STUDY REGARDING GENETIC CORRELATIONS BETWEEN MILK PRODUCTION TRAITS FOR HOLSTEIN POPULATION FROM IAȘI

M. Ivancia[1], A. Șerban[1], A. Ciobanu[1*], N. Roșca[1]

[1]*Faculty of Food and Animal Sciences, Iasi University of Life Sciences, Romania*

Abstract

Correlations between milk production traits play an important role in animal breeding. This study aimed to estimate the correlations between milk yield, fat yield, protein yield, fat percentage, and protein percentage in the dairy cattle population from Romania. Data from 121 Holstein cows during their first lactation were collected. These cows are descendants of 1 bull of the pure breed. The Test Interval Method was used to calculate milk yields, and ANOVA was employed to estimate correlations. The results showed strong positive correlations between milk yield and fat yield, as well as between milk yield and protein yield. A strong positive correlation was also found between fat yield and protein yield. Negative correlations were observed between milk yield and fat percentage, as well as between milk yield and protein percentage. Additionally, a strong positive correlation was identified between fat percentage and protein percentage. These findings provide valuable insights for optimizing breeding programs, improving milk productivity and quality, and guiding selection strategies in the Romanian dairy cattle industry. Further research is recommended to explore additional traits and underlying genetic mechanisms in dairy cattle populations.

Key words: *dairy cattle, milk yeild, fat, protein*

INTRODUCTION

Breeding plans, within the context of genetics and animal husbandry, include a systematic approach aimed at enhancing desired traits in a population through controlled mating strategies. These plans are devised based on the principles of heredity and the understanding of genetic variation within a species. The importance of breeding plans lies in their ability to optimize and accelerate the genetic progress of a population, ultimately leading to the production of improved individuals and subsequent generations. By selectively pairing individuals with desirable traits, such as increased productivity, disease resistance, or specific phenotypic characteristics, breeders can increase the frequency of these traits in subsequent generations. This process, known as selective breeding, exploits the phenomenon of genetic correlation, wherein the presence of one trait is associated with the presence of another. Genetic correlations are important in breeding plans, as they enable breeders to indirectly improve multiple traits simultaneously. For example, selecting for higher milk production in dairy cattle may also result in improved udder conformation and fertility. Breeding plans provide a strategic framework for optimizing genetic gain and achieving desired breeding goals in a scientifically informed, objective, and impersonal manner, by understanding and utilizing these correlations. [1, 2, 3]

In the field of animal science and dairy production, the significance of cow milk and its genetic correlation with milk yield, protein yield, fat yield, protein percentage, and fat percentage has been extensively studied. Cow milk contains essential

*Corresponding author: andrei.ciobanu9608@gmail.com
The manuscript was received: 05.10.2023
Accepted for publication: 30.10.2023

nutrients such as proteins, fats, vitamins, and minerals that are required for human nutrition [4]. Milk yield, protein yield, fat yield, protein percentage, and fat percentage are all important parameters in determining milk quality and quantity. Because these traits are heritable and subject to selective breeding, genetic factors play an important role in shaping them. Understanding the genetic relationship between these traits allows for the development of breeding strategies to improve milk production efficiency and composition [5, 6]. Dairy farmers can optimize their production systems, improve overall herd productivity, and meet the growing demands of the dairy industry by identifying and selecting cows with desirable genetic traits such as high milk yield, elevated protein and fat yields, and optimal protein and fat percentages. As a result, studying the genetic correlations of these traits in cow milk advances scientific knowledge and facilitates the development of sustainable and efficient dairy production practices. In other words, having a very important positive economic impact by the variety of the valuable products obtained from milk such as cheese, butter, cream, etc.

The study of correlations between milk production traits is of great significance in the field of animal breeding, as it provides valuable insights into the interrelationships among various quantitative characters. About 155 years ago, Charles Darwin highlighted the existence of correlations between different traits, emphasizing that the development of one character can influence the development of another character in a positive or negative manner (Darwin, 1859, citat de [3]. This insight underscores the importance of estimating correlations in practical animal breeding.

In the specific context of dairy cattle populations, understanding the correlations between milk production traits plays an important role in optimizing breeding programs and improving overall herd performance. Milk yield, fat yield, and protein yield are key traits that directly impact the profitability and productivity of dairy herds. Estimating the correlations between these traits provides valuable information about their simultaneous development and potential trade-offs.

