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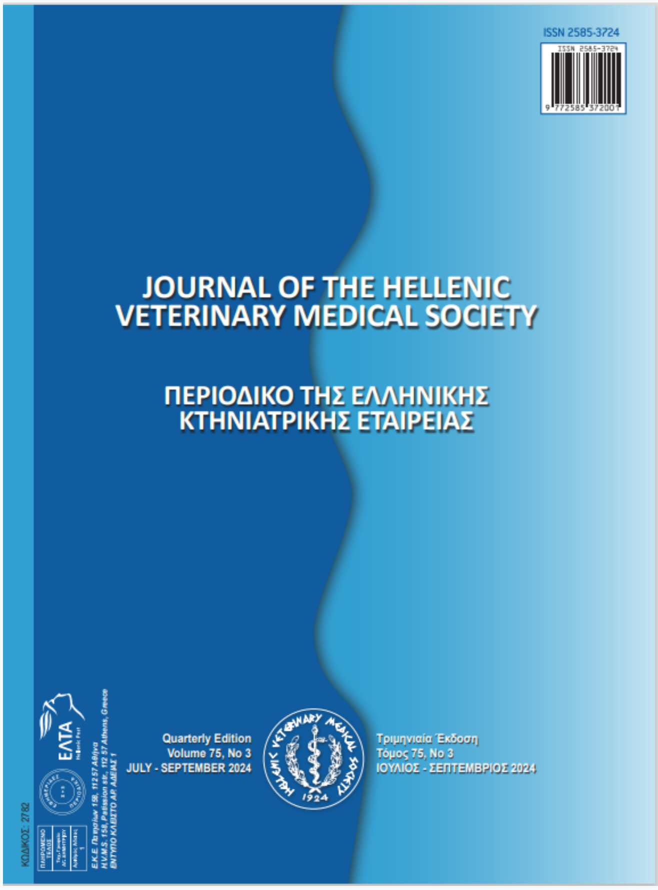

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Efficiency and somatic cell count: Unraveling Holstein cow productivity through stochastic frontier modeling

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ABSTRACT: The yield and quality decrease due to high somatic cell counts caused by mastitis, and this also negatively affects the profitability, efficiency, and sustainability of dairy farms. The main objective of this study was to investigate the effects of somatic cell counts on yield, milk quality, and the technical efficiency of Holstein dairy cows. A total of 165 lactating cows were involved in the research, and all cows were fed the diets as a total mixed ration three times a day. Milk samples were collected each day during milking and analyzed for chemical composition and somatic cell counts (SCC). The daily milk production of each cow was obtained from the SCR herd management program, which is integrated with the parlor. In conclusion, it was determined that for each group, the efficiency scores, SCC, and milk yield of cows varied between 0.80 and 0.99, 322.000 and 557.857 cells/mL, and 33.13 and 48.90 kg/d, respectively; they also differed significantly in each group. Considering the findings, milk production can be increased by 7% without changing any input. Additionally, every 1% decrease in SCC will increase the efficiency of milk production by 0.55%. Cows with low technical efficiency (TE) scores produced 2.87 kg/d/cow less milk compared to animals with high TE. Reducing the SCC of the group with a low TE (456.878 cells/mL) to a SCC of high TE (438.869 cells/mL) will increase milk yield by 2.87 kg/d/cow on average. In conclusion, minimizing losses due to mastitis is paramount to enhancing dairy farm efficiency. This research underscores the interplay between TE and udder health, providing a comprehensive understanding of individual cow performance. Addressing inefficiencies and promoting udder health can significantly contribute to sustainable and economically viable dairy farming practices.

