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Selection indexes in terms of functional features in modern dairy cattle breeding in Europe

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Abstract

The increase in demand for dairy products requires continued progress in dairy farming for a sustainable supply. Europe, known as the world's leading milk producer, plays a key role in meeting this growing demand. Modern dairy farming has moved beyond its historical focus on milk yield and now focuses on functional traits such as udder health, fertility and calf survival. As a result, selection indicators have become essential tools, combining multiple attributes to support selective decisions. However, these rates show considerable variability across countries, reflecting their distinct breeding goals. Poland's production and functionality (PF) Index emphasizes production and functional traits to enhance dairy cattle. Portugal uses the total economic merit (M€T) and total performance index (IPT) for a broader assessment covering a wider range of traits. Ukraine is transitioning towards a more comprehensive breeding system incorporating stress tolerance and longevity. Factors such as climate change and the need for sustainable practices drive this evolution, underscoring the economic importance of traits beyond mere production. Future trends may include features such as feed efficiency, methane emissions reduction and stress resistance. Diverse breeding objectives across countries lead to different selection index constructions, essential for effective selection, ranking and breeding of superior individuals. This comprehensive review offers insight into constantly evolving dairy farming strategies in Europe, with a focus on Poland, Portugal and Ukraine, while highlighting the key role of functional traits in shaping the future of dairy farming.

Introduction

The projected global population is expected to reach 9.7 billion people by 2050 (United Nations Department of Economic and Social Affairs, Population Division, 2022). This highlights the critical need for ongoing advancements in food production to ensure a consistent food supply for this expanding population (Wang, 2023). As the global population continues to grow, there will also be an increasing demand for dairy products, necessitating advancements in dairy cattle breeding (Crump *et al*., 2019). The dairy industry holds crucial significance within Europe's agriculture and economy. Notably, Europe ranks as the world's largest milk producer (Bórawski *et al*., 2020). In 2021, the European Union recorded an average raw milk production of 161.0 million tons (Eurostat, 2023). Moreover, the demand for cow's milk and dairy products is on the rise due to milk's richness in compounds such as protein, fat and minerals (Wodajo Tirfie, 2023). To meet market requirements and ensure food security, as well as a constant supply of raw materials for the dairy industry, genetic selection of cattle has become necessary (Brito *et al*., 2021). Modern animal husbandry focuses on the highest possible efficiency. The primary goal of dairy farming has traditionally been to maximize cows' productivity by increasing milk yield and its components (Cardoso Consentini *et al*., 2021). However, recent practical observations and scientific research have shed light on the negative consequences associated with this approach. These consequences include a decline in reproductive parameters and an increased incidence of metabolic diseases, such as ketosis, milk fever or displaced abomasum (Sdiri *et al*., 2023; Wang, 2023). As a result, there is an increasing international emphasis on functional attributes like udder health, fertility, ease of calving and calf survival. These traits play a pivotal role in enhancing the economic viability of milk production by lowering expenses and promoting the long-term well-being of cows (Mancin *et al*., 2021). The goal of breeding within a specific breed of dairy cattle is to make genetic advancements by producing offspring with greater genetic potential than their parents (Zhang *et al*., 2022).

This review aimed to provide a comprehensive overview of selection indexes in dairy cattle breeding and to highlight the diversity of approaches adopted by different European countries, with a particular emphasis on the evolving strategies in Poland, Portugal and Ukraine. By examining the selection indexes used in these regions and their relevance within the broader context of dairy farming, this review seeks to contribute to our understanding of the dynamic landscape of dairy cattle breeding strategies on a global scale.

Selection indexes

In response to the increasing worldwide demand for dairy products and milk, modern cattle breeders have embraced comprehensive selection indexes (SI). These indexes have been carefully designed to enhance various aspects of cattle, including their immunity and milk production (Brito *et al*., 2021).

Long-term efforts in animal selection have yielded significant improvements in three high-milk-producing breeds of cows: Holstein, Jersey and Brown Swiss, as well as their crossbreeds (Brito *et al*., 2021). The SI play a vital role in modern dairy cattle breeding by comprehensively evaluating multiple traits combined into a single value for ranking animals and making informed selective decisions (Cole *et al*., 2021). These synthetic indexes ensure that animals are not solely judged based on their performance in one trait, preventing the disregard of individuals with potential in other vital characteristics (Georges *et al*., 2019). The emphasis, or the weights assigned to each trait in the index, is of paramount importance in determining the direction of improvement. Defining the breeding goal forms a fundamental component of breeding programmes tailored to specific cattle breeds (Van Eenennaam, 2019).

