Calculation of Economic Weights for Optimization of Breeding Programs in Dairy Farming of Ukraine

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Summary

The effectiveness of dairy cattle husbandry depends on different factors. All farmers understand the importance of housing conditions and balanced feeding. But in modern agriculture, especially dairy cattle breeding with a high level of competition, the optimization of breeding programs also belongs to important measures which ensure the attractiveness of the branch. Economic weights for selection traits are used to adapt the breeding programs to market conditions. Currently, there are no reasonable economic weights applied for the Ukrainian market, and therefore the purpose of this work was to calculate the economic weights for important selection traits of dairy cattle. The study was conducted on Holstein cows. The main criterion for calculating of economic weights was the annual gross margin from breeding cows. The economic weights were calculated by multiple regression analysis. As a result of calculations, it was established that the economic weight for the trait "protein yield for 305 days of lactation" was 8.27 USD, for the trait "fat yield for 305 days of lactation" was 2.45 USD, for the trait "milk yield for 305 days of lactation" was 0.10 USD, for SCS was -21.39 USD, and for the length of lactation it was -3.51 USD (the average currency rate in the year 2019). It is proposed to apply the calculated economic weights for balancing of selection indexes during the organization of breeding work in Ukraine.

Key words

economic weights, breeding, gross margin, regression analysis, Holstein breed

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Introduction

Development of all economically important traits of dairy cattle occurs under the influence of both, genetic and environmental factors (Brotherstone and Goddard, 2005). Significant improvements in housing conditions have undoubtedly helped to increase the productivity of modern animals, but at the same time, the improvement of livestock by various genetic methods still belongs to significant driving force for improving of efficiency of milk production.

Further increase of the genetic potential of animals is possible only based on the processing of different individual data on cattle productivity (Wiggans, 1991; Brotherstone and Goddard, 2005) collected within existing breed improvement programs, thus allowing for monitoring and improving of economically valuable traits of animals (Lopez-Villalobos and Garrick, 2005). Improvement programs are used in beekeeping (Petersen et al., 2020), goat breeding and sheep breeding (Barillet, 2007), rabbit breeding (Ács et al., 2018), pig breeding (Ibeagha-Awemu et al., 2015), beef cattle breeding (Jonas and Koning, 2015) and dairy cattle breeding (Bouquet and Juga, 2012).

These programs are based on various mathematical models that combine different selection traits to determine the integrated breeding value of animals (Cole et al., 2020). This approach allows combining population-genetic characteristics of breeding traits and their economic significance in the form of economic weights (VanRaden, 2004). Different indexes have different weights for traits (Byrne et al., 2016; Cervo et al., 2017) depending on the purpose of breeding animals (Matvieiev and Getya, 2020). Some models are more focused on animal conformations (eg height, width), others focus on productivity (milk yield, milk fat, and protein yield), while others focus on health traits (resistance to udder and hoof diseases) (Egger-Danner et al., 2014). It should be noted that estimation of the breeding value of animals using indexes can be made correctly only for those economic conditions under which the animals are planned to be used (Yokoo et al., 2019). Since market situation is different in different regions, the choice of traits and their economic evaluation may also differ significantly between regions (Kargo et al., 2014). That is why the selection of breeding traits and calculation of their economic evaluation is a creative process that requires constant monitoring and updating in accordance with the market situation, which explains the constant increase in the number of selection traits in dairy farming (Miglior et al., 2017). Because of different reasons economic weights were neither calculated nor used in Ukrainian breeding practice.

It is generally accepted that the economic value of a trait is defined as the change in profit from the genetic improvement of the trait per unit (Groen, 1989; Krupová et al., 2008). Various methods of calculation of economic weights are used in the world: calculating of partial derivative of the profit function in relation to the selection trait (Sadeghi-Sefidmazgi et al., 2012), forming of bioeconomic models (BEM) (Wolfova´ et al., 2007; Komlósi et al., 2010; Hietala et al., 2014; Krupová et al., 2016), or forming bioeconomic models (BEM) using cluster analysis (Cervo, et al., 2017; Yokoo et al., 2019), and also stochastic modeling of economic values of productive and functional traits and their standard deviations (Hanne Marie Nielsen et al., 2004). They all have both advantages and disadvantages.

Work on genetic improvement of cattle has also been carried out in Ukraine, although not by considering individual productivity of cows, but through the control of the admission of foreign bulls to reproduction based on their calculated breeding index. Although a significant number of farmers make records of the dairy productivity of cows, due to the lack of reasonably calculated economic weights for the traits of dairy productivity, these data cannot be used for breeding and for re-calculation of indexes under Ukrainian conditions. In fact, the breeding bulls cannot be evaluated using local Ukrainian milk recording data.

