Department of Agricultural Sciences
Faculty of Agriculture and Forestry
University of Helsinki
Dissertationes Universitatis Helsingiensis
31/2024

Herd-specific breeding preferences in Finnish dairy herds

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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 examination in Lecture Hall 108 (LS B3), Latokartanonkaari 7, Helsinki, on April 19th , 2024, at 12 o'clock.

Helsinki 2024

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Publisher: University of Helsinki
Series: Dissertationes Universitatis Helsingiensis 31/2024

ISBN 978-951-51-9625-5 (print)
ISBN 978-951-51-9626-2 (online)
ISSN 2954-2898 (print)
ISSN 2954-2952 (online)
Electronic publication at http://ethesis.helsinki.fi

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PunaMusta, Joensuu 2024

ABSTRACT

Dairy farmers perform artificial insemination (AI) bull selection with the aim of improving the next generation of their dairy cows in many different traits. Selection practices have changed over the decades as more information on AI bulls and modern selection tools have become available. Structural change in agriculture, changes in the market, the availability of estimated breeding values (EBVs) for a wider range of traits, and access to international bull markets enable – and even force – dairy farmers to make more specific choices about AI bulls. Consequently, bull selection has become increasingly complex.

In dairy cattle production the selection of animals is usually made based on EBVs. Total merit indices (TMIs) are formed to provide a tool for selecting multiple traits simultaneously. The traits in a TMI are weighted with their economic value in the production system in which they are intended to be used. Finland is part of the joint Nordic dairy cattle breeding programme. In the Nordic Total Merit (NTM), in addition to yield, a strong emphasis is placed on health, fertility, conformation, and longevity. However, farmers may have herd-specific breeding goals that differ greatly from the NTM because of local conditions, subsidy policy, or personal preferences.

This study examined the use of AI bulls in Finnish dairy herds in the two main dairy breeds in Finland, namely Ayrshire (AY) and Holstein (HOL), using insemination data. Then, the preferences revealed based on insemination records were compared with stated preferences found in a survey among farmers, which has not previously been done. This study also examined how farmers' preferences for traits can be integrated into practical bull selection. The farmer survey was repeated five years later to determine possible changes in trait preferences as well as how a novel trait, namely feed efficiency, had been received by farmers.

This study had three parts, each of which had a different objective, which are described as follows. The first objective was to analyse the revealed AI bull usage in Finnish dairy herds from insemination, herd, and AI bull data (Publication I). The data consisted of 475 015 insemination records from 5 987 herds. A statistical cluster analysis was performed to characterise herd groups according to a herd's bull selection profile. A bull selection profile was determined by the traits' EBV mean weighted by the number of inseminations in the herd. The following four herd groups were identified in both breeds: Production, Fertility, All-rounders, and Conformation. The herds' bull selection profiles were close to the traits' weighting in NTM except in both breeds in the Conformation group, where traits other than conformation were almost neglected. Such a selection could lead to poorer expected genetic and economic gain than the use of NTM selection. Conformation herds were a minority, but on average, they were larger in terms of herd size, and investments in these farms had been made more recently.

The second objective was to investigate the farmers' stated AI bull selection preferences (Publication II and III). An online survey was conducted using the Analytic hierarchy process (AHP). In total, 657 farmers responded to the questionnaire for a response rate of 17.2%. Based on farm characteristics and background information, the respondents could be said to represent a future Finnish dairy farmer. Large differences emerged between the stated and revealed preferences in both breeds. Longevity was the most or second most important trait in both the revealed and stated preferences in both breeds. In the revealed preferences, yield was the most important trait in AY herds and the second most important in HOL herds; however, in the stated selection preferences, yield received remarkably little emphasis. In addition, conformation was more pronounced in the revealed selection than in the stated preferences. Moreover, health was quite poorly favoured in the revealed selection given that it ranked very high in the stated preferences. The revealed preferences for the traits followed NTM-based selection in both breeds relatively well.

The third objective was to investigate how the farmers' stated as well as revealed preferences had changed during the five-year period that separated the surveys and also how a novel trait (i.e., feed efficiency as a form of the Saved Feed Index) was received among them (Publication IV). The third part of the thesis also involved the development of a selection tool for performing herd-level AI bull selection based on stated or revealed preferences.

Most Finnish dairy farmers seem to use the NTM when performing AI bull selection, but it is not their only criterion for choosing AI bulls. The results from the first and second parts of the study suggested that either fine-tuning the weights in the NTM, forming alternative indices, or developing a herd-specific TMI could help farmers to find the most suitable AI bulls for their herd. Information on farmers' stated preferences and data on the selection in the preceding years could be used here.

Furthermore, the revealed preference for yield increased substantially over the five-year period in both breeds. In the other traits, the revealed preference was almost similar in both 2016 and 2021, while the importance of longevity decreased from 24% to 21% in AY herds and from 26% to 21% in HOL herds. In HOL herds, the importance of functional traits increased from 5% to 13%. No changes occurred in the emphasis of calving traits in either breed. In 2016, feed efficiency did not have an EBV yet, but it became available in 2020. In 2021, the AY farmers did not select for the trait at all, and HOL farmers even selected against it.

Moreover, there were only minor changes in the stated trait preferences from 2016 to 2021 in most traits. In all traits except feed efficiency, the preference stayed almost the same; however, the stated preference for feed efficiency decreased from 9% to 4% among the AY farmers and from 8% to 4% among the HOL farmers. The results for views regarding the Saved Feed Index supported this result. That is, while said index was well known, very few farmers indicated using it in their breeding decisions.

The reasons for the low preference for the feed efficiency trait could be its low accuracy as well as difficulties in comprehending it, appreciating its selection potential, or trusting that it can be improved through selecting based on yield. In the five-year period, changes and even uncertainty occurred in milk pricing, costs of production inputs, and the dairy sector's profitability, which may all have led to the focusing of selection mostly on yield.

The results of this thesis provide new information on dairy farmers' stated and revealed preferences when selecting AI bulls. A corollary outcome of the research is a tool for using this information in farm-level bull selection. The decision making and breeding choices in dairy cattle production are moving from a purely economic standpoint to a decision making one where other attributes are considered, such as those that reflect consumer expectations and environmental factors. How well dairy farmers' preferences reflect these factors should be investigated further. Thus, better strategies for including quantitative and qualitative information in the construction of TMIs should be explored.

Keywords: dairy cattle, breeding, total merit index (TMI), artificial insemination (AI) bull selection, trait preference

ACKNOWLEDGEMENTS

I grew up on a small farm in Southeast Finland. I was always interested in nature, biology, and animals but still surprised even myself that my professional life ended up being around dairy farms and cattle. Postgraduate studies were something I never aimed for nor thought I could be capable of doing. I'm grateful for this unexpected opportunity given to me and proud of myself for being able to do this. This has been wonderful, hard, and rewarding journey. Not only have I learned a lot from world of science and animal breeding but also, and probably most, about myself.

Reason for my studies in animal science is lecturer Jari Heikkonen who during my studies at university of applied sciences got me realising that animal breeding is something you can study at university. Thank you Jari.

The research presented in this dissertation was carried out in the University of Helsinki and at Faba co-op. These both have a great meaning in my life. My first job at Faba co-op was an internship back in 2005. I also did my final project on studies at university of applied sciences to Faba co-op. Already then, I studied farmers breeding preferences.

Thank you to my supervisor docent Jarmo Juga. Thank you for all the ideas, support, and keeping things positive. Thanks also to my co-supervisor professor emeritus Asko Mäki-Tanila. My respect towards both of you is great not only because of your long and respected careers in the field and helping me with my thesis but also because of your warm heart, humour, and humanity.

Thanks to PhD and researcher Daniel Martín-Collado for all your experience, ideas, help, writing, and teaching. Thanks for that very intensive week in Viikki back in 2016.

Thanks to all my wonderful co-workers at Faba co-op. Especially I would like to thank my foreman CIO Minna Toivonen for all the support and understanding during my post-graduate studies and during my whole career at Faba co-op.

This study was founded by Faba co-op and VikingGenetics. Thanks to former CEO at Faba Antti Latva-Rasku. Without his idea about the thesis, I would have never considered post-graduate studies. Thanks to Chief R&D Officer at VikingGenetics Søren Borchersen for acting as head of steering group for this thesis. Thanks also to senior researcher Morten Kargo, Professor Timo Sipiläinen and specialist researcher Anna-Maija Heikkilä for working in the steering group.

I acknowledge the University of Helsinki and the Department of Agricultural Sciences for the opportunity to accomplish my PhD studies. Courses and travel funding arranged by the doctoral programme in Sustainable Use of Renewable Natural Resources (AGFOREE) are highly appreciated.