Previous studies have contributed to our understanding of the correlations in dairy cattle populations [7, 8, 9]. Notably, researchers have reported a strong positive correlation between milk yield and fat yield, suggesting that an increase in milk production is generally accompanied by a corresponding increase in fat production [10]. Similarly, there is a positive correlation between milk yield and protein yield, suggesting that higher milk production is associated with an increase in protein content. [11].

Furthermore, investigations have focused on the correlations between milk yield and the fat or protein percentage. Studies have revealed a negative correlation between milk yield and fat percentage, indicating that cows with higher milk production tend to have a lower fat percentage [12, 13, 14, 3]. Additionally, a negative correlation has been observed between milk yield and protein percentage, suggesting that increased milk production is associated with a decrease in protein percentage [12, 13, 14, 3].

Considering the importance of correlations in dairy cattle populations, it becomes evident that estimating the relationships between milk production traits is an essential step in cattle breeding practices [15]. Therefore, the aim of this research is to estimate the correlations between milk yield, fat yield, protein yield, as well as between milk yield and the fat or protein percentage specifically for the dairy cattle population from Iași, Romania. By doing so, this study helps to provide valuable insights into the interrelationships of these traits within the Romanian dairy industry. The findings contribute to the development of more effective breeding programs and the enhancement of productivity in dairy cattle populations.

MATERIAL AND METHOD

The information for this study was gathered from the first lactation of 121 Holstein cows, allocated in 11 farms, all offspring of 1 bull of the identical breed (table 1). These cows are recorded with an association of Holstein breeders and reside on a dairy farm situated in Iași county, Romania.

Table 1 Descriptive statistics for milk yield obtained from daughters of the bull

Traits	n daughters	$\bar{x} \pm s\bar{x}$	v%	max	min
Milk yield (kg)	121	8668.86 ± 182.4	23.15	13783	3776
Fat (kg)	121	363.52 ± 7.82	23.67	664.38	174.94
Fat (%)	121	4.23 ± 0.05	14.17	5.81	2.66
Protein (kg)	121	278.59 ± 5.8	22.93	430.24	122.26
Protein (%)	121	3.22 ± 0.02	8.13	3.95	2.53

The data were collected from Holstein Ro association. The dataset incorporated monthly test-day observations, comprising measurements such as milk production, fat production, and protein production, from cows that gave birth over the span of a three-year study period.

The traits considered in the analysis were the 305-day first lactation milk yield (MY), 305-day fat yield (FY), 305-day protein yield (PY), all measured in kilograms, and the 305-day fat percentage (F%) and protein percentage (P%). Test-day milk yields were recorded from each individual cow once a month during one of three milking times per day, starting from the time of calving until the cow's dry off. Monthly milk samples were collected and sent to the laboratory of the Holstein Ro Organisation for the determination of the three traits for each given month.

The collected data underwent necessary editing to obtain appropriate results for statistical analyses. Using the Test Interval Method proposed by Sargent (1968) and described in the ICAR Guidelines (2022), the monthly test-day milk yields were utilized to calculate the 305-day milk yields. The Test Interval Method accounts for variations in the test intervals, ensuring accurate estimation of the overall milk yield for the entire lactation period [16, 17].

The primary goal of the statistical analysis was the estimation of correlations between the milk production traits. To achieve this, the ANOVA (Analysis of Variance) approach was employed. ANOVA allows for the decomposition of the total variation observed in the data into its various components, including the genetic component that contributes to the correlations between traits. By using ANOVA, the correlations between milk yield, fat yield, and protein yield were estimated [18, 19].

To estimate the genetic correlations between traits, the formula apllied was:

$$\mathbf{r_e} = \frac{\mathbf{Cov(X_1,X_2)}}{\sqrt{\mathbf{[Var(X_1)\times Var(X_2)]}}}, \text{ where}$$

- r_e represents the genetic correlation between two traits,
- $Cov(X_1, X_2)$ represents the covariance of the genetic values for traits 1 and 2,
- $Var(X_1)$ represents the genetic variance for trait 1, and

- $Var(X_2)$ represents the genetic variance for trait 2.
- X represents the genetic values for each respective trait.

These formulas allow for the estimation of genetic correlations between milk yield, fat yield, protein yield, fat percentage, and protein percentage using the general notation X [3].

Additionally, the standard error was calculated for each case to provide an understanding of the variability within the traits and to assess the precision of the estimated genetic correlations [20]:

$$SE(r_e)=\sqrt{\frac{1-r_e^2}{n-2}}$$

For each specific case with traits represented by X, the formulas for standard error can be adapted accordingly:

$$SE(r_e(X_1,X_2))=\sqrt{\frac{1-r_e^2(X_1,X_2)}{n(X_1,X_2)-2}}$$, where:

- r_e represents the genetic correlation and
- n represents the sample size (number of observations) for each respective trait combination represented by X [19].