The purpose of this work was to calculate the economic weights for productive dairy traits under the modern market conditions in Ukraine.

Material and Methods

Database Structure

The study was conducted on the farm in the southeast part of Ukraine on Holstein cows which had milk records for 305 days of lactation (milk yield, fat content, protein content) for the first three lactations. The animals were kept free with the same type of total mixed ration during the year, milking in a herringbone milking parlour. Calving took place evenly throughout the year.

Economic data and data on the productivity of cows of the first, second and third lactations were used for the study. The number of cows of the first, second, and third lactations was 101, 83, and 39, respectively.

Involved Traits

The samples of milk were taken monthly during control milking, the frequency of milking was 2 times a day (Selection scheme BP44, 2x) (ICAR, 2017). To do this, milk meters were used. The milk from milk meters was poured into special tubes (Volume 40 ml) in which the preservative Broad Spectrum Microtabs II (active ingredient Broad Spectrum Microtabs II) was previously placed. The analysis of milk, collected on the farm, was performed in the special laboratory (DairySpec FT User Manual, 2015). The laboratory determined the content of fat (%), protein (%), the number of somatic cells (thousand/cm^3).

The milk yields for control milking were determined under the conditions of the farm. The yield of milk fat and protein was calculated (ICAR, 2020).

To calculate the somatic cell score (SCS) in points the following formula (Wiggans and Shook, 1987) was used:

$$SCS = \log_2(SCC/100) + 3$$

where SCC is units of cells mL^{-1}

The analysis of variance of the effect of SCS (fixed factor) on gross margin was performed.

Economic Calculations (Calculation of Gross Margin)

A methodology developed by Weihenstephan-Triesdorf University (IMA MOOC, 2019) was used to calculate gross margin:

Gross Margin = Output (production) – Proportional variable costs (supplies & services).

The gross margin shows the amount of money per cow and year for covering the costs for all still remaining available factors.

The gross margin was calculated individually for each cow. For all animals (regardless the age of cows) was used the same value for longevity, live weight of cows, the percentage of herd replacement, which were all equal to the average in the herd. In addition, all variable cost values used in the calculation of gross margin were the same for all cows in the herd.

A special formula, recommended by the Ministry of Agriculture of Ukraine was used to calculate basic sale price (Order of the Ministry, 2004).

During the period of research realization, different prices were registered. For calculation of gross margin, the basic on-farm milk price at the level of the average price for one year was chosen, which was equal to 0.39 USD kg^{-1} of milk.

The costs of distributing feed, manure removal, and repair of equipment involved were not considered. The gross margin was determined only for those cows that completed lactation with a duration of at least 240 days, so the cows that had a shorter length of lactation were not considered.

Calculation of Economic Weights

The calculation was performed using the following multiple regression model

$$Y=a+\beta_1 x_1+\beta_2 x_2+\beta_3 x_3+\beta_4 x_4+\beta_5 x_5+\varepsilon$$

where Y is annual gross margin, a – regression constant, β_1, β_2, β_3, β_4, β_5 – regression coefficient for milk yield for 305 days of lactation, fat yield for 305 days of lactation, protein yield for 305 days of lactation, SCS for 305 days of lactation, and length of lactation responsively, x_1, x_2, x_3, x_4, x_5 – observed variables and ε – residual error.

Lactation length was used instead of calving interval because these traits have high significant correlations of 0.916 ($P \leq 0.01$). Calculations were performed for each lactation separately.

Results and Discussion

After the analysis of results obtained from cows of three lactations (Table 1.), it can be noted that the milk yield of the cows in the third lactation was highly significantly different ($P \leq 0.001$) from the cows in first and second lactations for about 1712.17 and 284.32 kg respectively. Other milk productivity traits were also the lowest in the first lactation. In particular, the fat yield in the first lactation was highly significantly lower ($P \leq 0.001$) compared to the second and third lactations by 83.35 and 99.14 kg respectively. A similar trend was detected for protein yield. The average SCS in the milk of all cows in the first lactation was the lowest – 2.11 points. SCS in the milk of second and third lactations was higher ($P \leq 0.001$) by 0.39 and 1.06 points respectively. Such an increase of somatic cells after the first calving was reported by Kul et al., 2019, and indicated an increase in daily milk yield and a simultaneous increase in the number of somatic cells in cows in the second and third lactations compared to the primiparous. These results also coincide with the data of other researchers; as the milk productivity of cows increases with age, so does the number of somatic cells, too. In the study of Zhao et al., 2015 the cows of the Holstein breed in the second parity had the highest milk yield compared to the cows in the first and third lactations, but the cows in the third lactation had the highest average somatic cell count.

