AI-use for a few years.

Young dairy breed test bulls intended as AI-sires still go through an individual growth test in Finland, and the records from the test station are used to predict the EBV for growth. The growth EBV was omitted from the total merit index in 1993, and its importance in selection of dairy breed sires has since declined. In future, if all dairy sires get progeny test result for carcass weight and carcass quality traits, the need for an individual growth test will have to be reconsidered. Even assuming a genetic correlation of 1 between the sire’s own growth and the various carcass traits of his progeny, the economic response in carcass traits to selection on own growth is vastly inferior to the selection on progeny carcass traits (V).

Large differences are present between proven sires with respect to carcass EBVs. Particularly amongst the FAy, individual sires can be found that combine excellent milk production, fertility and health traits with good carcass weight and carcass quality traits. Among the HFr, the situation is less promising, probably due to the rapid Holsteinization of the breed in recent years.

The breeding goal of dairy cattle breeds should reflect the economically important traits, i.e., both beef and milk traits. If animal breeding associations do not wish to combine the beef and milk traits in one index, they could promote the use of sires with good carcass EBVs by, for example, annually naming some “dual-purpose” sires with both promising milk and beef traits. However, breeding values of the sires with respect to calving difficulties and calf mortality should also be taken into account.
7 ACKNOWLEDGEMENTS

This study was carried out at the Department of Animal Science of the University of Helsinki, and at the Department of Animal Sciences of the Wageningen University and Research Centre in The Netherlands. I thank both institutes for providing their facilities, and the staff for their kind assistance. It has been a pleasure to work at both places!

I want to thank specifically several people who have contributed to this work in one way or another:

- First of all I have to thank my two supervisors, Professor Matti Ojala (Department of Animal Science, University of Helsinki) and Professor Johan van Arendonk (Department of Animal Sciences, Wageningen University and Research Centre). Matti has always provided me with a freedom to do my own things and try my own views, whereas Johan quite literally opened up the world for me and keeps pointing out that there is life outside the borders of Finland too. It has been sometimes quite challenging when dealing with these two gentlemen, but that is what keeps things interesting!

- I would also like to thank my other co-authors Päivi Parkkonen (Animal Production Research, Agricultural Research Centre of Finland) and Dr. Piter Bijma and Marc Rutten (Department of Animal Sciences, Wageningen University and Research Centre). Päivi did an enormous amount of work for the Paper I, and in addition wrote a very nice manuscript of it. Piter and Marc wrote the program I used in Paper V, and it is only due to them that I was able to write the Paper V in the first place.

- Professor Johann Sölkner (Department of Livestock Sciences, University of Agricultural Sciences Vienna, Austria) is warmly thanked for agreeing to be my opponent.

- Professor Asko Mäki-Tanila (Animal Production Research, Agricultural Research Centre of Finland) and Dr. Erling Strandberg (Department of Animal Breeding and Genetics, Swedish University of Agricultural Sciences, Sweden) are warmly thanked for pre-examining my thesis in a record time, and for offering valuable suggestions to further improve the manuscript.

- Tarja Korhonen (Finnish Animal Breeding Association) had a crucial role in the beginnings of the project that would later form the core of my thesis. In addition, she has offered valuable advice through the years and kindly checked through the manuscript of my thesis.

- Veijo Vilva (Department of Animal Science, University of Helsinki) has been an irreplaceable person as far as computers are concerned. I owe to him my deepest gratitude for rescuing me from numerous small and larger crises related to problematic programs and computers.

- I thank my former and present colleagues at the Department of Animal Science, University of Helsinki for sharing the everyday life during these past years. In particular, I want to thank Minna Toivonen, Tiina Ikonen, Outi Ruottinen and Katarina Mäki for friendship, encouragement and many laughs we have shared both in our animal breeders’ attic and around the world on various congress and course trips. The same thanks apply also to the folks at the Department of Animal Sciences, Wageningen University and Research Centre, especially to Liesbeth van der Waaij.
• Lihakunta Oy provided the field carcass data, and Tapani Hellman (Agricultural Data Processing Centre) provided several pedigree and other data sets. My warm thanks are due to both.

• Carol Ann Pelli (Language Centre, University of Helsinki) is thanked for the thorough language review of this thesis.

• This study was supported by the Ministry of Agriculture and Forestry, the Faculty of Agriculture and Forestry at the University of Helsinki, the Wageningen University and Research Centre, and the Finnish Academy. They all are gratefully acknowledged.

Finally, I would like to thank my family: two-legged, four-legged and six-finned alike. My work would never have been possible without the constant support of my parents, both mentally and also in taking care of my zoo whenever needed. The two Departmental Dogs Pumi and Buster brought joy to all my working days, dragged me out for walks afterwards no matter what weather, and in general saw after that I didn’t totally mummify behind my desk. The various fish taught me valuable lessons about breeding in practice, and in case of some very special goldfish also provided me with company during my travels through Europe. And last but certainly not least, my whole journey into the wonderful world of animals began in 1976 with the arrival of Alpertti the tortoise, whose presence continues very strongly now 24 years after and who always tries to teach me to *festina lente*. 
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