Keywords: Dairy farm; Mastitis; Somatic cell count; Stochastic frontier analysis; Technical efficiency

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INTRODUCTION

Due to recent changes in the economic context, major changes have occurred in dairy farms around the world to increase economic efficiency and profitability (Schuster et al., 2020). As a result of increasing technological developments in animal nutrition and herd management systems, the numbers of animals and milk yield in dairy farms have increased (Britt et al., 2021; Ebi et al., 2021; Fernandez-Novo et al., 2020). However, due to the high input prices used in production and the low price of produced milk, dairy farms have not been able to reach the desired level of profitability and have had to increase their efficiency levels (Kimura and Sauer, 2015). The increase in the number of animals on dairy farms has caused some best practices in herd management to become difficult. Recent studies have emphasized that dairy farms should increase their efficiency for sustainability based on conjunctural changes (Álvarez et al., 2008; Mor and Sharma, 2012). Technical efficiency (TE) is where the most milk is produced with the best available technology and production factors (Guth and Smędzik-Ambroży, 2020), and full TE can be achieved when the maximum possible improvement in milk production is obtained from a set of resources inputs in farms.

Although milk yield does not depend only on nutrition, udder health also has a significant impact on the quantity and quality of milk yield. Biological cells that provide information about the quality of milk and udder health are called somatic cells (Kaskous, 2021). The total amount of these cells in milk is called somatic cell counts (SCC). White blood cells, also known as leukocytes, are responsible for protecting the body from infection (Girdhar et al., 2022). As part of the immune system, leukocytes circulate in the blood and respond to injury or illness. In other words, leukocytes in the blood are responsible for the defense system in the body and travel through the bloodstream and tissues. They locate the site of an infection and notify other leukocytes of their location to help defend the body from an attack by an unknown organism (Girdhar et al., 2022). As a result of being exposed to any infection, the amount of leukocytes in the blood increases rapidly in a short time, and they can fight the pathogens that cause the infection (Girdhar et al., 2022). Therefore, most of the somatic cells in milk belong to leukocytes and are an indicator of inflammation in the udder. The SCC is quantified as cells per milliliter. General agreement rests on a reference range of less than 100.000 cells /mL for uninfected cows and greater than 250.000 for cows infected with significant pathogen levels (Schwarz et al., 2010; Hisira et al., 2023). Mastitis, which is the biggest udder problem in dairy farms around the world, causes huge financial losses in dairy farms (Ajose et al., 2022; Azooz et al., 2020; Lahari, 2023). These losses may include treatment costs, labor costs, and the potential yield and quality of milk that could be produced. Mastitis in dairy cows can be seen as clinical or subclinical (Sadat et al., 2023). Diagnosis of clinical mastitis is quite easy, but some tests, such as the California Mastitis Test, are needed to diagnose subclinical mastitis (Shinde et al., 2022). Therefore, subclinical mastitis is called a silent and hidden disease, and approximately 20 to 30% of cows on any dairy farm are infected annually (Zigo et al., 2019; Valle-Aguilar et al., 2020). Studies on the economic losses of mastitis around the world are increasing every day. Different statistical methods and models are used for the analysis of farm average economic losses (Jehan et al., 2020). However, in this study, the dairy animals on the farms were evaluated individually, and their efficiency scores were estimated separately for each cow. Therefore, this study identified more realistic findings. Recently, in studies regarding losses in milk yield due to mastitis, it has been reported that the amount of milk loss was between 0.28 and 2.41 kg/d/cow compared with 50.000 SCC/mL to 200.000 SCC/mL (Boland et al., 2013; Viguier et al., 2009). In a study on financial losses caused by mastitis, it was emphasized that the cost of mastitis ranges from €160 to €700 per animal (Viguier et al., 2009; Pakrashi et al., 2023). In another study investigating economic losses, it was stated that the former reduction in profit could be exemplified by milk that has to be discarded following treatment with antibiotics, while the latter could refer to milk that is never produced as a result of mastitis (Azooz et al., 2020).

This study is motivated by the need for dairy farms to enhance efficiency in response to economic challenges, particularly the impact of mastitis on individual cows. As a result, minimizing losses due to mastitis will increase the efficiency of dairy farms (Wani et al., 2022). Therefore, the main purpose of this study is to investigate the efficiency and the SCC as determinants of inadequacy for Holstein cows via the stochastic frontier model. Moreover, it discusses the efficiency scores on milk yield and milk fat, protein, and lactose production for lactating dairy cows.

