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DEFINITION OF SELECTION CRITERIA AND BREEDING OBJECTIVE TRAITS OF CROSSBRED DAIRY COWS FOR SMALLHOLDERS IN THE EAST ARSI ZONE, ETHIOPIA

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ABSTRACT

This study aimed to define selection criteria and breeding objective traits of crossbred dairy cows for smallholders in selected areas of the East Arsi Zone, Ethiopia, using discrete choice experiments. A multi-stage, purposeful sampling strategy was used. From the target population, 301 farmers were randomly selected and interviewed in person. To gather the necessary data, a semi-structured questionnaire was prepared and pretested, then translated into the local language. The data were entered and organised in an Excel spreadsheet and later analysed using the Plackett-Luce model in R software (version 4.3.2) to estimate the coefficients of the traits. Multinomial logit analysis was conducted for discrete choice experiment data using R software version 4.3.3. The most preferred selection criteria for dairy cows among farmers were milk production (7.70 ± 0.32), followed by butter yield (3.84±0.15) and temperament (2.74 ± 0.13). The farmers were primarily breeding dairy cows for income generation (1.94 ± 0.09), followed by improving milk production (1.10 ± 0.08). Improving productive traits had a negative effect (-0.23 ± 0.07) as a breeding objective. The number of lactations (0.76±0.07) was the most preferred breeding objective trait, followed by production lifetime (0.52±0.06) among the longevity traits in initial selection, whereas lifetime production (1.46 ± 0.45) was ranked first in the discrete choice experiment. Udder-type trait was identified as the most significant determinant of udder health in dairy cows. The primary concern of farmers was milk production per minute (2.56±0.09) and milking speed (2.25±0.09) among the milkability group traits. Age at puberty was economically the most important among reproductive traits. Ageing was identified as the primary reason for culling dairy cows, followed by low milk yield. The farmers placed greater emphasis on milk volume than on milk composition, a tendency that may stem from limited awareness of milk quality attributes. In the dairy cattle production sector, the success of breeding programmes largely depends on the selection criteria set by farmers. However, breeders often overlook the farmers' perspective in favour of their own preferences, which can result in unsustainable and nonviable breeding programmes. Hence, breeders and farmers must work together to develop breeding programmes that are both viable and sustainable. Besides considering farmers' interests and selecting a broad range of traits, breeders can design programmes that address the needs of both farmers and the dairy industry.

Key words: breeding objective, longevity, milkability, udder health, dairy cow culling

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INTRODUCTION

In developed agricultural systems, livestock is valued economically not as an end in itself, but for its performance in relation to a set of desirable traits with measurable monetary worth [1]. Consequently, economic efficiency serves as the main driver for genetic improvement and the development of future genetic alternatives in these systems. But given the anticipated rise in global population, urbanization, and animal product consumption [2], societal needs are changing, in part due to a desire to lessen the negative externalities of agricultural production [3]. Hence, the value of a breeding decision may not be adequately described by selection algorithms that only promote economic efficiency. The incorporation of both self and societal interests into breeding objectives is made easier by the growing interest in valuation methods based on an expanded utility framework that is inclusive of the plural values that may better describe the overall benefit of a given genetic improvement [4].

Breeding is to change the genetic merit of animals in future generations so that they can produce the intended products more effectively (compared to the current generation) under future economic, natural, and social conditions [5]. The breeding objective is defined as the reason(s) for which animals are specifically bred. It assumes that farmers have deliberately chosen to genetically improve the next generation of animals in terms of their performance relative to their parent generations. As in any other industry, the fundamental goal of livestock production is to achieve efficient and productive outcomes that maximise economic returns [6]. On the other hand, breeding objectives are sensitive to production conditions and levels, which depend on the level of inputs and outputs [7]. Nevertheless, due to a lack of knowledge of individual trait preferences and beneficiary involvement, genetic enhancement programmes in developing nations, including Ethiopia, are not successful [8]. The implementation of a sustainable participatory breeding programme depends on a thorough understanding of trait preferences, and clearly defined breeding objectives are crucial [9, 10].

Establishing clear selection objectives that encompass economically important traits is the essential first step in designing a breeding programme [11]. These selection criteria form the basis for constructing the profit equation, from which the economic values of traits are derived [12]. Selection criteria are measurable traits used as predictors for inclusion in the breeding objective [13].

Farmers' viewpoints on important traits in dairy cattle are often overlooked when developing breeding goals [14], highlighting the importance of understanding their preferences. In order to facilitate the design of effective breeding programmes, previous works introduced a reference measure that evaluates farmers' attitudes to animal breeding tools [15]. Understanding farmers' preferences is essential for

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developing appropriate breeding goals that support long-term, robust dairy production and for promoting the adoption of effective selection methods. This indicates that farmers should actively participate in developing breeding objectives, together with the stakeholders involved in selection and breeding activities. Nevertheless, breeding objectives, preferred traits, and the relative ranking of these traits differ considerably across communities, production systems, agroecological zones, and degrees of market integration [16]. Local environmental conditions substantially shape breeding practices [8]. Researchers recommend integrating surveys, ranking approaches, and choice experiment methods when identifying traits for selection [9].

In practice, surveys and trait-ranking techniques are widely used in trait-preference studies to generate preliminary information and provide a broad overview of traits that may form part of a breeding objective. The choice experiment method, however, has become increasingly prominent for quantifying farmers' trait preferences in several livestock species, including cattle [9], and pigs [16]. This method allows the quantification of qualitative preferences, enabling the estimation of preference strength, trade-offs among traits, and the likelihood that certain attributes will become more prevalent. Moreover, choice experiments outperform traditional surveys and ranking techniques in eliciting preferences and uncovering trade-offs between competing traits. Despite these advantages, choice experiments have not yet been applied to determine the relative importance of farmer-preferred dairy breeding objective traits in Ethiopia. Consequently, limited information exists to guide the development of breeding programmes that align with farmers' preferences. Thus, this study defined selection criteria and breeding objective traits of crossbred dairy cows for smallholders in the East Arsi Zone, Ethiopia, using discrete choice experiments.

MATERIALS AND METHODS

Study areas and site selection

The study was conducted in the East Arsi Zone, Oromia Regional State in Lemunabilbilo, Tiyo and Digelunatijo districts. The zone is selected purposively because of the huge cattle population in the area, with an estimated 2,904,201 number of cattle. For this study, three districts, Lemunabilbilo, Tiyo, and Digelunatijo, were purposively selected from a total of 25 districts.