I am grateful for the reviewers, Senior Researcher Hanne Nielsen and Professor Erling Strandberg for their comments. Thank you, Professor Eileen Wall, for agreeing to be my opponent and Professor Pekka Uimari for being my custos.

Thanks to all my fellow post-graduate students for your essential peer support. Special thanks to Katja Martikainen for tips, understanding, support, and travelling company.

Thank you, mom and dad, for the constant support, emphasising the meaning of studying, believing in me and for teaching the meaning of agriculture, and respect for nature.

I am grateful to my grandparents (farmers each) who all four served in the second world war in the front or on the home front. You protected this country and started to build it to a nation where a girl from a simple farm can end up being a PhD.

Thanks to all friends and family. I would like to thank my god mother and cousin Teea for being a role model in many ways. Special thanks go to my very dearest friends for listening, understanding, getting my mind off work and for your essential support in tough times in life. Thank you, Marja-Leena, Auri, Aleksi, and Kai. Special thanks to Juha for starting a new chapter in life together.

Kiitos isä ja äiti jatkuvasta tuesta, opiskelun merkityksen korostamisesta, uskomisesta kykyihini ja maatalouden merkityksen sekä luonnon kunnioituksen opettamisesta lapsuudesta lähtien. Olen loputtoman kiitollinen kaikille isovanhemmilleni, jotka kaikki neljä olivat maanviljelijöitä ja palvelivat sodassa rintamalla tai kotirintamalla. Suojelitte tätä maata ja jälleenrakensitte sen sellaiseksi, jossa tavallinen maatilan tyttö voi edetä tohtoriksi asti. Kiitos kaikille ystäville ja sukulaisille. Haluan kiittää serkkuani ja kummiani Teeaa, joka on ollut roolimallini monin tavoin. Erityiskiitokset rakkaimmille ystäville kuuntelemisesta, ymmärryksestä, ajatusten saamisesta pois työstä ja opinnoista sekä tuesta elämän raskaina aikoina. Kiitos Marja-Leena, Auri, Aleksi ja Kai. Erityiskiitos Juhalle uuden elämänvaiheen aloittamisesta yhdessä.

CONTENTS

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following publications:

I Paakala, E., Martín-Collado, D., Mäki-Tanila, A., and Juga, J. 2018. Variation in the actual preferences for AI bull traits among Finnish dairy herds. *Journal of Animal Breeding and Genetics*, 135: 410–419.

II Paakala, E., Mäki-Tanila, A., and Juga, J. 2018. Finnish dairy farmers' selection preferences compared with realized use of AI bulls. In: *Proceedings of the World Congress on Genetics Applied to Livestock Production*, Auckland, New Zealand, Feb 7–11 2018. 5p.

III Paakala, E., Martín-Collado, D., Mäki-Tanila, A., and Juga, J. 2020. Farmers' stated selection preferences differ from revealed AI bull selection in Finnish dairy herds. *Livestock Science*, 240: 104117.

IV Paakala, E., Martín-Collado, D., Mäki-Tanila, A., and Juga, J. 2022. Changes in Finnish dairy farmers' preferences for trait selection and uptake of feed efficiency. (In manuscript).

The publications are referred to in the text by their roman numerals. Copies of the original articles (I–III) are included with the kind permission of their respective copyright owners.

Author's contribution to articles I–IV:

The author participated in planning the studies, performed all data editing and statistical analyses, interpreted the results with the co-authors, and was the main author of all of the articles.

ABBREVIATIONS

AHP	Analytic hierarchy process
AI	Artificial insemination
AY	Ayrshire
CA	Cluster analysis
EBV	Estimated breeding value
HOL	Holstein
NAV	Nordic Cattle Genetic Evaluation
NTM	Nordic Total Merit
TMI	Total merit index

1 INTRODUCTION

Animal breeding is based on the principle of selecting the genetically best individuals as parents to produce offspring that perform better, on average, than the parent generation in the traits that are important, while simultaneously minimizing the negative effects on other traits. Ever since cattle (*Bos taurus*) were domesticated over 10 000 years ago (MacHugh et al., 2017), people have performed selection. Selection was, for millennia, based only on appearance and phenotype; however, for over 100 years now, it has been based on production performance and then on estimated breeding values (EBVs). For the last decade, it has also been based on genomic information. Breeding yields permanent and cumulative gains.

Yield has been and remains the most important trait in dairy cattle. Finland was the fifth country in the world to start milk recording in 1898 (Maijala, 1999). Information on yield was also collected on herd books. Now, there are data on several traits, and total merit indices (TMIs) are formed to provide a tool for multi-trait selection. The traits in TMIs are weighted with their economic value in the respective production context. While yield usually has the highest weight, TMIs also include many other traits that are important because of not only economics but also environmental sustainability and animal welfare (e.g., health, fertility, and longevity). Their weighting has increased over the decades in most major milk-producing countries (Miglior et al., 2005).

Today, the breeding goals for dairy cattle are being unified across the globe and top artificial insemination (AI) bulls are widely used internationally. However, at the farm level, the breeding goal and trait preferences might differ noticeably from the weights on different traits of the TMI of the respective coordinated breeding programme. Dairy farms differ from each other, and farmers can have highly versatile production environments in terms of available land, work force, milk price, and subsidies. They may also have trait preferences for their cattle that stem from personal preferences for a dairy cow. Such preferences might not all be justified only by economics.

1.1 Development of selection indices

For a trait to be considered for breeding, it must meet certain criteria. The trait should have an economic value, and its improvement should increase returns or reduce production costs (Miglior et al., 2017). The trait must also have sufficient genetic variation and known heritability. Moreover, it should be clearly defined and measurable, preferably at a low cost and repeatedly over cows' lifetime. Furthermore, indicator traits can be used if they have high genetic correlation with a desired trait.

When the selection of dairy cattle began, it focused on milk and fat production and was based solely on cows' own performance. Gradually, the understanding of heritability and the accuracy of selection improved, as did the measurement technology and data processing, and it became possible to calculate breeding values for different traits. Still, until the 21st century, breeding was internationally focused mostly on production and conformation traits (Leitch, 1994; Holstein International, 2019).

As an increasing number of traits could be improved using estimated breeding values (EBVs), TMIs were formed. The main goal of TMIs is to weight different traits in an optimal manner and maximise economical genetic change. In addition, they make selection easier and simpler. In TMIs, the most important traits are weighted according to their economic importance in the respective production environment to form a single index value. In the Nordic countries, health and fertility have been selected and been part of the TMI for decades, with information on these traits being recorded since the 1980s (Pedersen and Jensen, 1996; Juga et al., 1999). Now, fertility, health, and functional traits have become part of many countries' TMIs (Miglior et al., 2005) and their importance grows continuously (Holstein International, 2019).

In Finland, a TMI was first used in 1983 to select AI bulls (Mäntysaari, 1984; Juga et al., 1999). Traits and their weights have changed over the years. Fertility, protein yield, protein percentage, udder health, and udder conformation were included in the Finnish TMI before the Nordic co-operation. The organisation Nordic Cattle Genetic Evaluation (NAV; Aarhus, Denmark) was founded in 2002 to calculate breeding values for Nordic cattle breeds. First, Norway was also part of NAV, but the joint dairy cattle breeding programme was finally established with Finland, Sweden, and Denmark for the Nordic Red Breeds (Finnish Ayrshire [AY], Swedish Red, and Danish Red), Holstein (HOL), and Jersey in 2005. The programme was built and is maintained in close collaboration between researchers, breeding organisations, and farmers. It is coordinated by the AI organisation VikingGenetics (Randers, Denmark).

The joint Nordic breeding programme is based on the breed-specific Nordic TMI (NTM), which guides AI bull selection at the population level. The NTM was first constructed in 2008 (Pedersen et al., 2008). Today, the NTM includes 14 different EBVs or indices (Table 1). If all separate traits are considered, then the number of different EBVs is nearly 100. Farmer representatives from each country annually reassess the weights for the NTM. They are set according to each trait's economic importance but can be changed to more accurately reflect future needs in terms of environmental impact, animal welfare, and consumer preferences. Yield, longevity, fertility, and health traits have always received the strongest emphasis in the NTM.

The latest addition to the many available selection indices worldwide is feed efficiency. Improving feed efficiency is economically critical, not only because feed is the highest single production cost on a dairy farm (European Milk Board asbl [EMB], 2021; Miglior et al., 2017) but also because of environmental issues. Improvements in feed efficiency decrease feed consumption and costs without decreasing milk production, thereby improving herd profitability. Furthermore, improving feed efficiency is one of the most crucial strategies for reducing greenhouse gas emissions in dairy cattle production (Ahvenjärvi et al., 2022; Lovendahl et al., 2018; Stranden et al., 2022). Lastly, feed efficiency plays a role in providing food for the growing human population, as more food must be produced without increasing the area of arable land.