MATERIALS AND METHODS

Data collection

This study was conducted on a commercial dairy farm in the Marmara region of Turkey during May and June 2021. A total of 165 lactating Holstein cows participated in the research for a duration of 30 days, during which they were fed diets in the form of a total mixed ration three times a day following each milking session. The ration fed to the lactating cows was formulated with the help of NDS professional CNCPS version 6.55 (Van Amburgh et al., 2015). The dry matter intake was calculated by subtracting the total leftover feed from the total feed given daily. The diet given to the cows during the experiment is presented in Table 2, while the diet composition is detailed in Table 3. To ensure hygienic milking practices, a structured milking program was implemented. The milking sessions occurred three times daily at 08.00, 16.00, and 00.00 h. Prior to milking, udders were cleaned thoroughly using approved sanitizing agents, and teats were individually disinfected to minimize the risk of bacterial contamination. During each milking session, milk samples were systematically collected using sanitized equipment to maintain sample integrity. These samples were subsequently subjected to a detailed analysis for milk fat, protein, lactose, somatic cell count, and bacterial measurements. The analysis was carried out with the use of FOSS milk analyzers, ensuring accurate and efficient results.

Efficiency measurements via stochastic frontier modal

The stochastic frontier model (SPM) was used to measure TE (Coelli et al., 1998). At the cow level, TE scores were determined, and variables were analyzed with a regression model to determine whether there was an effect on efficiency (Coelli et al., 1998). Milk yield was used as a dependent variable, and dry matter intake, milk fat, milk protein, and milk lactose were used as independent variables in the production model. The stochastic production function used in the modal is given below:

$$Y_i = \beta X_i + v_i - u_i$$

$$v_i - u_i = \varepsilon_i$$

The Log-Likelihood Function is as given below:

$$\ln(L) = \frac{-N}{2}\ln(\frac{\pi}{2}) - \frac{N}{2}\log(\sigma_s^2) + \sum_{i=1}^{N}$$

$$z_i = \frac{(\ln y_i - x_i\beta)}{\sigma_s}\sqrt{\frac{\gamma}{1-\gamma}}$$

Cow-level TE scores were estimated using the formula given below:

$$E(\exp(-Ui)/ei) = 1 - \Phi\,(\sigma A\gamma\, ei/\sigma\, A)/1 - \Phi(\gamma\, ei/\sigma\, A)\exp(\gamma ei + \sigma A\, 2/2)$$

$$\sigma_A = \sqrt{\gamma(1-\gamma)\sigma_s^2}$$

The following equation was used to estimate the average TE scores of each cow:

$$E(\exp(-Ui)) = 2$$

FRONTIER v4.1 was used to estimate efficiency scores (Coelli, 1996). Technical inadequacy was estimated by subtracting the TE from 1 (1-TE), which represents full efficiency.

Grouping of cows for analysis

The cows included in the study were divided into two groups in terms of their TE scores using the K-mean clustering analysis method. The groups were named low and high TE. The commonly used sum of square error (SSE) criterion in the equation given below was used to evaluate the K-means clustering method (Nainggolan et al., 2019; Tan et al., 2006).

$$SSE = \sum_{i=1}^{K}\sum_{x\in C_i} dist^2\langle m_i, x\rangle$$

In the formula, "dist" is the Distance of Standard Euclidean, "x" is a cow in cluster Ci, and "mi" is the center point of cluster Ci. The function of Euclidean distance is as follows:

$$d(x_i, x_j) = \sqrt{\sum_{k=1}^{p} \quad (x_{ik} - x_{jk})^2}$$

In the formula, X_i and X_k represent the coordinates of one point, X_k and X_k are the coordinates of the other point. To evaluate the milk production of cows, 4% fat-corrected milk (4% FCM) was calculated by the formula as follows (Hall, 2023):

$$4\%FCM = 0.4 \times milkyield + 15 \times fatyield$$

Statistical analyses

In the comparative analysis, an independent samples t-test was employed to assess the significance of differences between the two groups using IBM SPSS Statistics version 20 (SPSS, 2011) with a significance level set at P<0.05.