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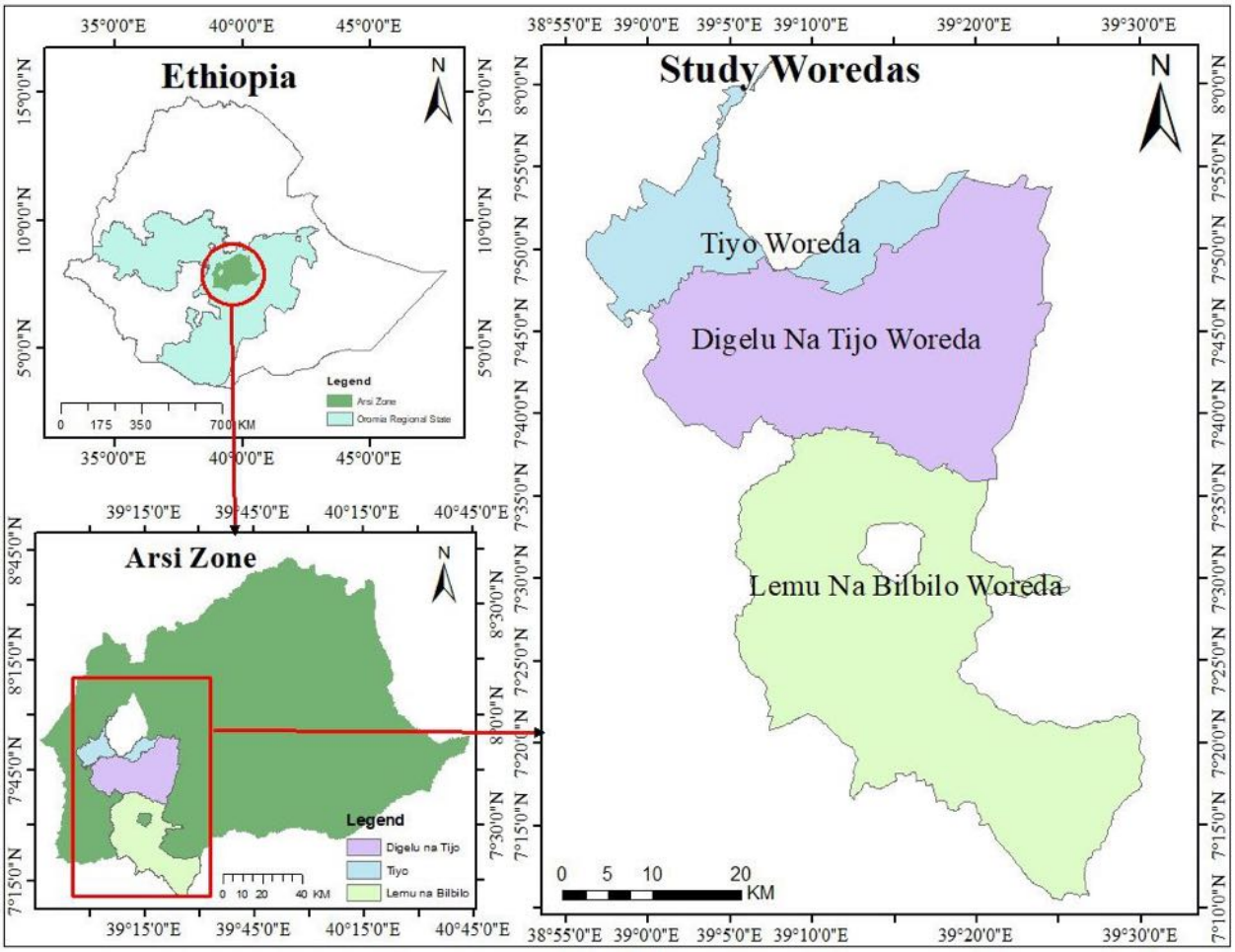


Figure 1: Map of the study areas

Study population and study design

A multi-stage, purposeful sampling strategy was used. First, potential districts were purposively selected, and experts from the livestock and fishery district office were briefed on the study's objectives. Second, based on the information from the districts' livestock and agriculture development agencies, the target population was defined (smallholder dairy farmers), necessitating that each farmer has at least one crossbred dairy cow. Then, peri urban and rural *Kebeles* (the lowest administrative division equivalent to a village) in each district were purposefully selected based on the status of dairying potential and road accessibility. Finally, dairy producers were randomly selected from each production system and informed about the study's aims.

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Sampling procedures and sample size determination

From the identified target population, smallholder dairy farmers were randomly selected to minimize bias. A sample determination technique suitable for large or infinite populations was used to ensure that the sample adequately represented the study populations in the selected areas. Hence, the sample size was determined using the formula by Arsham [17] for survey studies, assuming 5% margin of error.

$N = 0.25/SE^2 = 0.25/0.05^2$ = Where: SE = Standard error, N = required sample size.

At 5% standard error, 301 households were chosen (Lemunabilbilo = 100, Tiyo = 101 and Digelunatijo = 100).

Data collection methods and data analysis

To collect the required data, a semi-structured questionnaire was prepared and pretested, after which it was translated into the local language. Data was collected through face-to-face interviews using semi-structured questionnaires. Information was gathered on dairy cattle selection criteria, breeding objectives, selection criteria for longevity, udder health, milkability, reproductive traits, production traits, reasons for culling dairy cows, and constraints in dairy cattle production. The initially collected data were analysed to evaluate farmers' preferences across different groups of traits. Based on the results, four trait groups were selected, each represented by the three most preferred levels. These trait levels were then randomised into eight choice sets (A–H), each containing unique combinations that excluded any overlapping trait profiles. A questionnaire was subsequently developed and translated into the local language for administration to a randomly selected subsample of 30 farmers drawn from the original sample of 301 respondents. Before the interview, farmers were briefed on the benefits associated with each trait and informed that participation was voluntary and that they were free to select none of the traits if none matched their preferences. Then, they were presented with different options of animal traits and asked to choose the option that best matched their preferences. The data were entered and organised in the Excel spreadsheet and then subjected to statistical analysis using R version 4.3.2. The Plackett-Luce Model (PLM) procedure was used to estimate the ranking coefficients, employing the R library PlackettLuce for mass selection. Multinomial logit analysis was conducted for discrete choice experiment data using R software version 4.3.3.