The Test Interval Method by Sargent (1968) was chosen as the preferred methodology for calculating milk yields. This method considers the variations in test intervals, which commonly occur in practical dairy farming. It ensures reliable data for subsequent genetic correlation estimation, by accurately estimating the overall milk yield for the 305-day lactation period [21].

The ANOVA approach was selected for estimating the correlations between milk production traits due to its robustness, statistical rigor, and wide applicability. ANOVA enables the decomposition of variation, facilitating the identification and estimation of genetic components contributing to the correlations between traits. This established methodology has been extensively used in animal breeding studies, providing reliable and interpretable results [18, 22].

This study contributes to providing accurate estimates of correlations between milk production traits for the dairy cattle population from Romania, by employing the Test Interval Method and ANOVA. This methodology ensures the reliability and validity of the obtained results and supports the advancement of breeding strategies for improved productivity and genetic selection.

RESULTS

In the conducted research, the primary objective was to calculate and evaluate the correlations among milk production characteristics in the Holstein cow population from a dairy farm from Iași county in Romania. These traits included the 305-day first lactation milk yield (MY), 305-day fat yield (FY), 305-day protein yield (PY), as well as the 305-day fat percentage (F%) and protein percentage (P%). The sample data were extracted from a pool of 104 Holstein cows, which provided substantial empirical evidence to illuminate the interdependencies among these important traits. The obtained insights have profound ramifications for devising effective cattle breeding strategies (figure 1).

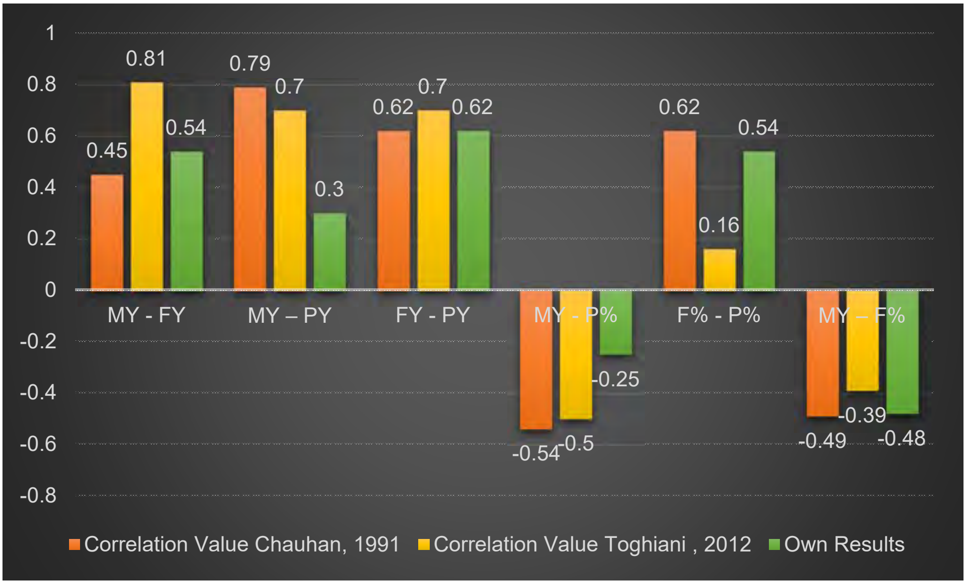

Fig. 1 Comparative Analysis of Genetic Correlation Values for Key Dairy Production Traits

Correlations between Milk Production Traits

The correlation between milk yield and fat yield was found to be strong, with a value of 0.54. This indicates a positive relationship between the two traits, suggesting that an increase in milk yield tends to be accompanied by a corresponding increase in fat yield. This information is valuable for dairy farmers and breeders, enabling informed decision-making in selecting animals for improved milk productivity (table 2).

The correlation between milk yield and protein yield was estimated to be 0.3. While this correlation is positive, it is relatively weaker compared to the correlation between milk yield and fat yield. This suggests that the increase in milk yield may have a less pronounced effect on protein yield compared to its effect on fat yield. (table 2).

The correlation between fat yield and protein yield was calculated to be 0.62, indicating a strong positive correlation between these traits. This implies that an increase in fat yield is typically associated with a simultaneous increase in protein yield. Understanding this relationship allows for targeted breeding strategies to enhance overall milk composition (table 2).