RESULTS

In this investigation, our primary focus was to explore the role of technical efficiency (TE) and somatic cell count (SCC) as critical determinants of inadequacy in lactating Holstein cows. Our central aim was to evaluate the efficiency levels of individual cows utilizing the stochastic frontier model, considering influential factors such as dry matter intake, milk fat, milk protein, and milk lactose in the context of milk yield. Additionally, we sought to appraise somatic cell count as a valuable indicator of udder health, aiming to uncover its potential implications for the overall productivity of the dairy herd. The lactating cows participating in the study exhibited average values for key parameters, including dry matter intake (22.59 kg/d), age (43.25 months), lactation number (1.76), days in milk (221.05 days), days in pregnancy (144 days), SCC (444.981 cells/mL), milk yield (39.39 L/d), milk fat (3.87%), and milk protein (3.31%). Descriptive statistics are detailed in Table 1.

Table 4 delineates the maximum likelihood estimates derived from the Cobb-Douglas-type stochastic production model (SPM), focusing on function variables, coefficients, standard errors, and t-ratios. The independent variables influencing milk yield per cow, including dry matter intake (kg/d), milk solids (%), milk fat (%), milk protein (%), and milk lactose (%), exhibit a significant impact on efficiency ($P < 0.01$). In the model, a 1% increase in dry matter intake, milk fat, milk protein, and milk lactose yields a corresponding increase in milk yield by 1.20%, 0.92%, 1.40%, and 1.28%, respectively. Conversely, augmenting milk solids has an expected negative effect on milk yield due to its inverse correlation with milk energy per unit, and the increase in milk fat diminishes progressively as milk yield rises linearly. Notably, a 1% rise in milk quantity leads to an additional 2% augmentation in milk protein content. Somatic cell count (SCC), identified as a statistically significant variance parameter in the model, elucidates that cows' technical inadequacy significantly influences milk production, amplifying technical inadequacy while diminishing efficiency ($P < 0.01$). A 1% surge in SCC contributes to a 0.55% escalation in technical inadequacy ($P < 0.01$).

Table 1. Descriptive Analysis of Experimental Cows with Key Metrics in Dairy Performance

Cows	Min	Max	Mean	Std. Dev.
Dry matte intake (kg/d)	19.27	23.63	22.59	1.42
Age in months	21.30	54.90	43.25	5.44
Lactation number	1.0	3.0	1.76	0.47
Days in milk	2	859	221	222
Gestation (d)	47	249	144	48
SCC (cells/mL)	322.000	557.857	444.981	54.183
Milk yield (L/d)	33.13	48.90	39.39	1.95
Milk fat (%)	3.38	4.36	3.87	0.20
Milk protein (%)	3.16	3.48	3.31	0.09

Table 2. Composition of Experimental Diet Ingredients and Proportions in Feed Formulation

Ingredients	A.F. kg	DM kg	% AF	% DM
Alfalfa hay	5.87	5.18	13.05	22.04
Corn silage medium	23.27	7.00	51.72	29.81
Corn steam flakes	5.76	5.05	12.81	21.50
Barley grain ground	0.53	0.47	1.19	2.01
Sunflower meal solvent	1.60	1.44	3.56	6.15
Distillers dried grains with solubles (DDGS)	1.07	0.95	2.37	4.04
Soybean meals solvent	2.67	2.40	5.93	10.22
Rumen bypass fat[1]	0.64	0.63	1.42	2.70
Dairy premix[2]	0.21	0.21	0.47	0.88
Sodium bicarbonate	0.16	0.15	0.36	0.65
Water	3.20	0.00	7.12	0.01

[1] (DM basis): Palmitic acid: 82%, Stearic acid: 3.4%, and Oleic acid: 10.7%.
[2] (DM basis): 1.500.000 IU of vitA/kg, 300.000 IU of vitD/kg, 10.000 IU of vitE/kg, 200 mg of biotin/kg, 2.000 mg of Co/kg, 4.000 mg of Cu/kg, 200 mg of I/kg, 15.000 mg of Mn/kg, 100 mg of Se/kg, and 15.000 mg of Zn/kg.