The length of the first lactation in the study was shorter by 14.5 and 18.84 days than the 2nd and 3rd lactations, respectively.

The low milk productivity of cows in the first lactation resulted in a negative gross margin from their breeding: the lowest gross margin of -288.50 USD was obtained from cows in the first lactation, so the breeding, based on results of the first lactation, was not effective. The most profitable were the animals in the third lactation, where the average gross margin from the breeding was by 508.48 and by 8.76 USD significantly higher ($P \leq 0.001$) than from the cows in first and second lactation.

Despite the highest gross margin obtained in the third lactation, it was decided to analyze more deeply the results after the 2nd lactation as well as to calculate economic weights based on the results of the second lactation, because as a rule, the breeders use the data of the second lactation for breeding purposes.

In Ukraine, as a criterion for culling of cows the milk yield per lactation is usually used. Obtained data showed that milk productivity of cows in the herd in the 2nd lactation was not homogenous and could be improved through targeted breeding.

Table 1. Productivity of cows of different lactations (Mean ± SE)

Trait	1st lactation, n =101	2nd lactation, n =83	3rd lactation, n=39
Length of lactation, days	398.49 ± 11.89	412.98 ± 13.20	417.74 ± 23.06
Milk yield for 305 days of lactation, kg	7099.78 ± 128.0^{a}	8527.63 ± 158.55^{b}	8811.95 ± 231.28^{b}
Fat yield for 305 days of lactation, kg	259.27 ± 2.49^{a}	342.62 ± 6.17^{b}	358.41 ± 11.57^{b}
Protein yield for 305 days of lactation, kg	200.65 ± 1.40^{a}	272.45 ± 4.67^{b}	279.11 ± 8.04^{b}
Somatic cell score (SCS) for 305 days of lactation, points	2.11 ± 0.12^{a}	2.50 ± 0.13^{c}	3.17 ± 0.23^{b}
Gross margin, USD	-288.50 ± 59.38^{a}	211.22 ± 76.63^{b}	219.98 ± 135.68^{b}

Note:
different letters ^{ab} within a row indicate significant difference at level 0.1%
different letters ^{bc} within a row indicate significant difference at level 5%

In the practical work, up to 25% of the population should annually be replaced with young animals, so the comparison of 25 % of best and worst cows according to the results after the 2nd lactation was performed. As it can be seen from Table 2, the productivity traits for 25% of the best animals significantly ($P \leq 0.001$) differed from the productivity of 25% of the worst animals. The best animals had significantly higher ($P \leq 0.001$) milk yields for 305 days of lactation by 2941.6 kg, fat yield by 90.5 kg, and protein yield by 79.2 kg compared with the worst 25% cows. It should be noted that the somatic cells score in the milk of more productive cows was by 0.13 points less than in the milk of the low productive group (differences are not significant). It means that within the same lactation high productive cows have lower somatic cells score.

At the same time, as the breeding criterion, the individual gross margin of cows can be taken. It was found that gross margin also varied significantly. In particular, the best 25% animals on their gross margin, had significantly higher ($P \leq 0.001$) milk yield by 2151 kg compared with the worst 25% animals (Table 3). The best animals had a significantly higher ($P \leq 0.001$) yield of fat and protein by 99.8 and 69.7 kg respectively. At the same time animals with a higher gross margin had a lower SCS by 0.55 points. Although the calculations of the SCS were not directly considered for the calculation of gross margin, it is obvious that due to the impact on milk quality, such a relationship exists.

However, it was not conformed using correlation analysis, as the relationship between somatic cell score and gross margin, calculated separately for the first, second, and third lactations, was not significant. The analysis of variance components showed that the influence of the factor "somatic cells score" of cows on the 2nd and 3rd lactations on the gross margin was not significant.

It is clear that for the improvement of the effectiveness of dairy cattle production it is necessary to perform intensive breeding of cows. The main question is; what criteria are to be chosen for breeding? Obviously, the culling of cows just on the basis of measurable natural values (milk, protein, and fat yield), does not influence directly the increase of profitability of production. Much more important for the economic profitability of milk production is the impact of breeding on gross margin. Understanding this, the calculation of gross margin in relation to changes in productivity was performed. Obtained after such calculation, values reflected monetary estimation of the changing of productivity per unit and could be considered as an economic weight for use in the selection index.