Feed efficiency has been a breeding goal for Finncattle, the indigenous dairy breed in Finland, for over a century, when a measure of butterfat / 100 feed units became a requirement for entering the herdbook (Maijala, 1999). However, the path to the development of an EBV for feed efficiency has been long. It is difficult and expensive to collect data on feed efficiency as the trait is complex, since it is influenced by many biological features of the cow and steered by genetics, nutrition, management, and environmental factors in different stages of lactation (Mehtiö, 2020). In the last decade, many different approaches to breeding for feed efficiency have been developed in different countries. For example, in Australia, an EBV for feed efficiency has been available since 2015 and is part of the national TMI (Pryce et al., 2018). The EBV includes a genomic component for residual feed intake calculated from feed intake measurements and an EBV for body weight predicted from type traits.

In the Nordic countries, the index for feed efficiency is called the Saved Feed Index and consists of two different EBVs, namely maintenance efficiency (first published in 2019) and metabolic efficiency (first published in 2020; Andersen et al., 2020; Stephansen et al., 2019, 2021). Maintenance efficiency describes the genetic potential to save feed because of a lower feed requirement for maintenance and is based on live weight measurements with classification records for stature, body depth, and chest width as indicator traits (Sørensen et al., 2018). Metabolic efficiency has the same objective through enhanced utilisation of consumed feed for production, and it is based on feed intake, live weight, and milk yield records. The Saved Feed Index is included in the NTM.

1.2 Changing production environment

The Finnish dairy sector has experienced major changes ever since Finland became a member of the European Union (EU) in 1995. From 2000 to 2022, the number of dairy herds decreased by 76%, with 4 599 farms continuing production in 2022 (Luke, 2023a). The number is estimated to reach as low as 3 152 by 2030. While the number of dairy farms has decreased, herd size has simultaneously increased as most of the farms that discontinued production had small herds with fewer than 20 cows. The average size of a dairy herd has trebled in 20 years from 17.1 in 2001 to 51.2 cows in 2022 (ICAR, 2023a). Furthermore, the average arable area per dairy farm has increased from 32 hectares in 2000 to 88 hectares in 2022 (Tauriainen and Latukka, 2023). However, the total quantity of milk received by dairies has remained essentially unaltered, with the yearly volume remaining approximately 2 300 million litres since 1995 (Niemi, 2019).

The development of reproduction technologies (e.g., embryo transfer and the use of sexed semen) and the rapid implementation of genomic selection have altered dairy breeding programmes across the globe. Moreover, automatic milking and management have increased and changed the profile of traits desired in a dairy cow. The importance of conformation and milkability has increased as most dairy cows are kept in loose-housing systems. For example, in Germany, an index for describing the suitability of a bull's daughters for automatic milking systems is used (The German Livestock Association [BRS], 2023). In Finland, 68% of dairy cows in milk recording were kept in loose-house stalls in 2021. On average, farms with a loose-housing system had 79 cows, while farms with a tie-stall system had 30 cows. New tie-stalls have not been built since 2014 (Huuskonen and Rinne, 2023). As the farms that discontinue production are usually small farms, the changes towards loose housing and larger farm sizes are occurring rapidly.

In addition, the profitability of milk production has always been a challenge in Finland. As farm sizes have increased, so too has the average value of production per farm - from 96 000 € in 2000 to 420 000 € in 2022 (Tauriainen and Latukka, 2023); however, the total national value of production has stayed the same throughout the 21st century. Moreover, production costs have increased; on average, they are now 620 000 € per dairy farm. In 2000, the production cost per dairy cow was 6 500 €, and in 2021 it was €8 700; hence, the increased farm size has not decreased the production cost per dairy cow. Because of significant increases in the prices of fertilisers, fuel, and feed in 2022, the production cost was predicted to increase to 12 900 € in 2022. Furthermore, the average producer price of milk in Finland fluctuated between 33.22 and 44.55 cents per litre from 2000 to 2021, but in 2022 the price rose to 49.40 cents (Luke, 2023b). In the same period, the price of 0.1% fat milk increased from 0.24 to 0.39 cents, while the price of 0.1% protein milk stayed the same (0.66 cents on average). The profitability ratio of

Finnish dairy farms stayed at approximately 0.5 for the first two decades of the 21st century, but in 2022 it was estimated to reach as low as 0.2 (Luke 2023c).

Furthermore, subsidy policy can have major effects on farmers' breeding preferences. In Northern Finland, unlike in other parts of the country, the national production subsidy for milk is paid based on milk litres delivered to the dairy. Dairies encourage the production of milk with a high solids content, but the subsidy policy does not support selection in this direction in all parts of the country. Instead of producing just litres, it is important from economic, human nutrition, as well as environmental standpoints to produce milk with a high solids content. Feed efficiency is another essential trait in this regard. It was estimated that it is possible, solely through genetic improvement, to reduce greenhouse gas emissions from milk production by 14–19% from current levels (Ahvenjärvi et al., 2022).

Another major change in the production environment in recent years has been the change in the proportions of dairy breeds in Finland. After Finncattle lost its place as the main dairy breed in the 1960s, AY was the most common dairy breed until 2018, when HOL took the leading position (Hellberg, 2023). In 2022, 56.4% of milk-recording cows were HOL and 41.7% were AY. The reason for AY losing its dominance concerns HOL's higher yield. Even though AY are healthier (Vahlsten, 2023) and stay in production longer (ICAR, 2023b), HOL beat AY in yield, including the energy-corrected milk yield (Hellberg, 2023).

A further change is that the dairy bull market has become highly international as doses of AI bull semen are actively sold and bought between countries. In Finland, the majority of used AI bull doses are of Nordic origin, but the number of annually imported AY and HOL semen doses has notably increased in recent years and is becoming relevant. In 2015, 10% of all AY breed doses (approx. 280,000 sold doses; Animal Health ETT, 2016) and 30% of all HOL breed doses (approx. 230,000 sold doses) were imported from outside of the three Nordic countries. Evidently, the share of doses imported from outside of the Nordic countries has increased since 2015, with statistical information no longer being available.

Before the development of the multiple across country evaluation (MACE) method in 1994, performing genetic comparisons of AI bulls between countries was difficult (Schaeffer, 1994). Since 1995, Interbull (founded in 1983) has calculated international breeding values with the MACE method (Interbull, 2023), making the comparison of AI bulls possible between populations, which has made import decisions easier. However, not all imported AI bulls receive Interbull evaluation, especially in AY, for which no Interbull evaluation of genomic EBVs is performed for young bulls.

1.3 Dairy farmers' versatile preferences for dairy cattle traits

All of the aforementioned changes are affecting dairy farmers' breeding preferences for dairy cattle. In addition, their preferences are affected by the availability of indices for various traits as well as the environment in which the milk production occurs. Other factors that are not so clear, precise, or economically rationalised also have an effect on what kind of dairy cows a dairy farmer desires in their herd.

In the 21st century, the number of traits evaluated in the dairy cattle industry has increased faster than ever. For farmers, this makes their decision making easier but simultaneously also increasingly complex (Martin-Collado et al., 2018). TMIs can make farmers' decision making simpler as they include all of the important traits weighted in an optimal manner in a single index. TMIs are used at the population level and in national breeding programmes to guide the selection of AI bulls, and they can also be used for AI bull selection at the farm level. Usually, a TMI suits most herds well. However, in some cases, the herd-specific breeding goals may differ significantly from the population-level breeding goals because of production costs, milk prices, subsidies, or land use. For example, the production circumstances in Finland can be highly diverse in different parts of the country. TMIs are updated and developed constantly as requirements for dairy cows change, while farmers' needs for their herds seem to diversify simultaneously.

Farmers can be grouped according to their trait preferences for dairy cattle traits (Martin-Collado et al., 2015; Slagboom et al., 2016). In response to the heterogeneity in their preferences, many breeding associations and companies have developed a series of TMIs instead of just one common index to meet specific farmer needs and preferences. For example, three indices – namely the Balanced Performance Index, the Health Weighted Index, and the Type Weighted Index – have been introduced to the Australian dairy sector. They are based on a combination of bioeconomic analysis, a farmer preference survey, and a desired gain approach (Byrne et al., 2016; Martin-Collado et al., 2015). Studying and taking farmers' trait preferences into consideration can strengthen farmers' participation in a breeding programme (Nielsen et al., 2014, 2005).