Model

The farmers' choices were calculated using the Plackett-Luce model (PLM). The purpose of the PLM is to estimate the possibility of a particular rank ordering for a collection of I objects based on Luce's axiom [18], which emphasizes that for a set of items, S, the probability of selecting item i from the set is given by:

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$$P(i|S) = \frac{\text{ai}}{\sum_{\text{i}\in S} ai}$$

Where:

αi =Worth of item i

A Discrete Choice Experiment (DCE) aimed at assessing farmers' preferences for dairy cow traits. The Multinomial Logit (MNL) model is one of the basic econometric approaches used to analyse choice data. The DCE presented respondents with a series of choice sets. Respondents selected the option they preferred in each choice set. The MNL model is based on Random Utility Theory, which assumes that the utility U_{ij} that individual i derives from the alternative j consists of an observable component and a random error term:

$$U_{ij} = V_{ij} + \epsilon_{ij}$$

The systematic component V_{ij} is usually defined as a linear function of the traits included in the experiment:

$$V_{ij} = \beta_1 x_{1_{ij}} + \beta_2 x_{2_{ij}} + \beta_3 x_{3_{ij}}$$

The MNL model estimates the probability that individual i chooses alternative j from choice set C:

$$P_{ij} = \frac{\exp(V_{ij})}{\sum_{h\in C} \exp(V_{hi})}$$

RESULTS AND DISCUSSION

Dairy cattle selection criterion for smallholder dairy farmers

Table 1 presents farmers' selection criteria for dairy cows, revealing statistically significant preferences ($P < 0.0001$) for milk production, butter content, temperament, body conformation, udder size, dewlap, navel flap size, feet, and leg shape and colour. The results indicate that farmers primarily prioritised cows with high milk production, followed by butter content, docile temperament, and favourable body conformation, in descending order of importance. In contrast, negative coefficients were estimated for coat colour, foot and limb structure, navel flap size, dewlap, and udder size. These negative coefficients do not imply that such traits are undesirable in absolute terms; rather, they indicate lower relative preference or reduced selection emphasis compared with the reference level or the average importance of other traits included. This suggests that, although these morphological traits are considered by farmers, they are secondary to production and behavioural traits in selection decisions. Consistent with farmers' stated preferences, milk

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production exhibited the highest positive coefficient (7.70), indicating that farmers strongly prioritise cows with superior genetic potential for milk yield. Overall, the findings highlight that dairy cow selection by farmers is predominantly driven by productivity-related traits, with physical appearance traits receiving comparatively less emphasis when trade-offs among multiple traits are required.

Farmers' prioritisation of dairy cows for high milk production aligns with the findings of earlier studies, which indicated a farmer preference for traits associated with increased milk yield [19, 20]. Furthermore, previous studies noted that the significance of sustained milk production for household income was reflected in farmers' greater emphasis on production traits compared to other traits [21]. A rise in per capita income and supportive policies for greater milk production capacity may be linked to farmers' aspirations for high milk output.

Temperament refers to how a cow reacts when handled by humans, moved around, or placed in unfamiliar or demanding surroundings. It can make all the difference in how well it performs and how easy it is to manage. The study indicated that temperament is the most important characteristic for selecting dairy cows. A preference for an easy temperament is associated with the involvement of family labour in feeding, milking, health care, and breeding of dairy cattle [20]. Stress adversely affects milk production because during milking, highly reactive dairy cattle exhibit higher plasma levels of cortisol and endogenous opioids, lower oxytocin levels, and faster heart rates [22]. For dairy cows to be milked as efficiently as possible and to ensure complete milking, the cow must react calmly to the process. Furthermore, temperament had a significant influence on milking speed, conformation traits, udder health, reproductive success, and milk yield.

The present study verified that body conformation is an important criterion in selecting dairy cows. It is associated with dairy performance [23] and longevity, which significantly affects lifetime milk production [24]. Furthermore, udder size is identified as a key selection criterion for dairy cattle. Previous studies revealed that milk production is favourably associated with udder size [25]. A strongly attached and well-balanced udder with fine texture will support high and persistent production over the cow's lifetime [26]. Other studies also reported dewlap and navel flap size as a selection criterion for dairy cows in Chora and Gechi Districts, Ethiopia [27]. Colour is another selection criterion for dairy cows, which aligns with the previous findings [28]. Foot and leg problems increase losses for dairy farmers via treatment costs, reduced milk production, decreased fertility, and expenses related to culling and replacement [29].

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Dairy cattle breeding objectives

The objectives of smallholder dairy breeding, including increasing milk production, generating revenue, providing draught power, and producing replacement heifers, were highly significant ($P < 0.0001$), while improvements in productive traits were also statistically significant ($P < 0.05$). Among these objectives, income generation was ranked first (1.94 ± 0.09) with a positive coefficient, followed by increasing milk production (1.10 ± 0.08), indicating that farmers place the greatest emphasis on economic returns and milk yield enhancement. This strong preference reflects the need to meet household expenditures and ensure the financial sustainability of smallholder dairy enterprises. In contrast, draught power (-0.50 ± 0.08), production of replacement heifers (-2.31 ± 0.12), and improvements in productive traits (-0.23 ± 0.07) exhibited negative coefficients. These negative coefficients do not imply that those traits are undesirable in absolute terms; rather, they indicate lower relative preference compared with the average importance of other traits included. This suggests that draught power, production of replacement heifers, and improvements in productive traits are considered by farmers as secondary to income generation and increasing milk production as a breeding objective.

Different studies reported that milk production is the primary breeding objective for generating income through milk sales [19, 30]. This finding contrasts with the present study, which revealed that the primary breeding objective is income generation in general. Furthermore, it was demonstrated that the primary goal of dairy cattle breeding by the farmers was to increase income through high milk yield [31]. The findings of the current study are consistent with the previous studies, which reported that income generation was the primary objective of dairy cattle breeding [32]. Also, milk production was identified as a primary breeding objective in Slovenia [33], aligning with the current findings regarding production traits. Improving productivity traits is essential for dairy cattle breeding. Because it directly affects milk production and the future of the dairy industry. The fundamental goal of dairy cattle breeding is to increase productivity (fertility) [31], which is in line with the current findings. Previous studies reported draft power as a breeding objective [30], which aligns with the current findings. Draft power is an important component of crop-livestock production systems. Raising heifers for replacement is an important risk management strategy, ensuring that adequate replacements are available when needed. Excess heifers offered an opportunity to get herd replacement animals and function as a marketable asset that could be sold to generate operating money. However, the current surplus of replacement heifers on farms has contributed to economic difficulties for many dairies.