As the tool for this calculation, a multiple regression analysis of various traits of productivity on the annual gross margin of milk production was chosen, which revealed that the regression coefficient for the trait "protein yield for 305 days of lactation" was the highest and equal to 8.27 USD, for the trait "fat yield for 305 days of lactation" it was 2.45 USD. The regression coefficient for the trait of "milk yield for 305 days of lactation" was the lowest – 0.10 USD. (Table 4).

The fact that under the current market conditions of Ukraine, the economic significance of the yield of protein and fat for the economy of milk production is much more important than the milk yield was well known (Getya et al., 2017), but exact calculated figures were not presented before. Such balance between importance of traits is typical not only for Ukraine but observed by other researchers in different countries (Byrne et al., 2016; Komlósi et al., 2010).

A similar situation is reflected in breeding indexes of different countries but in different ratios. In the Nordic Total Merit Index for the Holstein breed, the ratio between the economic value of fat, protein, and milk yield is 1.28; 4.6; -0.030. A similar trend (the most expensive protein and fat) is observed in other countries where dairy products are traditionally consumed (Denmark, Finland, and Sweden), but the absolute values for each trait are slightly different (Kargo et al., 2014). In contrast, in southern countries such as Iran, the ratio is 1.36; -1.02; 0.15 USD, respectively, which can be explained by the lack of market demand for protein in these countries (Sadeghi-Sefidmazgi et al., 2012).

Table 2. Productivity of 25% best and 25% worst cows of herd in 2nd lactation (ranged for milk yield) (Mean ± SE), n=21

Trait	Milk yield for 305 days of lactation (kg)	Fat yield for 305 days of lactation (kg)	Protein yield for 305 days of lactation (kg)	SCS for 305 days of lactation, point
25% the best cows on milk yield	9770.62 ± 226.29[a]	379.75 ± 8.50[a]	304.07 ± 6.56[a]	2.36 ± 0.26
25 % the worst cows on milk yield	6829.00 ± 235.72[b]	289.23 ± 10.98[b]	224.92 ± 7.95[b]	2.49 ± 0.24

Note: different letters [ab] within a column indicate significant difference at level 0.1%

Table 3. Productivity of 25% of the best and 25% of the worst cows on gross margin in 2nd lactation (ranged for gross margin) (Mean ± SE), n=21

Trait	Milk yield for 305 days of lactation (kg)	Fat yield for 305 days of lactation (kg)	Protein yield for 305 days of lactation (kg)	SCS for 305 days of lactation, point	Length of lactation (Days)
25% the best cows on gross margin	9330.67 ± 197.62[a]	386.4 ± 8.12[a]	301.7 ± 4.41[a]	2.34 ± 0.292	350 ± 10.7[a]
25% the worst cows on gross margin	7179.29 ± 302.07[b]	286.6 ± 12.03[b]	232.04 ± 9.88[b]	2.89 ± 0.247	455 ± 28.5[c]

Note:
different letters [ab] within a column indicate significant difference at level 0.1%
different letters [ac] within a column indicate significant difference at level 5%

Table 4. Coefficients of regression of dairy productivity and functional traits on the annual gross margin from milk production of cows of 2nd lactation

Trait	Coefficients of regression
Length of lactation, days	-3.51***
Milk yield per 305 days, kg	0.10
Fat yield for 305 days of lactation, kg	2.45*
Protein yield for 305 days of lactation, kg	8.27***
SCS for 305 days of lactation, point	-21.39

Note: **P* ≤ 0.05, ****P* ≤ 0.001

As for Ukraine, the country is oriented to the EU and North American markets and obtains genetic material from these regions. So, the calculated economic weight will help breeders to improve national breeding programs according to modern trends.

Conclusions

Based on the result of the research, it can be concluded:

1. To maximize gross margin it is needed to have a balanced herd structure, combining cows with first lactation and older lactating animals, because older lactating cows bring a higher gross margin.
2. The coefficient of multiple regression of each trait on the annual gross margin can be taken as the economic weight of the selection traits.
3. The economic weight for the trait "protein yield for 305 days of lactation" was the highest and amounted to 8.27 USD, while for the trait "fat yield for 305 days of lactation " was 2.45 USD. The economic weight for the trait "milk yield for 305 days of lactation" was the lowest, only 0.10 USD.
4. The economic weight for SCS and length of lactation were negative and were equal to 21.39 USD and 3.51 USD correspondently.

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