2 OBJECTIVES OF THE STUDY

The main goal of this thesis was to study and compare Finnish dairy farmers' revealed and stated preferences for AI bull selection. The study conducted an investigation of revealed AI bull selection preferences using insemination data, herd characteristics using herd data, and stated preferences using a survey; then, it developed a bull selection tool for herd-level selection that considers both revealed and stated preferences. In addition, this study examined the acceptance of a novel trait among dairy farmers named feed efficiency.

The aforementioned main goal was divided into more specific objectives. These are presented as follows, with the respective publication number provided in parentheses:

1) To investigate whether Finnish dairy farmers have diverse preferences in AI bull selection and whether their herds can be clustered into groups according to selection preference; to determine whether AI bull selection in such groups differs from the NTM; and to analyse how the herd groups differ with respect to herd characteristics (I).

2) To investigate the Finnish dairy farmers' stated trait preferences in AI bull selection in the main Finnish dairy breeds (i.e., AY and HOL), and to analyse how well the stated preferences match the revealed bull selection (II & III).

3) To analyse how stated and revealed preferences change over time (a five-year period) and how a novel trait is accepted as a breeding goal (IV).

4) To create a herd-level tool for selecting the best-fitting AI bulls for a herd using farmers' stated or revealed preferences for traits (IV).

3 MATERIALS AND METHODS

3.1 Materials

In this thesis, the analyses were based on data from milk-recorded herds, including herd characteristics and insemination data on AY and HOL cows and data on AY and HOL AI bulls' EBVs published in the Nordic countries. Farmers' stated preferences for eight different dairy cattle traits were studied with an online survey.

The data were of the following four different types: insemination data (I–IV), bull data (I–IV), herd data (I–III), and survey data (II–IV). The insemination data were provided by the Faba co-op (the Finnish Animal Breeding Association; Hollola, Finland), bull data by NAV (Nordic Cattle Genetic Evaluation; Aarhus, Denmark), and herd data by ProAgria (Association of ProAgria Advisory Centres; Vantaa Finland). The following subsections describe the data types in more detail as well as how they were used.

3.1.1 Insemination and AI bull data

Information on the use of AI bulls in milk-recording herds was retrieved from insemination data. The data covered the inseminations performed with AY and HOL AI bulls in 2015. After editing, the data set included 475 015 insemination records from 5 987 herds.

Another set of insemination data from milk-recording herds was from January to June 2021. This data set was edited similarly to the one from 2015 and included 158 053 insemination records from 3 836 herds. These data included fewer inseminations from fewer herds because during the five-year period the number of dairy herds declined and the time period was only six months instead of a whole year.

The 2015 insemination data were combined with AI bulls' EBV information based on AI bulls' animal ID using the R software package (R Core Team, 2016). The EBVs from the November 2015 evaluation of the 14 traits included in the NTM were used in the analysis. If an AI bull was used in fewer than 100 inseminations, then it was excluded from the data set. Furthermore, AI bulls with missing EBVs were excluded; EBVs were missing from 31 AY and 41 HOL bulls. The excluded bulls in both breeds were young bulls mostly from North America without genomic evaluation in the Nordic setting. The final data set consisted of 176 AY bulls and 232 HOL bulls. The use of AI bulls varied considerably: 67 bulls of each breed were used for more than 1 000 inseminations. The single most popular AY and HOL bulls were used 8 767 and 7 529 times, respectively, while 41 AY bulls and 85 HOL bulls were used only 100–200 times. Similar data editing was performed to the insemination data from January to June 2021. The final data set included data from 77 AY and 164 HOL bulls with adequate EBV data.

For the development of a herd-specific AI bull selection tool, EBVs (May 2021 evaluation) from the top 50 AY bulls (born in 2018) for the NTM were used as an example of available bulls.

3.1.2 Farm data

Data on farm characteristics were retrieved from all the herds with inseminations performed with AY or HOL AI bulls during 2015 (5 987 herds). Altogether, the following 23 different herd characteristics were analysed: herd size, average energy-corrected milk yield, average yield (cows and heifers), lifetime yield (live and culled cows), number of calvings per cow, calving age of heifer, calving interval, number of inseminations (cows and heifers), culling percentage (cows and heifers), cow mortality, percentage of stillborn calves, animal density per hectare of arable land, investment year of cow housing, average NTM of cows (including all cows and breeds of the herd), housing type, feeding type, milking machine type, agricultural subsidy region in Finland, and whether the farm was conventional or organic. The farm data were combined with the insemination data based on herd ID using R (R Core Team, 2016).

Finnish dairy farms usually have more than one breed in their herd. In the first part of the study, we sought to explore breed-specific bull selection; therefore, we included data only on herds in which more than 90% of the cows were AY or HOL (i.e., purebred herds). This data set consisted of 1 279 AY herds (70 158 inseminations) and 544 HOL herds (34 512 inseminations).

In the second part of the study, analyses with farm data were conducted with herds from which survey results were obtained (595 herds) and separately on herds with AY (340 herds) or HOL (255 herds) as the main breed (over 50% of cows of either breed).

3.1.3 Survey data

In 2016, an online survey for Finnish dairy farmers was conducted using the Webropol 2.0 online survey and analysis software (Webropol Oy, 2016). The survey explored farmers' stated preferences for eight dairy cattle traits or trait groups. The online survey also included questions on respondents' age and education, number of employees on the farm, and their plans for the future of the herd. Moreover, factors other than EBVs that affect the selection of AI bulls and opinions on the NTM were asked (questionnaire and results in publication II). The contents of the questionnaire were discussed beforehand with dairy breeding experts and farmer members in the dairy breeding committee.

An email invitation was sent to all Finnish dairy farmers who had used AY or HOL AI bulls in their herd during 2015 and whose email addresses were available from the Faba co-op (3 814 farmers). The survey was also advertised in Faba's electronic newsletter and on their social media. The survey was available for answering from 9 September to 3 October 2016; 657 farmers responded to the survey for a response rate of 17.2%. Because of an invalid herd number or the herd not belonging to milk recording, some answers were discarded. The final survey data included answers from 595 farmers, of which 340 had AY and 255 HOL as the herd's main breed (over 50% of the herd's cows were either AY or HOL). Table 1 presents the eight features whose preferences were determined by the survey.

Table 1. Eight dairy cattle traits or trait groups compared with each other in the survey and the corresponding estimated breeding value (EBV) or index included in the Nordic Total Merit Index (NTM).

Trait or Trait Group in the Surveys	**EBV or Index in the NTM**	**Description**
Yield	Yield	Milk, protein, and fat yield
Health	Udder health	Mastitis resistance
	Other diseases	Resistance to metabolic, feet and leg, and reproductive diseases
	Claw health	Resistance to claw diseases
Fertility	Fertility	Interval from first to last insemination, interval from calving to first insemination, and number of inseminations
Calving	Birth traits	Calf survival and calving ease, as a direct effect
	Calving traits	Calf survival and calving ease, as a maternal effect
Longevity	Longevity	Time from first calving to the end of third lactation
Functional traits	Milkability	Herd owners' assessment or milk flow data from automatic milking system
	Temperament	Herd owners' assessment
Conformation	Udder	Udder conformation
	Feet and legs	Feet and leg conformation
	Frame	Body conformation
Feed efficiency	Saved feed (since 2020)	How efficiently the animal uses energy from feed to milk production

The second online survey was conducted in June 2021 using the Surveypal online survey and analysis software (Surveypal Oy, 2021). It explored preferences on the same eight dairy cattle traits as in the previous survey to allow for direct comparison and the quantification of possible changes. In addition, the views and understanding of the inclusion of a new trait in the TMI – namely the Saved Feed Index into the NTM – was studied. An email invitation was sent to all farmers who had responded to the previous survey (i.e., 595 farmers, of whom 340 and 255 had AY and HOL as the main breed, respectively). The final data set comprised the answers of 105 and 80 farmers with AY and HOL as the main breed, respectively, in both 2016 and 2021. The response rate was 39.3%. The second survey was not promoted on social media or in a newsletter because the aim was to analyse how the stated preferences had changed in the same herds over a five-year period.

3.2 Methods

3.2.1 Estimating farmers' revealed AI bull selection

A cluster analysis (CA) was conducted to investigate whether the herds' bull selection profiles formed distinct herd groups. A "herd's bull selection profile" was formed from the averages of all 14 traits' EBVs included in the NTM that were available for the used AI bulls over all inseminations in the herd, thereby summarising farmers' revealed AI bull selection. The R software package and the k-means clustering method were used to perform the CA (MacQueen, 1967; R Core Team, 2016) for the AY and HOL herds separately. The number of clusters was predetermined, and the most appropriate number of clusters was based on a comparison of the loss of inertia (within-cluster sum of squares) at each partitioning of clusters and on the statistical testing of differences among the emerged clusters for the considered variables. The statistical significance for the differences in each trait's average EBV between the herd clusters was tested using an analysis of variance (ANOVA) with a subsequent Tukey's multiple comparison test for pairwise differences (Tukey, 1949).