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Selection criterion for dairy cattle longevity

The overall estimated coefficient for the longevity selection criterion in dairy cows demonstrated that all evaluated longevity-related traits were statistically significant. Among these traits, the number of lactations (0.76) was preferred as the most influential breeding objective, followed by length of productive lifetime (0.52), herd life (0.19), and survival rate (0.08), all of which exhibited positive coefficients, indicating their favourable contribution to longevity selection. In contrast, type traits (-0.55) and stability (-0.99) showed negative coefficients, suggesting that farmers tended to place less emphasis on animals exhibiting weak or unstable characteristics. Despite the negative coefficient, type traits remain essential in the breeding objective, as a cow's conformation and physical structure are important predictors of durability and lifetime production potential.

The discrete choice experiment indicated that production life was statistically significant ($p<0.01$), whereas the number of lactations and herd life were not. Among the longevity-related traits, production lifetime received the highest preference (1.46 ± 0.45), followed by the number of lactations (0.34 ± 0.41) and herd life (0.11 ± 40). The strong preference for production lifetime can be attributed to its direct contribution to higher profitability through sustained milk yield and continuous income generation. Moreover, cows generally reach their peak production around the third lactation, providing greater economic returns during this period. A longer productive lifetime also reduces the costs associated with rearing replacement heifers, thereby improving overall herd efficiency and profitability. This may be attributed to farmers placing greater emphasis on individual traits during discrete experimental choices rather than considering them collectively in mass selection. This may be attributed to farmers placing greater emphasis on individual traits during discrete experimental choices rather than considering them collectively in mass selection. Moreover, this could be associated with the reliance of the farmers on keeping the animal for a longer time since they consider it as a savings capital.

Dairy cows' longevity can be evaluated in two ways: herd life, defined as the time from birth to culling, and productive lifetime, defined as the time from first calving to culling [34]. Selection for herd life helps reduce the involuntary turnover of animals on farms. Selecting dairy cattle based on longevity traits is important for breeding objectives, as it significantly contributes to the sustainability and profitability of dairy farming for farmers. Similarly, a productive lifetime is important for lowering involuntary culling and replacement expenses. Studies showed that extending the productive lifetime of dairy cows can decrease the environmental impact of dairy production [35]. For instance, replacement heifers contribute between 20 and 33% of total herd enteric methane emissions, with this proportion reducing when the age at first calving is younger, and the productive lifespan is longer [36]. The current

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findings are consistent with previous studies, which described that the key selection parameters for longevity in Holstein Friesian and crossbred dairy cows include herd life, number of lactations, length of productive life, and type traits [37]. The number of lactations was used as the primary selection criterion for dairy cows' longevity, followed by production lifetime. This contrasts with the findings of Kidane et al. [37], which reported that, for crossbred dairy cows, the primary selection criterion for longevity was production lifetime (0.37), followed by the number of lactations (0.32).

Longer herd life reduces replacement costs and produces more calves during the lifetime of the cow. Culling dairy cows early in the production cycle, that is, before they are biologically mature, is economically unsustainable [38]. In dairy cattle production, lifetime productivity is a key factor in weighing dairy cow performance. Dairy cow longevity is mostly evaluated by predicting either lifetime production or the cost per day of life [35]. Previous studies reported that dairy farmers are more likely to cull cows with low productivity, even if they show good health traits, and that an increase in herd average milk yield significantly prolongs overall herd longevity, respectively, which is consistent with the current findings [39]. Lactation number is an important issue in determining dairy cow longevity, which may be associated with the increase in milk yield with successive lactations. Also, farmers tend to keep the cow for a longer period of time. This is because milk yield progressively increased from the first to the third lactation. This increase is attributed to the development and enlargement of the udder, which leads to a higher number of secretory cells [40].

Survival rate has a significant impact on the overall performance of dairy farms. For instance, previous studies reported that survival is the second most important trait after protein yield in the Australian balanced dairy performance index [41]. This is mainly because it directly reduces replacement costs. The study revealed that type traits are key factors influencing the longevity of dairy cows. Selecting type traits related to herd longevity can help reduce involuntary culling and increase profitability [42]. The type traits like udder, feet, and leg traits, such as anterior udder attachment, udder texture and depth, height of rear udder attachment, rear udder width, central ligament strength, bone quality, and hoof angle, have a significant impact on the lifetime productivity of cows [43]. Dairy cow longevity is a complex trait with low heritability and limited supporting data. It is influenced by several factors, including inherent ones such as lactation, health, conformation, and reproductive performance [44], as well as external factors like milk price, nutrition, management, policy, feeding costs, and the availability of replacement heifers [45]. Moreover, in dairy cattle, type traits are strongly associated with longevity [46]. Dairy farmers prefer animals with good conformation, as well-formed animals are believed to produce more and be more resilient than those with poor conformation.

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Dairy cattle selection criterion for udder health

Table 4 shows the estimated coefficient of selection for udder health. The findings revealed that somatic cell count, milking speed, and udder-type traits were statistically significant ($p<0.0001$); however, the incidence of mastitis was not statistically significant ($p>0.05$) as a selection criterion for udder health. Udder type traits (0.98) and milking speed (0.81) had the strongest favourable coefficients, with udder type traits recognised as a critical focus in dairy cow breeding. A negative coefficient (-1.80) for somatic cell count indicates that farmers preferred milk from animals with lower somatic cell counts. The study found that the incidence of mastitis was not a significant selection factor for udder health ($p>0.05$), which may be associated with the low incidence of mastitis in the study areas.

The results of the discrete choice experiment showed that milking speed and udder type trait were statistically significant ($p<0.05$), whereas mastitis incidence was not significant. Among the udder health traits considered, milking speed (0.96 ± 0.41) was the primary attribute preferred by farmers, followed by udder type trait (0.85 ± 0.41) and mastitis incidence (0.06 ± 0.41). This finding highlights the significance of udder type trait in dairy cattle breeding, because it is linked to lifetime productivity and has a substantial impact on both animal welfare and overall herd profitability.