SI for cattle breeding exhibit significant variations between countries and even within different breeds (Chang *et al*., 2020). Current trends underscore the significance of attributes such as milking speed (MS) and temperament (MT) within breeding initiatives. MS pertains to the efficiency of the milking process, while MT relates to the behaviour of cows during the milking (Szymik *et al*., 2021). These functional traits enhance production profitability, align with ethical standards and gain social acceptance (Chang *et al*., 2020; Alvarenga *et al*., 2023).

To attain efficient, healthy and profitable cattle, selection indices are continually evolving. They are gradually reducing the emphasis on production traits and integrating functional features into the selection criteria (Chang *et al*., 2020; Alvarenga *et al*., 2023). An increasing focus is being placed on integrating future characteristics into breeding goals. These traits encompass milk composition (such as linoleic acid, urea and lactose), lactation persistence, cattle well-being, milk conductivity, adaptability to high temperatures, and mitigation of environmental impacts, including addressing methane emissions (Brito *et al*., 2021; Manzanilla-Pech *et al*., 2022).

These evolving trends are primarily driven by factors like climate change. For example, feed efficiency is being prioritized to address greenhouse gas emissions. Improving feed efficiency not only reduces emissions per unit of milk production but also aligns with efforts to mitigate the environmental impact of cattle farming (Manzanilla-Pech *et al*., 2022). Another pressing environmental concern is methane emissions, which have a more significant impact on the greenhouse effect than carbon dioxide. Hence, efforts are underway to target and reduce methane emissions through breeding practices (Manzanilla-Pech *et al*., 2022). Moreover, there is a growing recognition of the importance of traits related to resilience in cattle. These include resistance to stress factors, including diseases, and the ability to quickly recover optimal condition (resilience). However, incorporating such traits into selection indices presents challenges, particularly in determining relevant phenotypes (González-Recio *et al*., 2020).

Selection indexes among different countries

Different countries prioritize various categories of traits in their breeding goals for dairy cattle when using the new method of selection known as the total merit index (TMI). These categories may include production, type, workability, functional traits, longevity and fertility. The relative importance of each category is determined by assigning different weights within the calculation of the TMI (Balasundaram *et al*., 2021).

For example, the economic breeding index (EBI) is widely used for dairy and beef cattle in Ireland. It is a multi-trait index that combines various production, fertility and health traits to estimate an animal's genetic merit. The EBI aims to improve the national herd's overall economic profitability and efficiency by selecting animals with desirable traits (O'Sullivan *et al*., 2020). In Spain, breeding programmes use the ICO (Spanish TMI) as a benchmark for selection purposes, which includes productivity, functionality and health (González-Recio *et al*., 2020). The ICO index encompasses various traits such as milk yield (MY), fat yield (FY), protein yield (PY), foot and leg index (FLI), udder composite index (UCI), longevity (LONG), somatic cell count (SCC) and open days (DO). These traits are considered crucial in evaluating the overall genetic merit of dairy cattle in Spain (González-Recio *et al*., 2020; Ziadi *et al*., 2021). In France, the ISU (Index Synthèse Unique) is a comprehensive individual index incorporating production, functional and type traits. The weighting of these traits varies based on the specific breed and breeding objectives. The ISU index enables breeders to assess and select animals that align with their desired breeding goals, considering a balanced combination of production, functional and type traits (Doublet *et al*., 2019). In addition, in Scandinavia (Denmark, Finland, Sweden), there is an NTM (Nordic total merit) index, which has been used since 2008. The NTM index is weighting each trait of cattle in terms of its economic value (Paakala *et al*., 2020). The breeding index utilized in Germany, known as RZG (Zuchtwert Gesamt), encompasses milk production and functional traits that hold economic value within the breeding programme. RZG consists of several sub-indexes, including complex milk production (RZM), complex longevity (RZN), complex conformation, complex fertility (RZR), complex udder health (RZS) and complex calving traits (RZKm). These sub-indexes capture different aspects of the cow's performance and health, enabling breeders to make informed breeding decisions aligned with their breeding goals (Meier *et al*., 2021). Also, in Ukraine, selection indices are used to improve such parameters as herd productivity, cows' longevity, fertility, exterior type and conformation (Palii *et al*., 2020). Based on TMI, the PF SI (productivity and functionality) was developed in Poland (Polish Federation of Cattle Breeders and Dairy Farmers, 2017).