The average of the "herd's bull selection profiles" in the different herd groups described the selection differential and half of the expected genetic gain as well as the subsequent economic change in the next generation resulting from the AI bull selection performed in each herd group. For comparison, the selection differential resulting from the NTM-based bull selection for both breeds was calculated based on the selection intensity and the genetic correlation between each trait and the NTM (Nordic Cattle Genetic Evaluation, 2016).

Next, the herd characteristics in the AY and HOL herd groups were analysed. For each group, an average was calculated for continuous herd characteristics and an occurrence percentage for categorical herd characteristics. The statistical significance of the differences between the four herd groups was tested for each farm characteristic using an ANOVA with a subsequent Tukey's multiple comparison test for pairwise differences among the groups. Then, the chi-squared test was used to test for differences in the categorical variables.

3.2.2 Estimating farmers' stated selection preferences

Farmers' preferences for dairy cattle traits were estimated using the Analytic hierarchy process (AHP; Saaty, 1980, 1977). The AHP was used to determine the relative preference for eight different dairy cattle traits or trait groups. The respondents were asked to perform a pairwise comparison of how much more important one trait or trait group was than another one on a scale from 9 to −9, where 1 represented equal importance and 9 or −9 indicated that a trait was either absolutely more or absolutely less preferred than the alternative trait (II). The total number of trait pairs compared in the survey was 28 [= 8 × (8 − 1) / 2]. A detailed description of the AHP method can be found in publications II and III. As a result, a stated preference among the eight traits was formed as a percentage or share of preference assigned to each trait in each herd. For both breeds, a geometric mean of the individual judgements in AHP was aggregated (Aczel and Saaty, 1983; Saaty, 1980).

3.2.3 Comparing the revealed and stated selection preferences

The revealed AI bull selection was compared with the stated preferences determined using the AHP. Only pure AY and HOL herds (i.e., over 90% of the herd was either AY or HOL) whose owners responded to the online survey were retained in the analysis to precisely compare the same herd's stated and revealed preferences. The results were also compared with the expected selection differential resulting from NTM-based AI bull selection. As such, stated selection preferences were used in the comparison, as they implied the percentual weight given to each trait and thus summed to 1. To compare the revealed and stated preferences, some traits in the revealed preferences were combined simply by calculating an average of the traits or trait groups to match those in the survey (Table 1). Subsequently, the revealed preferences and NTM selection (both as EBVs) were transformed to percentages by calculating each trait's deviation from the population average and then dividing each deviation by the sum of the absolute values of the deviations.

3.2.4 Studying views on the feed efficiency trait

The study also investigated how a novel trait named feed efficiency is accepted and considered as an improved trait and part of the TMI. For this purpose, in the second survey, the farmers' views and understanding of the Saved Feed Index were investigated using the following six different claims: "I have heard of the Saved Feed Index"; "I know what the Saved Feed Index means"; "I take the Saved Feed Index into consideration in my breeding decisions"; "The Saved Feed Index is an important breeding goal trait"; "The Saved Feed Index should be included in the total merit index"; and "The weighting of the Saved Feed Index in the total merit index for my herd's main breed is appropriate." The answer options ranged from 5 (totally agree) to 1 (totally disagree; Likert, 1932).

3.2.5 Developing a bull selection tool

An AI bull selection tool was tested in five AY herds. The available AI bull's EBV or combined EBVs was multiplied with the respective stated preference percentage (i.e., the AHP result) in the herd. The sum of these products formed a "herd index" for each AI bull. The top 50 AY bulls for the NTM born in 2018 were used as an example set of available AI bulls. The EBVs of the bulls were retrieved from the May 2021 evaluation. The AI bull with the highest sum can be considered the most suitable for the herd.

4 RESULTS AND DISCUSSION

This thesis studied Finnish dairy farmers' preferences for dairy cattle traits as well as their views on the TMI and a novel trait. The respective analyses used insemination data, AI bull data, and farm data as well as the results from two questionnaire surveys conducted among dairy farmers. The research involved an examination of revealed trait preferences using insemination records and AI bulls' EBV information (I); grouping of herds by the revealed preferences and an analysis of the herd characteristics in each group (I); a survey of farmers' stated trait preferences for AI bulls (II–IV) as well as their views on the NTM (III); and an investigation of a novel dairy cattle trait named feed efficiency (IV).

4.1 Farmers' revealed preferences for AI bulls and grouping of herds

4.1.1 Ayrshire herds' bull selection profiles

Four distinct herd groups were found amongst AY herds:

- *Production herds:* This herd group comprised 452 herds, with the farmers having the highest preference for yield and growth among the studied eight traits or trait groups. Milkability and temperament were also favoured more than in the other groups, while the lowest attention was given to udder conformation.
- *Fertility herds:* This herd group comprised 393 herds, with the farmers preferring fertility, calving traits, other diseases (including resistance to metabolic, feet and leg, and reproductive diseases), longevity, and feet and leg conformation more compared with the other groups.
- *All-rounder herds:* This herd group comprised 377 herds, with the farmers focusing fairly evenly on all traits. An exception was udder conformation, which had the second highest preference among the groups. Udder health was also highly favoured.
- *Conformation herds:* With 57 herds, this was the smallest and most distinct herd group. Udder conformation, frame, and claw health were highly favoured by the farmers, while all other traits were almost neglected.

Figure 1 presents the herds' bull selection profiles in the four AY herd groups and expected selection differential in NTM selection.

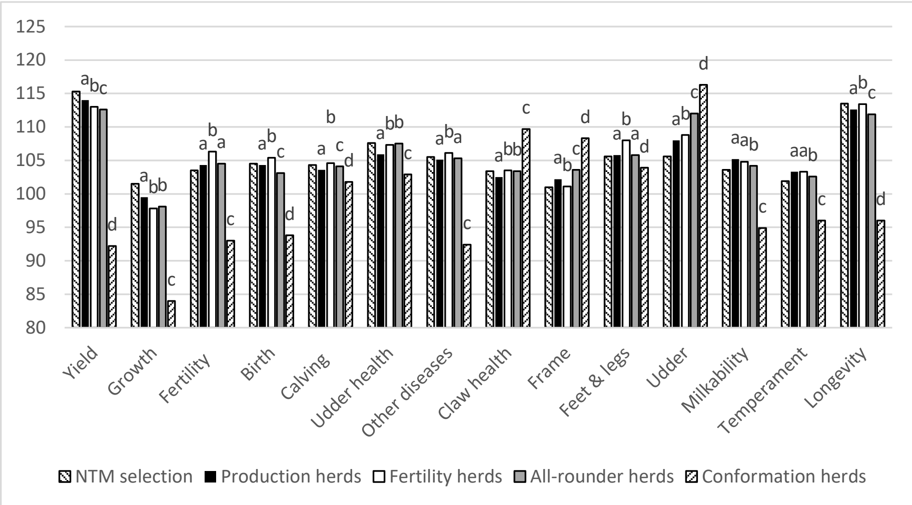

Figure 1. Expected selection differential in NTM selection and mean of herds' bull selection profiles in the four herd groups for AY herds in traits included in the NTM. EBVs in the Nordic countries are scaled to an average of 100 with a standard deviation of 10. (a–d) Averages with different superscripts within a trait differed (at least by $p < 0.05$) according to Tukey's multiple comparison test.

Farmers in the first three groups selected AI bulls in a rather similar manner even though there were statistically significant differences between the groups in many traits ($p < 0.05$). In these groups, the bull selection was close to the NTM-based selection but with less of a preference for yield and growth and slightly more of a preference for fertility, udder conformation, milkability, and temperament. The fourth group differed substantially from the NTM-based selection; specifically, farmers in this group placed far less emphasis on yield, growth, and longevity than in the NTM-based selection, focusing almost exclusively on frame and udder conformation.

The Conformation herds were larger; had loose housing, mixed ration feeding, and automatic milking more often; and their farmers had made investments in their cowsheds approximately 10 years more recently than those of herds in the other groups. Moreover, for the Conformation herds, more imported bulls from outside of the Nordic countries were used; thus, it seemed that the herds for which farmers are investing for the future use more genetics from outside of the Nordic countries.

Furthermore, Conformation herds together with All-rounder herds had a higher average yield than those in the other groups. All of the yield-related herd characteristics were lowest in Production herds, which implies that a farmer with intermediate-yielding cows emphasises yield traits in their breeding choices. Additionally, the calving interval was somewhat shorter in the All-rounder herds than in the other groups. The mean of the used AI bulls' NTM value was lowest in the Conformation herds (−6.33) and the highest in the All-rounder herds (0.80), with the latter exhibiting no statistically significant difference from the Fertility and Yield herds.