Table 3. Nutrient Analysis of Formulated Diet for Experimental Cows[1]: Proximate Composition, Fiber Fractions, and Energy Parameters

Composition	Unit	DM
CP[2]	%	16.20
RDP[3]	%	10.01
RUP[3]	%	6.19
CF	%	17.55
NDF[4]	%	33.30
ADF[4]	%	21.28
Ether extract[2]	%	5.61
NFC[3]	%	38.30
Starch[2]	%	24.33
Ca[2]	%	0.92
P[2]	%	0.44
ME[3]	Mcal/kg	2.65
NEl[3]	Mcal/kg	1.70
NEm[3]	Mcal/kg	1.81
NEg[3]	Mcal/kg	1.16

[1]CP: Crude Protein; RDP: Rumen Degradable Protein; RUP: Rumen Undegradable Protein; CF: Crude Fiber; NDF: Neutral Detergent Fiber; ADF: Acid Detergent Fiber; NFC: Non-Fiber Carbohydrate; Ca: Calcium; P: Phosphorus; ME: Metabolizable Energy; NEl: Net Energy for Lactation; NEm: Net Energy for Maintenance; NEg: Net Energy for Gain.
[2] Values calculated by chemical analysis.
[3] Estimated via NDS professional CNCPS v6.55
[4] Estimated via NDS professional CNCPS v6.55, using dry matter intake, milk yield, milk composition, and body weight of the cows during research.

Table 4. Maximum Likelihood estimates of Cobb-Douglass type SPM

Variables	Coefficient	Std. error	t-ratio
Function			
Beta	25.065	0.999	25.085*
Dry matter intake (kg/d/cow)	1.203	0.040	29.831*
Milk solid (%)	-1.011	0.274	3.691*
Milk fat (%)	0.918	0.288	3.181*
Milk protein (%)	1.401	0.496	2.822*
Milk lactose (%)	1.283	0.221	5.806*
Factors explaining technical inadequacy (1-TE)			
Somatic cell count (cells/mL) (LN)	-0.547	0.0001	52.481*
Variance parameters			
Sigma-squared	131.163	3.019	43.441*
Gamma	0.988	0.0002	33.973*
Log likelihood		-399.059	
LR		70.444*	

* Differ significantly at p<0.01

Table 5 present clusters of cows along with the distribution of technical efficiency scores in these groups. The technical efficiency (TE) scores observed in the studied cows ranged from 0.80 to 0.99, with an average score of 0.93. This variance indicates a discernible diversity in the efficiency levels among the lactating Holstein cows under investigation. Notably, the clustering approach in Table 5 reveals distinct groups with varying TE scores, offering insights into the heterogeneity within the population. Additionally, the observed TE scores suggest a prevailing trend towards relatively high efficiency levels among the cows, with the majority falling within the upper range of the scale. This trend is crucial for understanding the overall efficiency landscape of the dairy farm and can potentially guide targeted interventions to further enhance productivity. Furthermore, the consequential impact of eliminating technical inadequacies, leading to a remarkable 7.00% increase in average yield while utilizing the same inputs, underscores the significance of addressing inefficiencies in dairy farm management.

Table 6 provides a comprehensive comparison of milk composition and yield parameters between the High and Low Technical Efficiency (TE) groups, along with their corresponding 95% confidence intervals (CI) and P values. In terms of milk yield, a statistically significant difference was observed, with the High TE group exhibiting a mean yield of 40.36 kg/day (95% CI: 40.08 - 40.65) compared to the Low TE group's mean of 37.49 kg/day (95% CI: 37.17 - 37.80) (P = 0.04). Further exploration of solids content, fat, protein, and lactose percentages revealed no significant differences between the High and Low TE groups, with P values exceeding the significance threshold (0.05) in each case. However, somatic cell count (SCC) demonstrated a noteworthy disparity, with the High TE group recording a mean SCC of 438.869 cells/mL (95% CI: 428.221 - 449.518), while the Low TE group had a mean SCC of 456.878 cells/mL (95% CI: 443.872 - 469.885) (P = 0.04).