This study found that somatic cell count plays a key role in assessing udder health in dairy cows, as the number of cells in milk serves as an indicator of mastitis incidence. It was significant and favourably influenced farmers' decision-making to improve udder health features. Moreover, somatic cell count influences milk quality and udder health. For instance, milk somatic cell count has been incorporated into selection indices in many countries to reduce susceptibility to mastitis [47]. It has also been used as an indicator of udder health and milk quality. The incidence of mastitis was insignificant, which was attributed to farmers' limited awareness of the relationship between mastitis occurrence and the improvement of dairy cattle for higher milk production and quality. Improvement in mastitis tolerance was the most desirable attribute [41], which contradicts the present finding. Breeding cattle for higher milk production has been associated with an increased incidence of mastitis and elevated somatic cell counts, particularly leukocytes, secretory cells, and squamous cells, which are released into the milk in response to intramammary infection [48]. High-producing cows are more susceptible to production disorders such as metabolic stress and mastitis [49]. Therefore, farmers should remain aware of the risk of mastitis when aiming to increase production.

These findings indicated that milking speed was the most important selection criterion for udder health. However, in the Australian dairy industry, milking speed

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was the least preferred trait [41]. This may be due to a lack of understanding of how milking speed impacts both dairy cow health and milk yield. Some studies reported a correlation between milking speed and udder health, noting that cows with faster milking rates had a higher incidence of udder infections [50]. Moreover, the knowledge of milking speed is important, as faster milking has been associated with higher somatic cell scores. Genetic predictions for udder health traits can be improved by incorporating milking speed information into breeding programmes [51]. It was similarly reported that the incidence of mastitis, somatic cell count, and milking speed are selection criteria for udder health in Holstein Friesian and crossbred dairy cows [37].

Udder type traits are important in dairy cattle breeding because they are associated with lifetime production and affect both the welfare and profitability of dairy cows. Other works supported this idea, stating that poor udder and teat conformation negatively affect dairy herd profitability [52]. Furthermore, it was reported that cows with high angularity and well-attached fore udders produce higher quantities of milk, fat, and protein [53].

Selection criterion for milkability

The selection criteria for the milkability group traits are presented in Table 5. The findings revealed that all the traits considered were statistically significant ($p<0.0001$), except for residual milk. The following factors had positive importance coefficients: milk production per minute (2.56), milking speed (2.25), temperament (1.81), human approachability (0.96), and linear type traits (0.33). However, negative coefficients were observed for heart rate (-3.45), flinching, stepping, and kicking (-2.73), and running away from people (-1.74). The negative values indicate that farmers tended to avoid aggressive animals, as such behaviours interfere with feeding, milking, and general management. Milk yield per minute had the highest positive value (2.56). This may be associated with the desire to generate additional income through milk sales.

This study found that milking speed was a key trait among the milkability group when selecting dairy cows, as it affects milking time, udder health, and overall efficiency. Selecting cows with average milking speeds can enhance efficiency by reducing milking time, while preventing over-milking, benefiting both the farmer and the cow's health. In the Australian dairy industry, new breeding objectives and selection indices have given the least emphasis to milking speed [44], which contrasts with the present findings. Similarly, a correlation between shorter milking times and increased milk flow was also reported [54]. The way dairy cows respond to humans has a direct impact on the overall performance of the farm. Temperament plays an important role in dairy milkability, as it influences milk yield, milk flow rate during

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milking, milking duration, ease of milking, animal selection, and ultimately the economics of dairy farming [55]. Information on milk flow during milking can be used to improve process efficiency and promote udder health [56].

Dairy cow approachability to humans was important and positively influenced the selection of milkability traits, whereas flight distance from humans was significant and negatively influenced this selection. The study also found that flinch steps and kicking behaviour negatively influence milkability in dairy cows. The negative signs indicate that farmers dislike aggressive cows because they disrupt milking, feeding, and other farm activities. For instance, stepping and kicking negatively affect milking operations [57]. Furthermore, cows that kicked showed reduced milk flow, leading to lower milk output [58]. The study found that heart rate was an important factor and negatively affected the selection of the milkability trait. The negative sign indicates that a higher heart rate reduces milk yield by limiting oxytocin release. When an animal is frightened, its heart rate rises, leading to a decline in production performance. A decrease in milk yield was observed due to excessive residual milk and an elevated heart rate when cows were treated aversively [59]. Similarly, the study revealed that linear type traits are key determinants of milkability traits used for selecting dairy cows. For instance, higher correlation coefficients were reported among groups of linear traits characterizing dairy type, body conformation, udder, and milk production [60]. Moreover, linear type traits have become a vital tool in dairy cow management, as they help identify animals with phenotypic characteristics that contribute to a more productive life in the herd by enhancing both productive and reproductive potential [61]. This underscores the critical role of linear type scores in selecting traits related to milkability.

Selection criteria for reproduction traits

The selection criteria for reproductive traits are presented in Table 6. The results showed that all parameters were statistically significant ($p<0.0001$), while the body condition score was significant at a lower level ($p<0.05$). The highest positive coefficients were observed in the following traits, in descending order: age at puberty, age at first calving, calving interval, length of lactation, heifer pregnancy rate (fertility), days open, services per conception, and body condition. Negative coefficients were observed for ease of birth, birth weight, stillbirth, gestation length, pelvic measurements, rump angle, and rump width. The highest positive coefficients were observed in the following traits, in descending order: age at puberty, age at first calving, calving interval, length of lactation, heifer pregnancy rate (fertility), days open, services per conception, and body condition. Negative coefficients were observed for ease of birth, birth weight, stillbirth, gestation length, pelvic measurements, rump angle, and rump width.

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The discrete choice experiment indicated that age at puberty, age at first calving, and heifer pregnancy rate were statistically significant ($p<0.000$). Age at puberty (2.72 ± 0.61) was the most preferred reproductive trait, followed by AFC (2.57 ± 0.61) and heifer pregnancy rate (0.1.90 ± 0.52). This preference can be attributed to the fact that earlier puberty and higher pregnancy rates reduce the production costs of unproductive time. In addition, improvements in these traits contribute to an earlier age at first calving, which can extend the productive lifetime of the animal.

Age at puberty and age at first calving (AFC) were considered the most economically important breeding objective traits, as they affect an animal's productive lifespan and overall farm performance. For instance, heifers that reach puberty and conceive early in life tend to have greater herd longevity [62]. Age at puberty reported as a selection criterion for Holstein Friesians and crossbred dairy cows, with values of 0.03 and 0.08, respectively [37], which aligns with the current findings. Similarly, a reduced AFC in dairy cattle has been documented and is considered an indicator of rapid heifer maturity, resulting either from improved calf-rearing practices or from intensive selection for higher milk production [63].