4.1.2 Holstein herds' bull selection profiles

The following four distinct herd groups were found among HOL herds:

- *Production herds:* This herd group comprised 169 herds, with the farmers emphasising yield and growth in selection more than in the other groups. Moreover, longevity was highly favoured.
- *Fertility herds:* This herd group comprised 280 herds, with the farmers emphasising fertility, longevity, and health traits.
- *All-rounder herds:* This herd group comprised 48 herds, with the farmers favouring all traits evenly in their bull selection. Milkability received the highest emphasis compared with other groups.
- *Conformation herds:* This herd group comprised 47 herds, with the farmers especially favouring frame, in addition to udder conformation and temperament, more than those in the other groups. The average EBV of the used bulls for all other traits was low, particularly for fertility and health traits.

Figure 2 presents the herds' bull selection profiles in the four AY herd groups and expected selection differential in NTM selection.

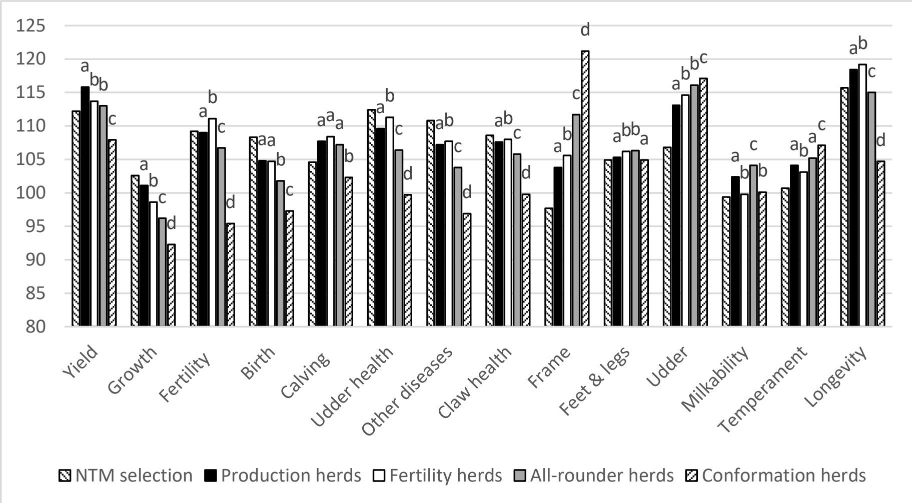

Figure 2. Expected selection differential in NTM selection and the mean of herds' bull selection profiles in the four different herd groups in HOL herds in traits included in the NTM. EBVs in the Nordic countries are scaled to an average of 100 with a standard deviation of 10. (a–d) Averages with different superscripts within a trait differed (at least by $p < 0.05$) according to Tukey's multiple comparison test.

In all herd groups, udder conformation and frame were emphasised more than in the NTM-based selection. The largest negative deviations from NTM-based selection occurred in the Conformation group in fertility, health, and longevity. The Production and Fertility herds followed NTM-based selection most closely.

Moreover, All-rounder and Conformation herds were larger; had loose housing, mixed ration feeding, and automatic milking more often; and their farmers had made investments in their farms more recently than farmers in the other groups. Furthermore, the average yield per cow and heifer was higher in these two groups than in the Fertility and Production herds. Notably, Cow mortality was the highest in Conformation herds. The average NTM value of the used bulls was lowest in Conformation herds (−3.32) and highest in Production herds.

4.1.3 Features differentiating the herd groups

The mean of the herds' average NTM value for cows was lowest in the Conformation group for both breeds. This indicated that farmers in these groups had also previously used AI bulls with a low NTM value. The reason for the lower NTM value for the bulls used in the Conformation group, especially among AY, is that the imported bulls had a lower NTM value on average than the Nordic bulls. Among HOL, there were also imported bulls with a high NTM value, but the NTM values were still lowest in the Conformation group for HOL as well.

A farmer may focus on conformation traits due to satisfaction with the other traits' genetic level in their herd. For instance, the HOL Conformation group exhibited the highest average phenotypic yield in cows and heifers. The preference for conformation traits in the Conformation group may stem from the view that the traits serve as reliable indicators of longevity.

We also studied mixed herds (i.e., both AY and HOL cows) in a similar manner (I). Regarding the use of AI bulls, both purebred (herds with more than 90% of the same breed) and mixed herds were quite similar. This suggests that the selection of AI bulls is performed similarly regardless of the breed or breed proportions within the herd.

In addition, in the Production, Fertility, and All-rounder herd groups, the bull selection deviated only slightly from the NTM-based selection, and the majority of farmers mostly chose AI bulls that follow the Nordic breeding goal. Diverse AI bulls were available on the market, so different breeding choices were possible, as we could see most obviously in the Conformation group. Farmers were found to be willing to sacrifice genetic progress in production traits for improving functional traits related to ecological and ethical sustainability (Nielsen et al., 2005). Our study also revealed that farmers are willing to make compromises, such as by concentrating only on conformation traits even if it results in drawbacks in economically important traits, such as yield and longevity. Diverging from NTM-based AI bull selection could slow or accelerate the genetic progress in different traits.

Traits are weighted in the NTM in an optimal manner for the Nordic production environment, but individual herds may benefit from having the breeding objective fitted to their own conditions. Based on our study, a low number of herds in Finland deviate from the commonly adopted breeding goal, and at the population level, the effect of deviating selection goals due to these herds on genetic progress is minimal. Overall, the genetic progress in Finnish dairy herds closely follows that predicted from the NTM. In some traits, a higher selection differential and therefore a better economic impact compared with NTM-based selection was observed. This is possible because of the availability of bulls with higher EBVs, which provide a higher selection differential in the traits compared with NTM-based selection.

In terms of herd characteristics, the within-group variation was substantial in both breeds; however, the group averages of the characteristics provided insights to explain the deviating selection preferences. The Conformation group herds were larger and had made investments more recently. This could explain farmers' focus on conformation traits, as they are usually valued more in automatic milking systems and loose housing than in tie-stall barns. New technology and scale benefits may have led to a higher yield even though the genetic level in these herds (measured in the NTM) is lower than in other herd groups. For example, the All-rounder AY herds had the highest average milk yield per cow while the other yield traits were also high, while the calving interval was lower than in the other herd groups, which was reflected in bull choices; for example, farmers in this group emphasised yield and fertility traits less than farmers in the Production and Fertility groups. This could be because the farmers have less need to improve these traits. For example, a high phenotypic yield would allow them to focus on other traits as the yield is already at a satisfactory level. Simultaneously, it is crucial not to neglect yield traits as they might deteriorate if they are not given continuous attention.

4.2 Farmers' revealed vs. stated preferences

Among AY farmers in 2016, the most preferred trait in revealed selection in the considered eight dairy cattle traits or trait groups was yield, followed closely by longevity. Conformation was also highly emphasised. Functional traits were least favoured, followed closely by fertility and calving traits. Among HOL farmers, longevity was clearly the most preferred trait, followed by yield and conformation. Fertility was more favoured in HOL than in AY. Functional and calving traits were the least preferred traits by HOL farmers.

The farmers' revealed preferences differed from the stated preferences for both breeds in 2016. The largest differences between the revealed and stated preferences among the AY farmers were found in yield (25% vs. 10%), longevity (24% vs. 17%), and health (11% vs. 18%). Conformation was selected more than was indicated by the stated preferences (17% vs. 11%), whereas fertility (8% vs. 14%) and functional traits (7% vs. 12%) were selected less than was implied by the stated preferences. Among the HOL farmers, the largest differences between the revealed and stated preferences in 2016 were in yield (22% vs. 11%) and longevity (26% vs. 16%). Moreover, conformation was more favoured in the revealed preferences than in the stated preferences (16% vs. 12%), whereas health (11% vs. 18%) and functional traits (5% vs. 12%) were less favoured. Figures 3 and 4 present the stated and revealed preferences in 2016 and 2021 in AY and HOL herds.