Table 5. Efficiency Scores for High and Low Technical Efficiency Groups

Clusters	N	Mean	Std. Deviation	Min	Max
High TE	109	0.96	0.016	0.93	0.99
Low TE	56	0.89	0.026	0.80	0.92
Total	165	0.93	0.036	0.80	0.99

Table 6. Comparison of Milk Composition and Yield Parameters between High and Low Technical Efficiency (TE) Groups

				95% CI		
		Mean	Std. Dev.	Lower Bound	Upper Bound	P Values
Milk yield (kg/d/cow)	High TE	40.36	1.50	40.08	40.65	0.04
	Low TE	37.49	1.18	37.17	37.80	
	Total	39.39	1.95	39.09	39.69	
Solids (%)	High TE	12.81	0.28	12.76	12.86	0.37
	Low TE	12.85	0.25	12.78	12.92	
	Total	12.82	0.27	12.78	12.87	
Fat (%)	High TE	3.86	0.21	3.82	3.90	0.35
	Low TE	3.89	0.18	3.85	3.94	
	Total	3.87	0.20	3.84	3.90	
Protein (%)	High TE	3.30	0.09	3.28	3.32	0.32
	Low TE	3.32	0.08	3.29	3.34	
	Total	3.31	0.09	3.29	3.32	
Lactose (%)	High TE	4.97	0.10	4.95	4.99	0.49
	Low TE	4.98	0.11	4.95	5.01	
	Total	4.97	0.10	4.96	4.99	
SCC (cels/mL)	High TE	438.869	56.087	428.221	449.518	0.04
	Low TE	456.878	48.569	443.872	469.885	
	Total	444.981	54.183	436.652	453.310	

DISCUSSION

This study unveils a positive correlation between dry matter intake (DMI) and milk yield, where a 1% increase in DMI corresponds to a noteworthy 1.20% augmentation in milk production efficiency. This underscores the crucial role of adequate nutrition, emphasizing the contribution of higher DMI to enhanced milk production efficiency. Additionally, a 1% increase in both milk fat and milk protein results in a respective 0.92% and 1.40% boost in milk yield, highlighting their critical roles in overall milk production efficiency. Similarly, a 1% rise in milk lactose leads to a substantial 1.28% increase in milk yield, emphasizing the significance of lactose in promoting overall production efficiency, potentially through its role in supporting energy metabolism. Conversely, augmenting milk solids demonstrates an expected negative effect on milk yield, indicating a trade-off between milk quantity and quality and suggesting a need for a balanced approach to optimize production efficiency.

The coefficients associated with DMI, milk fat, milk protein, and milk lactose are statistically significant ($P < 0.01$), underscoring the influence of these variables on milk yield efficiency. The observed inverse correlation for milk solids reinforces the importance of considering trade-offs involved in maximizing both quantity and quality in dairy production systems. Adequate dry matter intake and higher levels of milk fat, protein, and lactose contribute positively to milk yield efficiency, collectively promoting optimal nutrition and udder health for increased milk production. However, the negative impact of milk solids on milk yield efficiency suggests the necessity of a balanced approach in managing milk composition for optimal efficiency in dairy production.

The somatic cell count results for lactating Holstein cows were examined as a crucial indicator of udder health and its potential impact on overall productivity. The lactating cows exhibited an average SCC of 444.981 cells /mL (Table 1). Comparing these SCC values with established reference ranges, a general consensus suggests a reference range of less than 100.000 cells /mL for uninfected cows and greater than 250.000 for cows infected with significant pathogen levels (Schwarz et al., 2010; Hisira et al., 2023). The observed average SCC falls within the latter range, indicating a potential prevalence of infection or inflammation in the udders of the studied cows. This variation in SCC among the cows carries substantial implications for udder health. Mastitis, a prevalent udder problem worldwide, results in substantial financial losses in dairy farms, encompassing treatment costs, labor costs, and the potential yield and quality of milk. The classification of mastitis into clinical or subclinical forms further emphasizes the nuanced nature of udder health issues. Subclinical mastitis, representing a silent and hidden disease, affects approximately 20 to 30% of cows on any dairy farm annually (Zigo et al., 2019; Valle-Aguilar et al., 2020). The findings underscore the need for vigilant monitoring and management practices to mitigate the impact of subclinical mastitis on individual cows. Diagnostic tests, such as the California Mastitis Test, become crucial in identifying and addressing these subtle udder health challenges (Shinde et al., 2022). The significant disparity in SCC between the High and Low Technical Efficiency (TE) groups further highlights the potential correlation between udder health and overall efficiency.