This study showed that pregnancy rate in dairy cows is an important indicator of the reproductive performance of a dairy herd. Reproductive efficiency has a significant impact on insemination costs and herd replacement expenses [64]. Although days open are primarily influenced by environmental factors rather than genetics, minimizing them is economically beneficial. Reduced days open increases milk yield relative to labor and feed costs, enhances the number of calves produced and lifetime productive days, lowers breeding costs and culling rates [65].

Body condition score was found to be statistically significant in this study and is an important factor in dairy cow management. For instance, maintaining the optimal body condition of dairy cows is vital for achieving superior herd performance and high milk production, as cows that are either too thin or too fat are at greater risk of reduced milk yield and elevated somatic cell counts [66]. Calving ease was the most important trait in selecting breeding objectives for dairy cows. It is one of the secondary traits with the greatest economic impact, as it directly affects both animal welfare and herd profitability [67]. This study reported a negative coefficient for birth weight because excessively heavy calves cause calving complications. It is also a key factor influencing calving ease. Birth weight is a common early selection criterion in cattle breeding.

Stillbirth was another breeding objective trait that was negatively associated with farmers' interests. This negative association may indicate farmers' unwillingness to admit stillbirths, as they lead to financial losses and replacement challenges. Stillbirth poses a significant financial risk in dairy cow production [68]. Although

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gestation length remains constant, several studies have shown that there is sufficient genetic variation for selection to influence it [69]. Many economically important traits, such as lactation performance, productive life, health traits, ease of calving, and calf mortality, are correlated with gestation length [69, 70]. Furthermore, higher calf birth weight and an increased incidence of dystocia are associated with longer gestation lengths; these factors can result in higher rates of calf and cow mortality, as well as extended postpartum intervals [70]. Therefore, it is important to include gestation length in the genetic selection process.

Pelvic size is an important factor in evaluating dystocia. The results showed a negative coefficient for pelvic size, indicating that farmers tend to avoid animals with a smaller pelvic size. About 12% of dystocia cases are caused by issues related to the pelvic size [71]. Similarly, the study revealed that the rump angle has a negative coefficient, indicating that animals with pin bones positioned higher than the hip bones were less preferred by the farmers. Reduced fertility in animals may be influenced directly or indirectly by longevity, particularly in those with pin bones positioned above the hip bones [72]. The argument is based on the fact that elevated pin bones tilt the vaginal canal, causing it to lie at an angle rather than flat. Since the vagina cannot drain efficiently at an upward angle, the reproductive system becomes more susceptible to infections, which can negatively affect conception, pregnancy, and delivery [73]. Because the calf's natural exit path is downhill, the angle of the vaginal canal can make parturition difficult. If the pin bones do not drop sufficiently during calving, it can further complicate the process, making parturition more challenging [74]. Similarly, rump width is an important conformation trait in the linear scoring system for dairy cattle. A wide rump provides a larger area for udder attachment and a roomier pelvic cavity, facilitating easier calving. Milk yield and udder dimensions are positively correlated with rump width [75].

Fertility was the most preferred breeding trait among the reproductive characteristics studied and ranked third. This finding is consistent with the previous studies, which reported that fertility was the most prioritised breeding objective among functional traits [33]. On the other hand, fertility was reported as the second most preferred breeding goal among farmers, after milk production for crossbred dairy cows [19]. Furthermore, several studies reported that fertility is the most important breeding objective trait, as it has a major impact on the profitability of milk production [76].

Selection criteria for production traits

In Table 7, the selection criteria for production traits are presented. The study revealed that fat yield was not significant ($p>0.05$), whereas milk yield, protein yield, and lactation length were statistically significant ($p<0.0001$). Among the production traits, milk yield was the most desired (3.42), followed by fat yield (0.04). The lowest

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estimated coefficient was obtained for protein yield (-2.09), followed by lactation length (-1.38). This suggests that, since milk prices in the country are driven more by volume than by composition, farmers are largely unaware of the importance of milk protein.

The discrete choice experiment indicated that milk was statistically significant ($p<0.001$), whereas fat and protein yields were statistically significant ($p<0.05$). Among the evaluated production traits, milk yield (3.06 ± 1.05) was the most preferred, followed by fat yield (0.94 ± 0.47) and protein yield (-2.18 ± 1.05). Protein yield was the least preferred trait, which may be attributed to knowledge gaps regarding milk quality, as milk pricing in the study area is solely based on volume. Milk fat content is widely known as an indicator of milk quality and plays an important role in determining the flavour of milk and milk products. In developed countries, milk composition is a major determinant of both milk quality and price, whereas in Ethiopia, milk price is seldom influenced by compositional attributes and is largely determined by volume alone.

This study found that among the production traits, milk yield was the most important breeding objective trait, followed by fat yield. This preference may be attributed to the continuous cash income generated from milk sales, which enables farmers to meet their financial needs. Milk production was the most desired breeding objective trait compared to other traits [20], which is consistent with the current finding. The primary focus on milk production was to ensure a continuous supply of milk for household income [21]. Moreover, previous studies reported a strong preference for high milk yield [19, 77]. Furthermore, it was reported that milk production is the most desirable breeding objective trait in dairy cattle production in Slovenia and Kenya, respectively [33, 78], which is consistent with the current findings. This suggests that producers prioritise high milk production to maximize profits from milk sales. In contrast to the present findings, protein yield ranks second among production traits in breeding objectives [78]. Milk production traits, including milk yield, fat content, protein content, and somatic cell score (SCS), are important economic indicators for assessing milk quality [79, 80]. However, in Ethiopia, farmers do not consider milk composition, as milk prices are determined exclusively by volume.

Fat yield was the second most preferred production trait and was positively associated with the farmers' choices of breeding objective traits. Fat content was identified as the second most desirable breeding trait in Kenya [78], which aligns with the current findings. This preference may be associated with the income generated from butter sales and hair care, as most farmers favoured butter over synthetic cosmetics. In contrast to the present findings, it was reported that milk fat is the least economically important trait [19, 41].