Poland

In 2007, a significant milestone was reached in the Polish Holstein–Friesian breeding programme with the introduction of the production and functionality (PF) index for bulls. This comprehensive index encompassed four key components: production, conformation, fertility and somatic cells. It marked a crucial shift in how bulls were evaluated and selected for breeding, laying the foundation for more accurate and informed breeding decisions (Polish Federation of Cattle Breeders and Dairy Farmers, 2017; Trela and Choroszy, 2010). The formula for the PF index was:

$$PF = 0.5 \times PI\_PROD + 0.3 \times PI\_POKR + 0.1 \times PI\_PŁOD + 0.1 \times WH\_KSOM$$

Legend: PF – production and functionality, PI_PROD – production subindex, PI_POKR – conformation subindex, PI_PŁOD – fertility subindex, WH_KSOM – breeding value for somatic cell content in milk.

Initially, cows were evaluated based on an outdated production index for breeding selection. Advancements in breeding value assessment techniques emerged over time (Kosińska-Selbi *et al.*, 2022; Siekierska, 2022). In 2007, the assessment frequency shifted from biannual to triannual, aligning with INTERBULL's international schedules. Changes to the PF index began with a focus on the fertility sub-index in 2010, which now includes four indicators. 2012 brought revisions to the conformation sub-index. In 2014, adjustments refined the PF index, including reducing production and conformation weights and adding longevity, while somatic cell content remained unchanged. The PF index formula for Polish Holstein–Friesian cows mirrors that for bulls (Adamczyk *et al.*, 2021).

Over time, the PF index underwent several modifications to better align with evolving breeding goals and advancements in breeding value assessment techniques. These changes aimed to improve the accuracy of trait estimation and enhance the overall breeding programme. The Polish Federation of Cattle Breeders and Dairy Producers computes selection indices for Polish Holstein-Friesian, Simmental and Polish Red breeds. In the case of Polish Holstein–Friesian cattle, the predominant focus is on the PF SI, which takes into account a combination of production and functional traits (Adamczyk *et al.*, 2017; Polish Federation of Cattle Breeders and Dairy Farmers, 2017). The construction of this synthetic index, including its components and their respective weights, determines the breeding direction for the specific subpopulation of cattle. Based on these indices, animals can be ranked, and breeding selections can be made to align with the desired breeding goal (Wellmann, 2023). Currently, the formula of the Polish breeding index for the Polish Holstein–Friesian breed is as follows:

$$PF = 0.4 \times PI\_PROD + 0.25 \times PI\_POKR + 0.15 \times PI\_PŁOD + 0.1 \times WH\_KSOM + 0.1 \times WH\_DUG$$

Legend: PF – production and functionality, PI_PROD – production subindex, PI_POKR – conformation subindex, PI_PŁOD – fertility subindex, WH_KSOM – breeding value for somatic cell content in milk, WH_DŁUG – breeding value for longevity.

The development of Polish SI is influenced by its specific natural conditions, technological advancements, cultural practices and legislative framework. For instance, the focus on conformation traits and somatic cells reflects both the local environmental challenges and the technological capabilities available to assess these traits. The inclusion of longevity in 2014 indicates a cultural shift towards sustainable breeding practices, influenced by both economic and legislative pressures to improve animal welfare and productivity.

During the selection of cows and bulls for breeding, the central focus is on identifying individuals with the greatest breeding value, which is frequently indicated by the highest indices for particular traits (Berghof *et al.*, 2019; Adamczyk *et al.*, 2021; Brito *et al.*, 2021). Within this context, the PF SI is utilized, which has been standardized with an average value of 100 and a standard deviation of 10. This standardization facilitates a comparative assessment of individuals based on their performance across various traits, thus aiding breeders in making well-informed breeding choices (Jędraszczyk, 2010). Moreover, breeders are provided with distinct information regarding breeding values for longevity, enabling them to give due consideration to this crucial trait during their selection process (Adamczyk *et al.*, 2021).

The production sub-index (PI_PROD) combines breeding values for fat and protein yield, focusing on enhancing milk production potential. The conformation sub-index (PI_POKR) assesses physical characteristics, including udder, legs, feet and body frame. The fertility sub-index (PI_PŁOD) considers non-return rates in heifers and age at first insemination to improve reproductive performance. Somatic cells (WH_KSOM) evaluate the udder health (Olechnowicz *et al.*, 2016).