The grouping of lactating Holstein cows into low and high technical efficiency (TE) categories was conducted through the rigorous application of the K-means clustering analysis method, a statistical technique designed to identify distinct clusters within a dataset. This method allowed for a nuanced examination of efficiency levels, providing valuable insights into the diverse efficiency landscape of the studied dairy farm. The criteria employed for grouping cows were strategically selected to encapsulate key aspects influencing milk production efficiency. These criteria included dry matter intake (DMI), milk fat, milk protein, and milk lactose, each contributing significantly to the overall milk yield efficiency. The rationale behind selecting these criteria lies in their established impact on dairy cow performance and production. Dry matter intake serves as a proxy for nutritional efficiency, while milk fat, protein, and lactose are fundamental components influencing milk quality and quantity. The K-means clustering algorithm, known for its ability to partition a dataset into distinct groups based on inherent patterns, iteratively assigned cows to either low or high TE groups. This grouping facilitated a comprehensive examination of the factors influencing efficiency, offering a detailed understanding of the heterogeneity among the lactating Holstein cows. Observed differences between the low and high TE groups yielded valuable insights into the interplay between efficiency and various parameters. Table 6 provides a comprehensive comparison of milk composition and yield parameters, including statistically significant differences in milk yield. The High TE group exhibited a mean yield of 40.36 kg/day, compared to the Low TE group's mean of 37.49 kg/day ($P = 0.04$), underscoring the impact of efficiency on overall productivity. Despite the observed variations in milk yield, other parameters such as solids content, fat, protein, and lactose percentages showed no significant differences between the two groups. This analysis indicates that while milk quantity is influenced by efficiency, the quality parameters remain relatively consistent, emphasizing the importance of a balanced approach in optimizing both quantity and quality in dairy production systems.

The current findings resonate with prior research emphasizing the paramount importance of enhancing efficiency in dairy farms, particularly in the face of economic challenges. The surge in technological developments, as highlighted by Schuster et al. (2020), underscores a global trend toward leveraging advancements in animal nutrition and herd management to optimize milk yield. The emphasis on technical efficiency (TE), portrayed as the maximum milk production achievable with available resources, aligns with Guth and Smędzik-Ambroży's (2020) conceptualization. The significance of conjunctural changes for promoting sustainability, as highlighted by Álvarez et al. (2008) and Mor and Sharma (2012), resonates with the economic challenges faced by dairy farms globally. The investigation into SCC as a determinant of inefficiency aligns with existing literature that underscores the crucial role of udder health in milk production. The quantification of SCC as cells per milliliter, with a reference range indicative of infection levels, aligns with the works of Schwarz et al. (2010) and Hisira et al. (2023). The recognition of mastitis as a significant udder problem causing substantial financial losses is consistent with findings from Ajose et al. (2022), Azooz et al. (2020), and Lahari (2023). The prevalence of subclinical mastitis, a silent and hidden disease affecting a considerable percentage of cows annually, echoes the concerns raised by Zigo et al. (2019) and Valle-Aguilar et al. (2020). Additionally, this study's revelation of a connection between SCC and inefficiency aligns with reports by Boland et al. (2013) and Viguier et al. (2009), showcasing the economic losses associated with mastitis. The impact of mastitis on individual cows, as emphasized by the cost range of €160 to €700 per animal (Viguier et al., 2009; Pakrashi et al., 2023), concurs with the economic repercussions outlined by Azooz et al. (2020). Moreover, the current study's individualized evaluation of dairy animals provides a more nuanced understanding, potentially offering more realistic findings compared to studies employing farm average economic losses (Jehan et al., 2020). While corroborating previous findings, this study extends the discourse by linking SCC with technical inadequacy, uncovering the effects on dairy cow efficiency and milk production. The revelation of a 1% surge in SCC contributing to a 0.55% escalation in technical inadequacy offers a novel perspective. The comparison of efficiency scores on milk yield and milk fat, protein, and lactose production adds granularity to the understanding of the multifaceted relationships within dairy farming.