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This study found that lactation length was negatively correlated with dairy cattle selection among the production traits considered. This may be explained by farmers' reluctance to select cows with below-standard lactation lengths, as doing so can negatively affect both the overall performance of the dairy herd and the farm's profitability. Selection for lactation length, which is used to assess the genetic merit of individual cows, neither penalises cows that do not reach the defined lactation length nor rewards those that lactate for longer periods [81]. This finding aligns with the previous studies [19], which reported that lactation length was the third most important attribute favoured by farmers among the factors considered.

In both selection scenarios, protein yield was ranked last among farmers' preferred breeding objective traits. This finding contradicts the previous studies, which reported that protein yield was the most valued trait among production-focused farmers in Australia [41, 76]. In Australia, milk payment is based on milk fat and protein content, with penalties applied for milk volume. Protein yield is considered more valuable than fat yield [82]; unlike in Ethiopia, milk payment is based solely on volume. Moreover, protein yield was the most valued attribute in the efficiency scenario but the least valued in the resilience scenario [83], which contradicts the present findings. The variation in trait preferences across studies suggests that farmers tend to prioritise improving traits that pose greater challenges in their herds.

Dairy cattle culling reasons

Fig. 1 summarises the main justifications for dairy cow culling in the research areas. The study revealed that age was the leading cause of dairy cow culling, followed by low milk production. Difficulties during birth were the least common reason for culling. Poor body conformation, health problems, and fertility issues also played significant roles in the decision to cull dairy cows. All factors considered in this study were statistically significant.

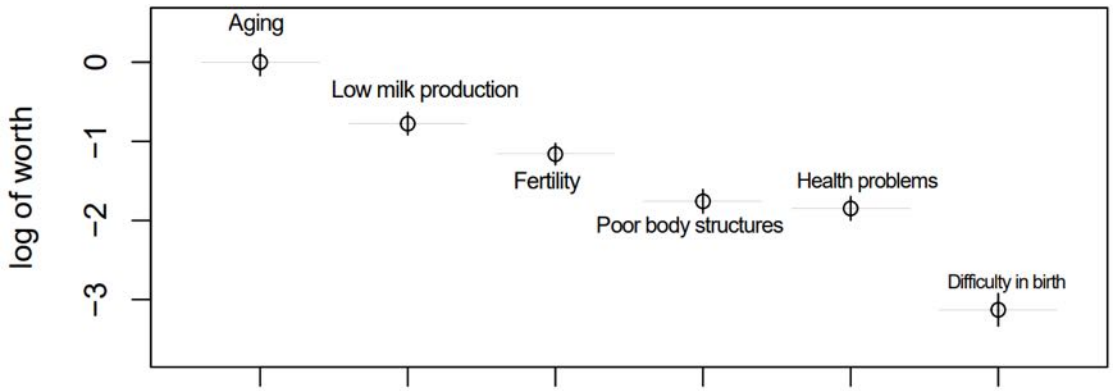


Figure 1: Reasons for culling dairy cows

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Previous works reported that health issues were the primary cause of dairy cow culling, which contrasts with the findings of the current study [84]. This inconsistency may be due to a higher prevalence of diseases in their study regions compared to the areas examined in the present study. In this study, low milk production was the second most significant reason for dairy cow culling, consistent with the previous findings [84]. In Khartoum, Mekelle City, Tigray, Ethiopia, low milk production, ageing, and health problems were identified as the primary reasons for culling dairy cows [84], which is consistent with the present finding. Making the appropriate decision to remove an animal from the herd is crucial, as it affects farm performance and incurs replacement costs. The same authors reported that infertility was the main reason for dairy cow culling, which is consistent with the current findings.

Poor body conformation is a major factor influencing whether dairy cows are retained on the farm or culled. The study revealed that inadequate body structure is a key reason for culling dairy cows. With the growth of dairy cattle breeding, body conformation traits are directly associated with cow health, productivity, longevity, and ease of calving. Consequently, producers tend to avoid cows with poor body conformation. From the farmers' perspective, another barrier to culling dairy cows was difficult calving. Consistent with the current findings, earlier works noted that calving difficulties in crossbred and Holstein Friesian cows acted as a barrier to culling [37]. Difficult calving leads to significant financial losses due to reduced milk yield, lower lifetime production, decreased longevity and fertility, and increased veterinary expenses. The dairy industry recognises the economic significance of difficult calving, as it affects not only short-term farm profits through calf loss, dam mortality, veterinary costs, and additional labour [85], but also the animal's long-term performance, including health, fertility, milk production, and risk of premature culling.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

Farmers prioritise milk production as the primary criterion in dairy cow selection, followed by high butter yield, reflecting a production-oriented breeding strategy. Their primary breeding objective is income generation, with increased milk production ranking second. Concerning longevity, the number of lactations was preferred as the most important trait in dairy cow selection under mass-selection approaches, followed by lifetime productivity. In contrast, production lifetime was identified as the principal criterion in discrete experimental choice evaluations. For udder health, milking speed was considered the most economically important trait. Within the broader milkability trait group, milk yield per minute and milking speed were identified as the key selection attributes. Among reproductive traits, age at puberty was the most preferred characteristic. The findings indicate that farmers place greater emphasis on milk volume than on milk composition, likely due to limited

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awareness of milk quality parameters. Similarly, somatic cell count (SCC) received comparatively little attention among udder health traits, suggesting insufficient knowledge of its role in milk quality, mastitis control, and market value. These results highlight the need for targeted extension and educational interventions to improve farmers' understanding of milk composition traits and the economic and health implications of SCC in dairy production systems. Additionally, temperament, a complex behavioural trait, was recognised as influential in routine farm operations and overall dairy productivity. Therefore, based on the findings, the following recommendations can be drawn:

1. Rebalance Breeding Objectives Toward Comprehensive Profitability

As the farmers prioritise milk volume and income generation, breeding programs should:

- Integrate milk composition traits (fat %, protein %) into selection indices alongside milk yield.
- Establish the economic returns of quality-based milk pricing systems to shift focus from solely quantity selection.
- Promote lifetime profitability models instead of short-term production gains.

2. Strengthen Farmer Awareness on Milk Quality and Udder Health

The low emphasis on somatic cell count (SCC) and milk composition indicates a knowledge gap. Therefore:

- Implement targeted extension and training programs explaining SCC as an indicator of mastitis, milk quality, and market penalties.
- Develop practical on-farm tools for SCC monitoring and interpretation.