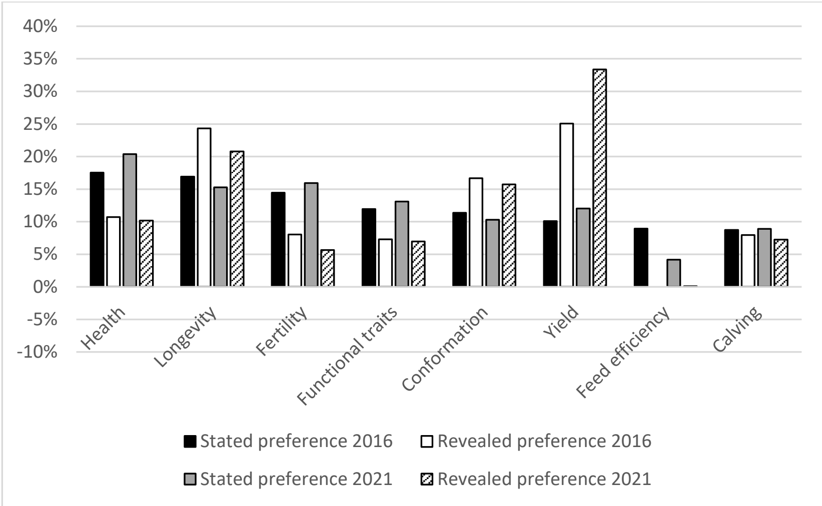

Figure 3. Stated and revealed preferences in 2016 and 2021 in Ayrshire herds.

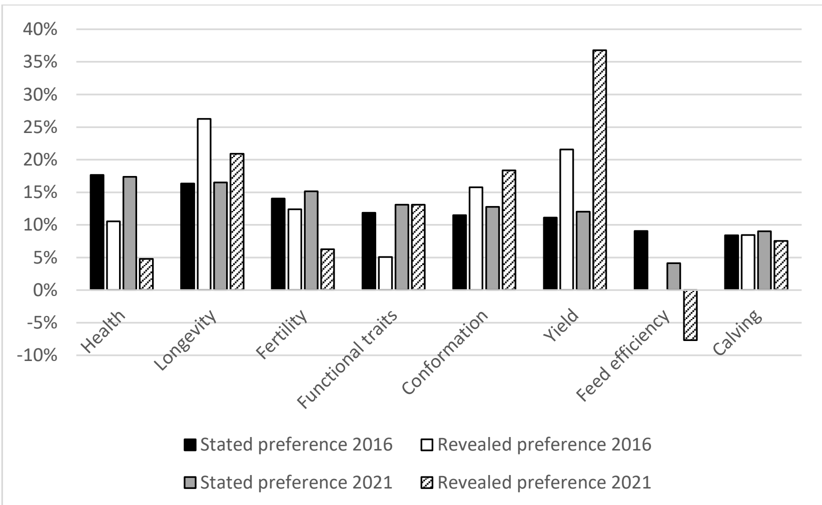

Figure 4. Stated and revealed preferences in 2016 and 2021 in Holstein herds.

Most of the used bulls had a high NTM value. This could be one reason for the low ranking of yield in the stated preferences, as NTM value and yield are highly correlated and selection based on NTM automatically improves yield; hence, it can be considered taken care of without the need to pay much attention to it. This could be seen in the revealed preferences, where yield was very important trait for both breeds in 2016 and particularly so in 2021.

However, NTM-driven progress was not assumed by farmers to be effective at improving longevity and health, both of which had a high position in the stated and revealed preferences. Another reason for the high preference for yield and longevity among the revealed preferences could be due to these traits having higher mean EBVs among the available bulls compared with the other traits. However, as stated previously, the availability of AI bulls does not constrain the selection.

When the survey was conducted in 2016, feed efficiency did not yet have an EBV in the Nordic countries. This may have affected the results as feed efficiency may have been considered a trait that could not be selected for and was therefore also not preferred in the stated preferences.

It is also possible that respondents answered survey questions according to their perceived expectations of an acceptable opinion, thereby concealing their honest opinions or preferences. This type of response bias is known as social desirability bias (Krumpal, 2013). For example, among the stated preferences in this study, the phenomenon may have occurred for yield. Favouring health and fertility over yield could be perceived to be socially acceptable because of animal welfare and general opinion among the public and consumers. This could explain why health, fertility, and longevity were found to be the most important traits, whereas in the revealed selection, yield was clearly the most preferred trait. Moreover, answers to our survey questions could reflect the respondents' wishes and hopes regarding the traits they wished to focus on. In practice, implementing such wishes can be difficult because of the available bulls, market situation, and even peer pressure from other farmers.

The eight dairy cattle traits or trait groups were chosen and combined to cover the 14 traits included in the NTM. The number of traits was limited to eight to ensure that the survey was not overly time consuming and complex (Saaty and Ozdemir, 2003). The comparison of stated preferences with revealed preferences and with NTM selection would have been more straightforward if the survey had included all 14 traits in the NTM. For example, udder conformation and frame could have been preferred very differently if they were considered as separate traits and not included in the overall conformation trait as in the survey.

4.3 Changes in farmers' trait preferences and views on the novel trait of feed efficiency

The revealed preference for yield clearly increased during the five-year period in both breeds – from 25% to 33% among AY farmers and from 22% to 37% among HOL farmers (Figures 3 and 4). Other traits were selected almost similarly in 2016 and 2021 in AY herds, but the importance of longevity decreased from 24% to 21%. It also decreased from 26% to 21% in HOL herds. Furthermore, in HOL herds, the emphasis on fertility and health both decreased from 12% and 11% to 6% and 5%, respectively, while the importance of functional traits increased from 5% to 13%. No changes occurred in the preference for calving traits in either breed.

In 2016, feed efficiency did not yet have an EBV nor was it part of NTM. Still, the AY farmers did not even select for the trait in 2021 (revealed preference of 0%), while HOL farmers even selected against the trait as the mean of bulls' EBVs weighted by the number of inseminations for the Saved Feed Index in HOL herds was below the population average (100).

Among both AY and HOL farmers, the order of importance of dairy cattle traits in the survey results from 2016 was the same: health was the most favoured trait, followed by longevity, fertility, functional traits, conformation, yield, feed efficiency, and calving traits. In 2021, the order stayed the same among HOL farmers except for calving traits and feed efficiency, which switched order. For AY farmers, health was still the most important trait while fertility and longevity, conformation and yield, and feed efficiency and calving traits switched positions.

Notably, the largest changes in stated preferences between 2016 and 2021 were in feed efficiency. The stated preference for feed efficiency decreased from 9.2% to 4.3% among AY farmers and from 8.6% to 4.3% among HOL farmers, making it the least preferred trait in 2021. Some small changes also emerged in other traits between the two time points, which can be explained by change or the inaccuracy of the AHP.

In addition to trait preferences, the farmers' awareness and views of the novel trait of feed efficiency, evaluated by the Saved Feed Index, were queried. The Saved Feed Index was well known among the respondents, most of whom had heard of the trait, and 81% either agreed totally or to some extent with the statement. The respondents also said that they knew what the Saved Feed Index means (68% either totally or somewhat agreed). Still, only 12% either agreed totally or to some extent that they consider the trait when making breeding decisions. Opinions concerning the importance of the index and whether it should be included in the NTM were evenly distributed between the options. Most respondents (61%) could not say whether the weighting in the NTM for the Saved Feed Index is appropriate. No significant differences were found between AY and HOL herds in views on the trait. Figure 5 presents the result for farmers' awareness and views on Saved Feed Index.

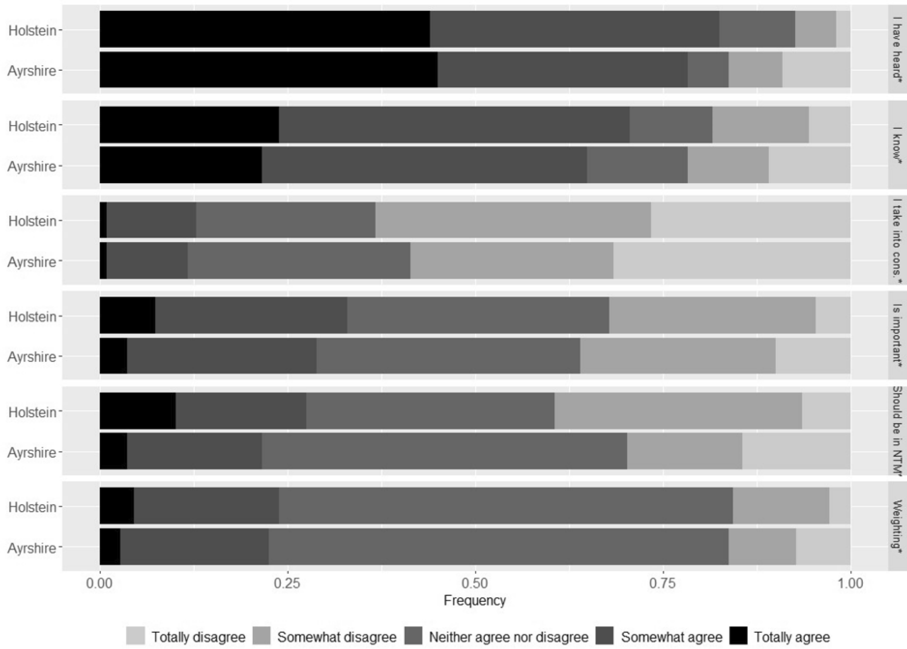

Figure 5. Knowledge and views of the Saved Feed Index. 5 (darkest grey) = Totally agree, 4 = Somewhat agree, 3 = Neither agree nor disagree, 2 = Somewhat disagree, 1 (lightest grey) = Totally disagree. I have heard* = I have heard of the Saved Feed Index; I know* = I know what the Saved Feed Index means; I take into cons.* = I take the Saved Feed Index into consideration in my breeding decisions; Is important* = The Saved Feed Index is an important breeding goal trait; Should be in NTM* = The Saved Feed Index should be included in the total merit index; Weighting* = The weighting of the Saved Feed Index in the total merit index in my herd's main breed is appropriate (weight factors in the NTM for Ayrshire = 0.13 and for Holstein = 0.08. With these weight factors, the correlation between the NTM and the Saved Feed Index (how much genetic progress is expected when selecting according to the NTM) was 0.17 for Ayrshire and 0 for Holstein).