The implications drawn from the study have significant relevance for effective dairy farm management, particularly in the realm of enhancing economic efficiency and tackling udder health challenges. The established correlation between technical efficiency (TE), somatic cell count (SCC), and milk production emphasizes the necessity for targeted interventions to optimize overall dairy farm performance. The observed 7.00% increase in average yield following the elimination of technical inadequacies presents a tangible opportunity for dairy farms to boost productivity without requiring additional resource inputs. The implementation of efficiency enhancement strategies and encompassing improved herd management practices can contribute to elevated milk yield without proportional increases in costs. Recognizing the substantial impact of somatic cell count on technical inadequacy and, subsequently, milk production, prioritizing udder health management becomes paramount. Robust protocols for mastitis prevention, early detection, and treatment are recommended. Regular monitoring of SCC, coupled with prompt action in cases of elevated counts, can effectively mitigate economic losses associated with udder health issues. Furthermore, the individualized evaluation of dairy animals in this study offers a more nuanced understanding of efficiency scores. Dairy farm managers stand to gain by adopting individualized approaches to assess and address the specific needs of each cow. This tailored approach has the potential to enhance resource utilization and overall efficiency on the farm more effectively. Based on the findings of the study, several crucial recommendations emerge to assist dairy farm managers in optimizing both efficiency and udder health. It is recommended to develop and implement comprehensive health monitoring protocols, incorporating regular assessments of somatic cell counts. Early detection of subclinical mastitis, coupled with prompt treatment, is essential to prevent economic losses linked to diminished milk yield and the potential culling of infected cows. In addition, there is a need to cultivate a culture of awareness and knowledge among dairy farm staff regarding the economic implications associated with inefficiencies and udder health issues. Implementing training programs focusing on best practices in herd management, udder health, and efficiency improvement can empower farm personnel to actively contribute to the success of the farm. Furthermore, dairy farms are encouraged to embrace emerging technologies, such as automated milking systems, precision feeding systems, and sensor-based health monitoring tools. Beyond enhancing operational efficiency, these technologies provide real-time data for proactive decision-making, thereby reducing the likelihood of inefficiencies. By integrating these advanced tools, dairy farm managers can stay at the forefront of innovation and ensure a sustainable and economically viable operation.

This study acknowledges limitations inherent in its single-farm scope, a brief data collection period, and exclusive concentration on technical efficiency and somatic cell count. Additionally, the stochastic frontier model involves certain assumptions that warrant consideration. To enhance scientific understanding, future investigations should embrace a more expansive, multi-farm approach, incorporate longitudinal perspectives for temporal analysis, integrate diverse variables comprehensively, scrutinize the efficacy of emerging technologies, conduct intricate economic evaluations, explore diverse cattle breeds, and delve into socio-economic factors influencing dairy farm efficiency.

CONCLUSIONS

This study addresses the imperative need for dairy farms to enhance efficiency, particularly in response to economic challenges, with a specific focus on the impact of mastitis on individual cows. The overarching goal is to minimize losses due to mastitis, thereby increasing the overall efficiency of dairy farms. The importance of this research lies in its contribution to the broader understanding of the interplay between technical efficiency (TE), somatic cell count (SCC), and milk production in lactating Holstein cows. It is suggested include prioritizing regular monitoring of SCC levels, early detection, and management of mastitis for sustainable and economically viable dairy farming practices. Future research could explore the generalizability of findings across diverse dairy farming systems and delve into targeted interventions for udder health management. Overall, proactive measures to improve udder health emerge as indispensable for fostering resilient and sustainable dairy farming practices.

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CONFLICT OF INTEREST

The author/s declared that there is no conflict of interest.

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