The production sub-index (PI_PROD) is computed by combining the breeding value for fat yield (kg) with twice the breeding value for protein yield (kg). The general conformation sub-index (PI_POKR) is constructed from several individual sub-indices, each assigned specific weights: 50% for the udder sub-index, 30% for the legs and feet sub-index, 10% for the milk strength sub-index and 10% for the body frame sub-index. The sub-indices for conformation traits are determined based on the estimated breeding values for the linear traits evaluated in the type and conformation assessment (Polish Federation of Cattle Breeders and Dairy Farmers, 2019). The composition of these sub-indices is as follows:

- Udder sub-index (35% – udder location, 18% – fore udder attachment, 15% – rear udder height, 10% – central ligament, 10% – rear udder width, 6% – rear teat position, 3% – front teat placement, 3% – teat length).
- Milkiness sub-index (50% – milk character, 25% – chest width, 15% – body depth, 10% – height at the back).
- Feet and legs sub-index (45% – foot angle, 35% – rear legs, rear view, 20% – rear legs, side view).
- Body frame sub-index (40% – rump angle, 25% – stature, 20% – rump width, 15% – chest width).

These individual sub-indices collectively contribute to the assessment of conformation traits within the breeding programme (Polish Federation of Cattle Breeders and Dairy Farmers, 2019).

The fertility sub-index (PI_PŁOD) is composed of four traits, each assigned specific weights: fertilization rate of heifers (70%), fertility rate of cows (10%), length of postpartum downtime (10%) and interpregnancy period (10%), which collectively aid in evaluating bull fertility (Siekierska, 2022). Assessing udder health, the somatic cell content (WH_KSOM) relies on individual test milking during the first three lactations, with a WH_KSOM score above 100 indicating an improvement in offspring udder health. Longevity

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(WH_DŁUG) measures an animal's lifespan by calculating the duration between first calving and culling (Hu *et al.*, 2023). It is estimated using the average breeding value of bulls born from 2009 to 2011, with at least a 50% assessment repeatability. The formula determines the breeding value for longevity:

$$\text{WH\_DŁUG} = 100 - 0.5 \times (\text{WH of father} - 100) + 0.25 \times (\text{WH of maternal grandfather} - 100)$$

The PF SI is instrumental in evaluating cows' breeding value, assisting in identifying potential breeding candidates and embryo donors, as well as guiding sire selection for the next generation (Kosińska-Selbi *et al.*, 2022). Fertility, a critical factor, affects milk production, cow longevity and culling rates, with factors like calving intervals and perinatal calf mortality playing significant roles (Mock *et al.*, 2020; Wrzecińska *et al.*, 2021; Lafontaine *et al.*, 2023). Functional traits, focusing on cow resilience and health, demand integration with breeding strategies (Brito *et al.*, 2021). Mastitis resistance, a key concern for cow health, productivity and management costs, involves somatic cell counts and conformation traits (Hufana-Duran and Duran, 2020; Hasan *et al.*, 2021; Zeng *et al.*, 2023).

Portugal

Portugal's Genetic Evaluation of Holstein Friesian cattle is conducted by two main institutions: the Research Centre in Biodiversity and Genetic Resources (CIBIO), responsible for assessing milk production parameters and somatic cell counts, and the Center for Animal and Veterinary Research (CECAV), which evaluates morphological parameters. These evaluations are based on data collected by the Regional Structures Supporting Dairy Cattle (ABLN and EABL), the farmer associations of the Autonomous Region of Azores, and the Portuguese Association of Breeders of the Frisian Breed (APCRF). The collected data are processed by the informatics department of the National Association for the Improvement of Dairy Cattle (ANABLE), and both data collection and processing adhere to ICAR (International Committee for Animal Recording) standards.

National genetic evaluations in Portugal commenced systematically in 2001, initially focusing on productive traits such as milk (kg), fat (kg and %), protein (kg and %), and somatic cell scores (SCC). With the implementation of the BOVINFOR database in 2009, evaluations expanded to include key conformation characteristics. Around 2011, Portugal introduced its first comprehensive SI, the M€T (total economic merit). This index amalgamates various genetic traits, including milk, fat, protein, somatic cell scores, foot and leg conformation, and mammary system and leg traits, into a single value. Economic weights assigned to each trait reflect estimated market value trends for the upcoming years.