3. Improve Selection for Longevity and Lifetime Productivity

Given the importance of the number of lactations and production lifetime, breeding programs should:

- Emphasis longevity traits within national or regional breeding indices.
- Promote data recording systems to accurately capture lifetime performance.
- Encourage selection strategies that balance production intensity with functional durability.

4. Prioritise Functional Traits for Operational Efficiency

Since milking speed and milk yield per minute were identified as economically important:

- Include milkability traits in structured breeding indices.

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- Align selection with farm management systems (like automated milking systems, where milking speed directly affects throughput).
- Avoid extreme selection that may negatively affect udder conformation or teat health.

5. Enhance Reproductive Efficiency Through Early Maturity

Since age at puberty was the most preferred reproductive trait:

- Promote heifer management practices that support optimal growth and earlier reproductive maturity.
- Integrate reproductive efficiency traits into breeding objectives to reduce non-productive days.

6. Integrate Temperament into Breeding Programs

Given the operational and productivity implications of temperament:

- Conduct systematic research to quantify temperament's genetic parameters and economic weight.
- Incorporate temperament into selection indices, particularly in systems relying on automated milking or large herd management.
- Provide farmer training on behavioural assessment and handling strategies.

7. Strengthen Recording and Data Infrastructure

Many of the identified gaps (milk composition, SCC, longevity traits) require reliable data. Therefore:

- Expand herd recording schemes.
- Encourage participation in performance testing programs.

Generally, dairy breeding strategies should change from a predominantly volume-based approach toward a balanced, profitability context that incorporates production, health, longevity, reproductive efficiency, and behavioural traits. This combined approach will boost sustainability, operational efficiency, and long-term economic returns in dairy production systems.

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Universities for the chance to carry out this study, and to smallholder dairy farmers who participated in the study and extension workers.

CONFLICTS OF INTEREST

No potential conflict of interest

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Table 1: Estimates of the overall coefficient of dairy selection criteria for smallholder dairy farmers with the mean as the reference

Variables	Coefficient	SE	Z-score	P-value	Probability of being ranked first (%)	Rank
Milk production	7.70	0.32	24.17	<0.000	96.9600	1
Butter yields	3.84	0.15	26.36	<0.000	2.0480	2
Temperament	2.74	0.13	20.66	<0.000	0.6784	3
Body conformation	1.79	0.13	14.26	<0.000	0.2634	4
Colour	-0.65	0.11	-5.66	<0.000	0.0231	5
Udder size	-2.18	0.12	-18.44	<0.000	0.0050	6
Dewlap	-3.46	0.13	-27.40	<0.000	0.0014	7
Navel flap size	-4.19	0.13	-31.25	<0.000	0.0007	8
Feet and legs	-5.60	0.16	-34.36	<0.000	0.0002	9

Table 2: Estimates of the overall coefficient of breeding objective for smallholder dairy farmers with the mean as the reference

Variables	Coefficient	SE	Z-score	P-value
Generate income	1.94	0.09	21.39	<0.000
Increase milk production	1.10	0.08	14.35	<0.000
Improve productive traits	-0.23	0.07	-3.12	0.0178
For draught power	-0.50	0.08	-6.53	<0.000
For heifer replacement	-2.31	0.12	-20.09	<0.000

Table 3: Estimates of the overall coefficient traits of longevity selection for smallholder dairy farmers with the mean as the reference

Variables	Coefficient	SE	Z-score	P-value
Number of lactations	0.76	0.07	11.57	<0.000
Production lifetime	0.52	0.06	8.11	<0.000
Herd life	0.19	0.06	2.94	0.003
Survival rate	0.08	0.06	1.23	0.219
Type trait	-0.55	0.07	-8.02	<0.000

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Stability	-0.99	0.08	-12.99	<0.000

Table 4: Estimates of the overall coefficient for udder health selection with the mean as the reference

Variables	Coefficient	SE	Z-score	P-value
Udder type traits	0.98	0.08	12.99	<0.000
Milking speed	0.81	0.07	11.05	<0.000
Incidence of mastitis	0.01	0.07	0.13	0.893
Somatic cell count	-1.80	0.11	-16.27	<0.000

Table 5: Estimates of the overall coefficient of selection criteria for the milkability group traits with the mean as the reference

Variables	Coefficient	SE	Z-score	P-value
Kilograms of milk per minute	2.56	0.09	29.55	<0.000
Milking speed	2.25	0.09	25.67	<0.000
Temperament	1.81	0.08	22.79	<0.000
Approachability to humans	0.96	0.08	12.62	<0.000
Linear type traits	0.33	0.08	4.34	<0.000
Residual milk	0.00	0.08	0.05	0.96
The flight distance from humans	-1.74	0.09	-19.38	<0.000
Flinch step and kick behaviour	-2.73	0.10	-26.50	<0.000
Heart rate	-3.45	0.12	-28.08	<0.000

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Table 6: Estimates of the overall coefficient of selection for reproduction traits with the mean as the reference

Variables	Coefficient	SE	Z-score	P-value
Age at puberty	3.01	0.08	35.97	<0.000
Age at first calving	2.30	0.07	31.27	<0.000
Heifer pregnancy/fertility rate	1.05	0.07	15.07	<0.000
Lactation length	0.84	0.07	12.70	<0.000
Calving interval	0.60	0.06	9.40	<0.000
Days open	0.50	0.06	7.91	<0.000
Service per conception	0.46	0.06	7.13	<0.000
Body condition score	0.13	0.06	2.11	0.035
Ease birth	-0.29	0.06	-4.64	<0.000
Pelvic measurement	-0.76	0.07	-11.14	<0.000
Birth weight	-1.02	0.07	-15.57	<0.000
Rump angle	-1.29	0.07	-19.14	<0.000
Rump width	-1.80	0.07	-24.05	<0.000
Stillbirth	-1.58	0.07	-21.97	<0.000
Gestation length	-2.14	0.08	-25.59	<0.000

Table 7: Estimates of the overall coefficient of selection for production traits with the mean as the reference

Variables	Coefficient	SE	Z-score	P value	Probability of being ranked first (%)	Rank
Milk yield	3.42	0.18	19.362	<0.000	95.58	1
Fat yield	0.04	0.09	0.472	<0.637	3.25	2
Lactation length	-1.38	0.09	-14.577	<0.000	0.78	3
Protein yield	-2.09	0.11	-18.259	<0.000	0.39	4

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