Table 2 Correlations between Milk Production Traits

Traits Correlated	Chauhan, 1991	Toghiani, 2012	**Own results**
MY – FY	0.45	0.81	**0.54**
MY – PY	0.79	0.7	**0.3**
FY – PY	0.62	0.7	**0.62**

Correlations between Milk Yield and Percentage Traits

The correlation between *milk yield and fat percentage* was estimated to be -0.48. This negative correlation suggests that cows with higher milk production tend to have a lower fat percentage. As milk yield increases, there is a tendency for the fat percentage to decrease. These findings suggest that higher milk production is associated with lower fat and protein percentages. Dairy farmers and processors can utilize this information to optimize milk quality and develop strategies to maintain desirable fat and protein levels in their products (table 3).

The correlation between *milk yield and protein percentage* was found to be -0.25. Similar to the correlation between milk yield and fat percentage, this negative correlation indicates that higher milk production is associated with a lower protein percentage (table 3).

The correlation between *fat percentage and protein percentage* was determined to be 0.54, representing a strong positive correlation. This indicates that cows with a higher fat percentage tend to also have a higher protein percentage. This reinforces the genetic link between these traits and emphasizes the importance of considering both characteristics in breeding programs aimed at enhancing milk composition (table 3).

Table 3 Correlations between Milk Yield and Percentage Traits

Traits Correlated	Chauhan, 1991	Toghiani, 2012	**Own results**
MY – F%	-0.49	-0.39	**-0.48**
MY – P%	-0.54	-0.5	**-0.25**
F% - P%	0.62	0.16	**0.54**

While higher milk yield is correlated with greater fat and protein yield, it is important to note that it does not guarantee a proportionate increase in the fat and protein percentage of the milk. The dilution effect comes into play, suggesting that solely breeding for higher milk yield may not be sufficient to improve milk quality in terms of fat and protein content. Therefore, it is important to consider both yield and composition traits in genetic selection to maintain an optimal balance between quantity and quality.

Future research could delve deeper into the genetic basis of these correlations through Genome-Wide Association Studies (GWAS) to identify specific genes influencing these traits, providing a more detailed understanding of the underlying biological mechanisms. Additionally, expanding the study to include other factors such as cow's age, breed, feeding regimen, and environmental conditions would be beneficial in isolating genetic effects from environmental influences and providing a comprehensive understanding of the factors contributing to milk yield and composition.

Investigating potential trade-offs between these traits and understanding the limits of increasing milk yield without negatively impacting fat and protein percentages is another area for future research. This knowledge would aid in making informed decisions in breeding programs.

Longitudinal studies tracking changes in these correlations over time would also be valuable to observe how relationships evolve with changes in breeding strategies, technological advancements, and shifts in industry practices.

The insights gained from this study serve as a foundation for future research directions, promising to enhance our understanding of dairy cattle genetics and contribute to the sustainable advancement of the dairy industry. This study provides valuable insights into the correlations between milk production traits in the dairy cattle population from Romania. The results demonstrate the complex interplay between milk yield, fat yield, protein yield, and their respective percentages. Understanding these correlations is necessary for making informed decisions in animal breeding, enabling the development of targeted selection strategies to enhance milk productivity and composition.

The findings of this study have practical implications for dairy farmers, breeders, and processors in Romania, as they provide a foundation for optimizing breeding programs and improving the overall performance of dairy cattle herds. By considering the correlations between milk production traits, stakeholders in the dairy industry can work towards maximizing milk yield, enhancing milk quality, and ultimately achieving greater profitability.

Further research can build upon these findings by exploring additional traits and investigating the underlying genetic mechanisms that contribute to the observed correlations. Continual advancements in understanding the genetics underlying milk production contribute to progress in animal breeding and support the sustainable development of the dairy industry.

The study contributes to the body of knowledge in animal breeding and provides valuable insights for improving milk production and quality in dairy cattle populations. It underscores the importance of considering correlations in breeding programs to achieve desired outcomes.

CONCLUSIONS

This study provided significant insights into the interrelationships among milk production traits in dairy cattle from Iași county, Romania. The findings highlight the complex interaction between milk yield, fat yield, protein yield, and their respective percentages. This knowledge is essential for breeders in making informed decisions and developing targeted selection strategies. Moreover, the study's practical implications extend to various stakeholders in the dairy industry, as it supports the goal of enhancing milk yield, improving milk quality, and ultimately increasing profitability. The research emphasizes the importance of these correlations in shaping future breeding programs and encourages further investigation into the underlying genetic mechanisms influencing these traits.