M€T has the following weights (ANABLE, 2023):

$$\text{M€T} = 100 + 30 \times \left\{ \left[22 \times \left(0.4 \times \frac{\text{Milk}}{\text{SD}_{\text{Milk}}} + 0.1 \times \frac{\text{Fat}}{\text{SD}_{\text{Fat}}} + 0.5 \times \frac{\text{Prot}}{\text{SD}_{\text{Prot}}} \right) \right] + \left[1 \times \left(-1 * \frac{\text{SCS}}{\text{SD}_{\text{Scs}}} \right) \right] + 10 \times \left((0.38 \times \frac{\text{FL}}{\text{SD}_{\text{FL}}} + 0.62 \times \frac{\text{MS}}{\text{SD}_{\text{MS}}} \right) \right\}$$

Legend: Milk – Milk, Fat – Fat, Prot – Protein, SCC – Somatic cell score, FL – Foot and leg, MS – Mammary system.

Each trait's importance is represented by specific weights, and standard deviations standardize their contributions. The M€T index aims to maximize overall productivity and health while considering the variability of these traits within the population. Breeders utilize this index to make informed decisions about which cows to select for breeding, ultimately improving the performance of their herds (ANABLE, 2023).

Starting from 2020, the assessment of production characteristics (fat and protein), functional traits (somatic cells), conformation (mammary system, foot and legs, and strength), and reproductive traits (pregnancy rate, calving interval, and calving-1st artificial insemination interval) has been implemented using the IPT – total performance index SI. IPT aims to maximize animal productivity, positively influencing all these characteristics simultaneously. It serves as an additional tool to assist breeders in the complex task of selecting the genetic future of their farms.

Total performance index (ANABLE, 2023):

$$\begin{aligned} \text{IPT} &= 29.376 \times \left\{ \left[17.32 \times \left(0.57 \times \frac{\text{Fat}}{\text{SD}_{\text{Fat}}} + 0.43 \times \frac{\text{Prot}}{\text{SD}_{\text{Prot}}} \right) \right] \right. \\ &\quad + . \left[1 \times \left(-1 \times \frac{\text{Scs}}{\text{SD}_{\text{Scs}}} \right) \right] \\ &\quad + \left[10.76 \times \left(0.35 \times \frac{\text{PR}}{\text{SD}_{\text{Pr}}} - 0.17 \times \frac{\text{C1Ia}}{\text{SD}_{\text{C1Ia}}} - 0.48 \times \frac{\text{CI}}{\text{SD}_{\text{CI}}} \right) \right] \\ &\quad \left. + 4.29 \times \left(0.20 \times \frac{\text{FL}}{\text{SD}_{\text{FL}}} + 0.60 \times \frac{\text{MS}}{\text{SD}_{\text{Ms}}} + 0.20 \times \frac{\text{Str}}{\text{SD}_{\text{Str}}} \right) \right\} \end{aligned}$$

Legend: Fat – Fat, Prot – Protein, SCs – Somatic cell score, PR – Pregnancy rate, C1Ia – Calving 1st AI interval, CI – Calving interval, FL – Foot and leg, MS – Mammary system, Str – Strength.

The IPT formula amalgamates various trait components, each assigned specific weights and standard deviations. These weights and factors are typically influenced by the breeding programme's specific objectives and the relative importance of each trait in accomplishing those goals. Consequently, the resulting IPT value serves as a numerical indicator of the animal's comprehensive genetic merit, encompassing a spectrum of traits. In essence, the total performance index in Portugal is a mathematical equation that integrates multiple aspects to evaluate the genetic quality of dairy cattle. These aspects include production, health, reproduction and conformation traits. It is worth noting that the specific components and their associated weights within the formula can vary, contingent on the breeding programmes distinct objectives and priorities (ANABLE, 2023).

These two indices are available to all dairy breeders through the National Dairy Cattle Association (ANABLE, 2023). The emphasis on economic weights in the M€T index reflects the country's economic and market conditions, while the comprehensive nature of the IPT index indicates a legislative focus on animal welfare and productivity standards.

Ukraine

Historically, throughout the world, in breeding indices of the breeding value of animals, the main place was given to productivity traits. However, over the past 25 years, the number of 'non-productive' traits has increased as breeders consider the profits and costs associated with keeping and feeding animals. Northern European countries (Denmark, Sweden, Finland) were more forward-thinking than others and added health indicators to their screening programmes several decades ago, giving them an advantage over other countries (Cole and VanRaden, 2018).