It was surprising that the stated preference for feed efficiency decreased across the five-year period. Furthermore, it was also surprising that the revealed preference of the trait was very low at a time when climate and environmental issues were becoming increasingly important in all areas of life – especially in animal production.

By 2021, the Saved Feed Index had been available for almost two years, and even though it had a low relative weight in the NTM (0.04 for AY and 0.02 for HOL), the trait was expected to have been selected more intensively. Selection for the trait was possible as there were AI bulls with high Saved Feed Index values among those available in 2021. The stated preference was also expected to have been higher.

In addition, the result that only 12% of the respondents selected for feed efficiency supports the finding that feed efficiency was not selected (revealed preference) nor even claimed to be selected (stated preference) among the respondents. The survey, however, also revealed that feed efficiency was well known as a trait.

Many reasons could exist for why feed efficiency was not considered an important trait among the respondents and was not considered when they made breeding decisions, such as the low accuracy of the trait, difficulties in understanding what feed efficiency is, and its acceptance as a selected trait. Feed efficiency as a trait is not as concrete and measurable as yield or health traits. It can also feel safer to breed for the more traditional traits such as yield, which can be thought to also include feed efficiency. It simply takes time for a new trait and the EBV to be fully understood and utilized by farmers. The information available on AI bulls is vast and it can be difficult for farmers to adopt new EBVs. Farmers may also think that they already have enough traits to breed or EBVs to breed with. Simultaneously, some respondents stated that feed efficiency is an important trait and that they breed for it.

Furthermore, the relative weight for the Saved Feed Index is quite low in the NTM (0.04 for Nordic red breeds [includes AY] and 0.02 for HOL); therefore, the correlation between the Saved Feed Index and the NTM is also low (0.17 for AY and −0.01 for HOL), which means that the selection differential is low and does not support the selection of the Saved Feed Index when it is based on the NTM. The low selection differential may also stem from low reliability. The reliabilities of the two EBVs included in the Saved Feed Index (i.e., maintenance efficiency and metabolic efficiency) differ greatly (Lidauer et al., 2020). At the time the Saved Feed Index was launched, the reliability for maintenance efficiency was 60%, which was quite high considering that the reliability for yield traits, for example, was 70%. For metabolic efficiency, the reliability was only 1–3% for AY and 3–7% for HOL. Low reliability and simply the fact that the two feed efficiency traits and the Saved Feed Index formed from these two indices were new to farmers could explain why the EBVs were not thought to be reliable or important enough to encourage their active use in breeding choices.

4.4 Practical solutions and future research

Using farmers' opinions, in this case stated preferences, in AI bull selection at the herd level could be beneficial for the national breeding programme as well as for individual herds. Using the suggested customised AI bull selection tool to form a herd-specific TMI can make bull selection easier and simpler for farmers and enable the most important traits in the herd to be focused on. It can also enable the selection of the best-fitting bulls for the herd from among bulls with similar NTM values. In cases where the farm's production environment is significantly different from that of the average Nordic farm, the use of a herd-specific TMI could also result in faster gains in profitability compared with using the NTM (Mulder et al., 2006). Focusing only on a few traits instead of all economically important ones would usually not increase total profitability. Therefore, the use of the herd-specific TMI could result in the impact of trait correlations on genetic progress being ignored. In practice, most of the AI bulls used in Finland have been selected based on the NTM, and therefore, using the herd-specific TMI would just re-rank the preselected bulls. As an economic analysis is not included in the suggested bull selection tool, the economic benefit of the tool cannot be assessed. An easy AI bull selection tool that allows farmers to decide how to weight the different traits would probably make them more engaged and interested in improving their herd.

In practice, the bull selection tool based on the AHP or another method for measuring stated preferences could be used either by farmers themselves or in cooperation with a breeding advisor. It could be incorporated into a breeding planning software package or semen-selling companies' webshops to ease purchase decisions. The number of options or traits included in the AHP is limited (the maximum number of options should not be more than 7), which may restrict the AI bull selection tool's use in practice as there are dozens of traits as options. One solution could be for the user to choose which traits to include. This could enhance a more focused selection on a few traits but also result in many other important traits being neglected. Moreover, revealed preferences (i.e., past selection preferences) could be used to select suitable AI bulls for a herd if the preferences stay the same year after year.

In this study, the focus was on farmers' preferences and understanding which dairy cattle traits are important in their herds. In a broader sense, societal and consumer needs also affect farmers' breeding goals. Societal needs, such as human nutrition and food security, are considered when forming national breeding goals or breeding goals valid for more than one country, as in the case of Nordic countries. Consumers' preferences, wishes, and willingness to pay for dairy products are, however, rarely asked about. Consumers' preferences represent more often softer values and attributes that are more difficult to measure or do not have direct monetary value, like the farmers' preferences more often do. Such attributes may include animal welfare, food safety, and sustainability. They usually cannot be directly experienced or identified (Yang and Renwick, 2019), which makes them difficult to convert into individual traits, include in breeding goals, and compare with farmers' preferences. However, these attributes are relevant and increasingly important for guiding future dairy production.

How well dairy farmers' preferences reflect consumer preferences should be investigated further. This has already been done in crop breeding (Okello et al., 2022). The decision making and breeding choices in dairy cattle production are moving from purely economic considerations to decision-making considerations, where other attributes also have more weight. Thus, better strategies for including quantitative and qualitative information in the construction of TMIs should be explored.

5 CONCLUSIONS

This study investigated Finnish dairy farmers' revealed and stated breeding preferences using insemination data and survey results. Based on the findings, most Finnish dairy farmers choose AI bulls and prefer dairy cattle traits according to the NTM. However, clear heterogeneity exists among the farmers. Four distinct herd groups could be formed based on farms' insemination data. In one of these groups, the selection differed substantially from the NTM. The group consisted mostly of large, advanced, and well-managed dairy herds, and the selection was focused on improving conformation traits while almost neglecting other traits. In this group, farmers were willing to make compromises to concentrate only on conformation traits, even if this would result in drawbacks in other economically important traits.

Furthermore, farmers' stated selection preferences and revealed AI bull selection differed from each other. Longevity, conformation, and yield were favoured less, while health and fertility were favoured more in the stated preferences than in the revealed AI bull selection. Furthermore, the stated preferences changed very little over time regardless of major changes in the production environment. Larger changes were observed in revealed selection during the studied five-year period.

In addition, the survey results revealed that the novel trait of feed efficiency is not widely used by Finnish dairy farmers in making breeding choices, despite an EBV for the trait being available since 2020. While farmers consider feed efficiency to be an important trait, it is not yet implemented in practice.

Information on farmers' stated preferences obtained through a survey could be used to form alternative TMIs to be used in herd-specific AI bull selection. The herd's genetic progress could be enhanced, as could its economic profitability, if a TMI could be tailored specifically for the herd. Moreover, the data on actual AI bull selection could be used to form a herd-specific TMI. The possibility of tailoring TMIs would probably also more effectively engage farmers in finding the national or regional breeding goal, thereby better motivating them to improve their herds' genetic level. Most crucially, using herd-specific TMIs would increase the systematicity of breeding planning as herd-specific goals and selection would be considered more.

Whether farmers use the TMI or how well they use it has not been investigated. The differences between revealed selection and stated selection preferences have also not been studied before. The results of this study indicate that making breeding selections is not only herd specific but also not always rational or based solely on farmers' wishes, but it is affected by the availability of bulls, the market situation, and peer pressure from other farmers, among other factors. In the future the breeding choices are likely to become even more versatile between different farms. This should be considered in the development of TMIs and also in practice at the herd level.

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