REFERENCES

1. Dronca D. (2004) Animal and plant improvement, University course, Mirton Publishing House, Timișoara
2. Oroian T., Dronca D. (2005) Genetic values and animal selection. Mitron Publishing House, Timișoara
3. Ivancia Mihaela (2020) Animal improvement, Alfa Publishing House. Iasi
4. Smith N. W., Fletcher A. J., Hill J. P., & McNabb W. C. (2022). Modeling the contribution of milk to global nutrition. Frontiers in Nutrition, 8, 716100
5. Duguma B. (2022). Milk composition, traditional processing, marketing, and consumption among smallholder dairy farmers in selected towns of Jimma Zone, Oromia Regional State, Ethiopia. Food Science & Nutrition, 10(9), 2879-2895;
6. Ormston S., Davis H., Butler G., Chatzidimitriou E., Gordon A. W., Theodoridou K., Huws S., Yan T., Leifert C., Stergiadis, S. (2022). Performance and milk quality parameters of Jersey crossbreds in low-input dairy systems. Scientific reports, 12(1), 7550
7. Banos, G., Wall, E., Coffey, M. P., Bagnall, A., Gillespie, S., Russell, G. C., & McNeilly, T. N. (2013). Identification of immune traits correlated with dairy cow health, reproduction and productivity. PloS one, 8(6), e65766;
8. Jenko, J., Wiggans, G. R., Cooper, T. A., Eaglen, S. A. E., Luff, W. D. L., Bichard, M., & Woolliams, J. A. (2017). Cow genotyping strategies for genomic selection in a small dairy cattle population. Journal of Dairy Science, 100(1), 439-452;
9. Hein, L., Sørensen, L. P., Kargo, M., & Buitenhuis, A. J. (2018). Genetic analysis of predicted fatty acid profiles of milk from Danish Holstein and Danish Jersey cattle populations. Journal of dairy science, 101(3), 2148-2157
10. Chauhan, V. P. S., & Hayes, J. F. (1991). Genetic parameters for first lactation milk production and composition traits for Holsteins using multivariate restricted maximum likelihood. Journal of dairy science, 74(2), 603-610. Darwin, C. On the Origin of Species by Means of Natural Selection. London: John Murray.1859

11. Toghiani, S. (2012). Genetic relationships between production traits and reproductive performance in Holstein dairy cows. Archives Animal Breeding, 55(5), 458-468.
12. Ivancia Mihaela (2004) Somatic cells: milk quality indicator, Alfa Publishing House, Iasi
13. Ivancia Mihaela (2006) Interrelations between the content of somatic cells in the cow's milk intended for processing and other quality attributes. PhD Thesis.
14. Ivancia Mihaela (2007) Animal improvement, Alfa Publishing House. Iasi
15. Popa, R., Popa, D., Vidu, L., Diaconescu, C., Băcilă, V., Bota, A., & Dronca, D. (2014). Genetic Parameters Estimates for Milk Yield, Milk Quality and Mozzarella Production of Romanian Buffalo. Bulletin of the University of Agricultural Sciences & Veterinary Medicine Cluj-Napoca. Animal Science & Biotechnologies, 71(2).
16. Sargent, F. D., Lytton, V. H., & Wall Jr, O. G. (1968). Test interval method of calculating dairy herd improvement association records. Journal of Dairy Science, 51(1), 170-179.
17. ***ICAR Recording Guidelines – Section 2 „Cattle Milk Recording” – Overview – Cattle Milk Recording - Standard methods for calculating accumulated yields - Procedure 2 of Section 2 of ICAR Guidelines - Computing of Accumulated Lactation Yield The test interval method (Sargent, 1968), 4-5, 2022
18. Strabel T., Jamrozik, J. (2006). Genetic parameters for first and second lactation milk yield of Polish black and white dairy cows. Journal of Dairy Science. 2006, 89(9), 3672-3678.
19. Schaeffer L.R. (1993). Linear Models and computing strategies in Animal Breeding, University of Guelph, Guelph, Ontario
20. Misztal, I. (2016). Inexpensive Computation of the Inverse of the Genomic Relationship Matrix in Populations with Small Effective Population Size. Genetics, 202(2), 401–409.
21. Butcher, K. R., Sargent, F. D., & Legates, J. E. (1967). Estimates of genetic parameters for milk constituents and yields. Journal of Dairy Science, 50(2), 185-193.
22. Bakri, N. E., Pieramati, C., Sarti, F. M., Giovanini, S., & Djemali, M. N. (2022). Estimates of genetic parameters and genetic trend for Wood's lactation curve traits of Tunisian Holstein–Friesian cows. Tropical Animal Health and Production, 54(4), 223.