Since the 1980s, the Ukrainian dairy cattle breeding system has been centred around the problem of assessing bulls, but this assessment is directly related to the offspring of bulls, including their daughters – dairy cows, based on selection indices. Breeding indices are an essential component of animal selection programmes. They help to combine information about different traits into a single indicator used to rank animals and obtain the information necessary for reproducing the herd. If at first the selection was carried out only on milk yield and the amount of milk fat, then by 2014 milk yield as such had practically lost its importance as a selection trait. Milk fat and protein, functional traits of livestock, as well as milk quality indicators received greater importance (Matvieiev and Getya, 2020).

The dairy cattle management system 'Orsek' (Orsek-SC Dairy Management System) has been introduced in Ukraine. Due to this system, an information database of bulls from breeding enterprises in Ukraine was created, including data on 47.5 thousand bulls. The determination of the breeding value of servicing bulls is carried out by an authorized breeding centre, namely the Institute of Animal Breeding and Genetics named after M.V. Zubets of the National Academy of Sciences of Ukraine, which in 2023 calculated selection indices for 1306 bulls, including the following breeds: 10 Ayrshire, 8 Angler, 18 Brown Carpathian, 1 Ukrainian brown dairy, 9 white-headed Ukrainian, 947 Holstein, 72 Jersey, 18 Montbeliarde, 78 Simmental, 38 Ukrainian Black-and-White Dairy, 32 Ukrainian Red-and-White Dairy, 8 Ukrainian Red Dairy, 5 Red Danish, 3 Red Steppe, 13 Lebedinskaya, 38 Brown Swiss, 2 Pinzgau and 6 others. Using the DMS 'Orsek-SC' method of estimated breeding value (EBV), 299 bulls were assessed and catalogued, including 180 by offspring, 119 by origin (Vdovychenko *et al.*, 2023).

The breeding value of bulls carrying recessive mutations causing lethal hereditary diseases (bovine leucocyte adhesive deficiency (BLAD), uridine monophosphate synthetase deficiency (DUMPS), complex vertebral defect (CVM), citrullinemia, factor X1 deficiency (FXID), cholesterol deficiency) is not determined. And bulls that have not passed a genetic examination of origin have a fertilizing capacity of sperm of less than 50% and quality indicators of sperm production that do not meet the requirements.

The selection of breeding animals is carried out according to SI:

$$CIj = \left(60\left(\frac{\boldsymbol{EBV}Fj}{\sigma F} + \frac{\boldsymbol{EBV}Pj}{\sigma P}\right) + 40\left(\frac{3\boldsymbol{EBV}Tj}{\sigma T} + \frac{4\boldsymbol{EBV}Uj}{\sigma U} + \frac{2\boldsymbol{EBV}Lj}{\sigma L} + \frac{\boldsymbol{EBV}BFj}{\sigma BF}\right)\right) \times 1.2$$

Legend: EBVFj, *EBVPj*, *EBVTj*, *EBVUj*, *EBVLj*, *EBVBFj* this is the estimated breeding value of the *j*-th animal according to milk fat (F), milk protein (P), according to the assessment of general type (T), udder (U), limbs and hooves (L), body format (BF), in units of measurement of the *i*-th trait of the *j*-th animal, calculated according to the formula, $EBV\ j = 2\ (\text{DP} + \text{AB})$, where *EBVj* is the estimated breeding value of the *j*-th bull based on the indicators of its daughters and peers; DP is the difference between the performance of daughters and peers; AB is the difference between the herd and breed averages.

$\sigma_F, \cdot\sigma_P, \sigma_T, \sigma_U, \sigma_L, \sigma_{BF}$ – standard deviation for these characteristics (SD).

Based on the results of this assessment, bulls are assigned a category of breeding value according to the SI (*CIj*):

I5 – improver 'excellent' (rank 95…99%);

I4 – improver 'good' (rank 75…94%);

I3 – improver 'satisfactory' (rank 65…74%);

N + – neutral plus (rank 50…64%); N– – neutral 'minus' (rank 35…49%);

D – deteriorator (rank 1…34%).

In Ukraine, in the future, the assessment of breeding bulls will be based on the materials of the information database of state books of breeding animals, which continues to be created. The methodology involves a phased transition to the animal assessment system according to the BLUP Animal model as such a database is created. This phased approach reflects the country's legislative and technological development, adapting best practices from other nations while considering local conditions.

Ukraine is traditionally characterized by the development of industrial dairy farming. Reducing the productive longevity of dairy cows is a significant problem under conditions of intensive exploitation and technological stress (Milostiviy *et al.*, 2017). Therefore, breeding dairy cattle to increase productive longevity and assessing bulls for stress resistance may be included in breeding indices in the near future (Bordunova *et al.*, 2022).

Selection is closely related to the profitability of milk production and, accordingly, to the formation of prices for it. On the one hand, the efficiency of milk production directly depends on the level of cow productivity, which cannot be increased without an effective breeding system. On the other, the mechanism for setting the price of milk has a direct impact on the composition of the selection indices by which bulls and cows are assessed and selected, as well as on the economic weights of the traits involved in them.

Considering the temporary lack of government orders and subsidies for the volume of products produced, control of prices for products and energy resources, it is still impossible to fully use foreign calculation methodology and the use of the main criteria of the selection process (Goncharenko, 2016).

The use of breeding value indices taking into account economic weights in countries with developed cattle breeding has become an integral element of milk production. This experience is gradually gaining popularity in the breeding work of Ukrainian farms, since breeders understand that the selection of breeding animals only for productive traits, without taking into account their economic significance, affects the objectivity of the results of breeding decisions (Matvieiev and Getya, 2020).

The similarities and differences between cattle breeding in these three countries are presented in Table 1.

Conclusion

In conclusion, selection indices act as a guiding compass for dairy farming strategies across different countries, each with its distinct

Table 1. Similarities and differences between three cattle selective indexes

Aspect	Poland	Portugal	Ukraine
Index name	PF (production and functionality)	M€T (total economic merit), IPT (total performance index)	CIj (Селекційний індекс, SI)
Introduction year	2007	M€T: 2011, IPT: 2020	1980s
Primary components	Production (fat, protein), conformation (feet and legs), fertility, somatic cells, longevity	Milk, fat, protein, somatic cell scores, foot and leg, mammary system, strength, reproductive traits	Milk fat, milk protein, general type, udder, limbs and hooves, body format
Historical revisions	2010 (fertility), 2012 (conformation), 2014 (overall adjustments, including longevity)	2009 (expanded evaluations by conformation), 2020 (IPT introduced)	Shift from milk yield to broader traits by 2014, recent focus on developing comprehensive indices (functional traits, milk quality)
Economic considerations	Focuses on overall breeding efficiency and productivity	Explicitly includes economic weights, reflecting market trends	Increasing focus on economic significance, evolving practical implementation
Standardization	PF index standardized with average value of 100 and standard deviation of 10	Traits weighted and standardized, contributing to overall productivity and health	CIj index standardized, bulls categorized based on breeding value
Functional traits	Somatic cells, longevity	Somatic cell scores, foot and leg, mammary system, strength	Somatic cells, stress resistance to be included in future indices
Implementation	Focus on identifying individuals with highest breeding value	Utilizes BOVINFOR database, indices available through National Dairy Cattle Association	Orsek-SC system, the Institute of Animal Breeding and Genetics named after M.V. Zubets of the National Academy of Sciences of Ukraine
Focus on milk components	Production sub-index combines fat and protein yield	Milk, fat, protein included in both M €T and IPT indices	Milk fat, milk protein emphasized
Legislative framework	Governed by Polish Federation of Cattle Breeders and Dairy Farmers	Adheres to ICAR standards, national regulations through ANABLE	National Academy of Sciences oversees, evolving legislative support for breeding programmes
Data processing	Conducted by Polish Federation of Cattle Breeders and Dairy Farmers	Conducted by CIBIO, CECAV, processed by ANABLE, adhering to ICAR standards	Orsek-SC Dairy Management System, Institute of Animal Breeding and Genetics
Breeding objectives	Improve milk production, conformation, fertility, health and longevity	Maximize overall productivity, health and economic value	Enhance milk fat and protein, overall health and resilience

objectives and circumstances. These indices encapsulate the influence of economic and environmental factors, enabling breeders to tailor genetic selection to meet their region's specific needs. The weighting of individual traits within these indices forms the foundation of this process, signifying the traits' significance and aligning with each country's economic priorities. These indices underscore the importance of functional traits and ecological considerations in cattle breeding, playing a crucial role in achieving breeding goals and addressing the dairy industry's challenges posed by a burgeoning global population and evolving consumer preferences.

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