EXPLORATORY ANALYSIS IN THE RELATIONSHIP OF PARITY AND LACTATION PERIOD ON MILK PRODUCTION

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Abstract

This study presents a comprehensive analysis of the effect of parity and lactation period on the milk yield of dairy cows. Data were collected from a dairy farm over a period of 32 days, which included daily milk yield, parity, days in milk, and lactation period. The data were preprocessed and analyzed using statistical software. An Analysis of Variance (ANOVA) test showed significant differences in milk yield between cows of different parities and lactation periods. Post-hoc testing further identified specific groups that differed significantly from each other. Correlation analysis revealed a subtle negative correlation between parity and average milk yield. Furthermore, a predictive model was developed using a linear regression approach, which estimated the average milk yield based on a cow's parity and lactation period. This model can serve as a valuable tool for farmers and dairy industry stakeholders to optimize milk production, especially in the respective dairy farm in the future. The findings underscore the importance of considering parity and lactation period in managing dairy cow milk yield.

***Key words**: dairy cows, parity, lactation period, milk yield*

INTRODUCTION

Dairy farming is a critical industry that provides essential nutrition to populations worldwide, especially in developing countries (Adesogan & Dahl, 2020). Milk yield, the amount of milk a dairy cow produces, is a key factor determining the profitability and sustainability of dairy operations (Krpálková et al., 2014; Schorr & Lips, 2018). Various factors influence milk yield, including the genetic potential of the cow (Gai et al., 2021; Wahinya et al., 2020), its health and nutrition (Alimirzaei et al., 2020; De Vries, 2020; Ducháček et al., 2020; Li et al., 2020; Roesch et al., 2005), and its management (Bateki et al., 2020; Hill & Wall, 2015; West et al., 2003).

Among the manageable factors, the parity or number of calvings (Ma et al., 2020; Marumo et al., 2022; Mayasari et al., 2017) and lactation period (Bewley et al., 2010; Siewert et al., 2019; Vijayakumar et al., 2017) of a cow are of particular interest, as they are directly linked to the reproductive cycle of the cow and can be influenced by farm management practices.

Previous research has indicated that both parity and lactation period can have a significant impact on milk yield (Vijayakumar et al., 2017). Generally, milk yield increases with parity until it reaches a peak, and then gradually declines in subsequent lactations (Marumo et al., 2022; Vijayakumar et al., 2017). The lactation period, defined as the number of days since a cow last calved, is also critical; cows typically have a period of increasing milk production (early lactation), followed by a period of peak production (mid lactation),

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and then a period of declining production (late lactation) (Marumo et al., 2022).

Despite the recognized importance of these factors, there is a need for more detailed, case-specific studies to quantify their impact on milk yield, especially given the variability between different breeds of cows and different farming systems. Such information is valuable not only for understanding the biology of lactation but also for informing management decisions on farms.

In this study, we analyze a dataset from a dairy farm collected over 32 days, which includes daily milk yield, parity, days in milk, and lactation period. Using this data, we aim to (1) examine the influence of parity and lactation period on milk yield, (2) investigate the correlation between these factors, and (3) develop a predictive model for milk yield based on parity and lactation period.

MATERIALS AND METHOD

Dairy Farm and Data Collection

This study is conducted in a commercial dairy farm located in Central Java Province, Indonesia. The dairy farm implemented a modern housing and management, involving 96 lactating dairy cows. The type of feed in this study includes forage, concentrate, and beer waste. The feed is given simultaneously, with the forage being the bottom layer, followed by the concentrate, and finally the beer waste. The feed ingredients and composition used to make the concentrate are 24.64% polar, 3.52% DDGS (Distillers Dried Grains and Solubles), 17.60% CGF (Corn Gluten Feed), 10.56% palm kernel cake, 28.16% bread waste, 14.08% soybean waste, and 1.40% mineral mix. The concentrate has a TDN content of 88.32% and a CP of 21.01%, corn cob forage has a TDN content of 65% and a CP of 8%, and odot grass forage has a TDN content of 63.98% and a CP of 14.35%.

The dataset used in this study was collected from a dairy farm over a period of 32 days, from January 5th to February 5th, 2023. The data included daily milk yield measurements for each cow, as well as additional information such as the cow's house, parity (number of calvings), and days in milk (DIM), which we used to categorize the lactation period (Table 1). The lactation period categorized into 'Early Lactation' (<100 days), 'Mid Lactation' (100 to 200 days), or 'Late Lactation' (>200 days), as categorized by (Kuczyńska et al., 2021; Vijayakumar et al., 2017). The number of cows that included in this study The data collection followed ethical guidelines and ensured the well-being of the animals.

Table 1 Number of cows categorized by parity and lactation period

Categorization		Number of Cows
Parity		
	1	14
	2	24
	3	11
	4	18
	5	29
Lactation Period		
Early Lactation		19
Late Lactation		46
Mid Lactation		31

Data Pre-processing

Prior to analysis, the dataset was cleaned and pre-processed in SAS version 9.2. This included handling missing values and outliers and standardizing the format of the data. Calculations such as the total and average milk yield for each cow over the study period were performed using the DATA procedure in SAS.

Statistical Analysis

Statistical analysis was performed using SAS version 9.2. An Analysis of Variance (ANOVA) test was conducted using the PROC GLM procedure to compare the average milk yield between cows of different parities and lactation periods. Moreover, we used PROC MIXED to determine the p-values of average and total milk yield between cows of different parity, lactation period, and interaction between them. We considered parity, lactation period, and interaction as fixed effect, and include the animal number as repeated effect with covariance structure of autoregressive into the statistical model. Post-hoc testing was performed using the Tukey's test in the PROC GLM procedure to identify specific groups that differed significantly from each other. In addition to the ANOVA, correlation analysis was performed using the PROC CORR procedure to investigate the relationship between parity and average milk yield.

Predictive Modelling

A predictive model was developed to estimate the average milk yield based on a cow's parity and lactation period. This model was built using the PROC REG procedure in SAS, with parity and lactation period as independent variables and average milk yield as the dependent variable. The model's performance was evaluated based on its R-squared value and the significance of the predictor coefficients.

Data Visualization

Data visualization was conducted using the SGPLOT procedure in SAS version 9.2. Several plots were created to help visualize the data and the results of the statistical analyses, including bar plots, line plots, and scatter plots. These visualizations provided a clear and concise representation of the data and facilitated the interpretation of the results.

RESULTS

Our analysis involved the examination of daily milk yield data collected over a 32-day period from a dairy farm. The data comprised of measurements from multiple cows, allowing us to determine average milk yield values for each day of the study period.

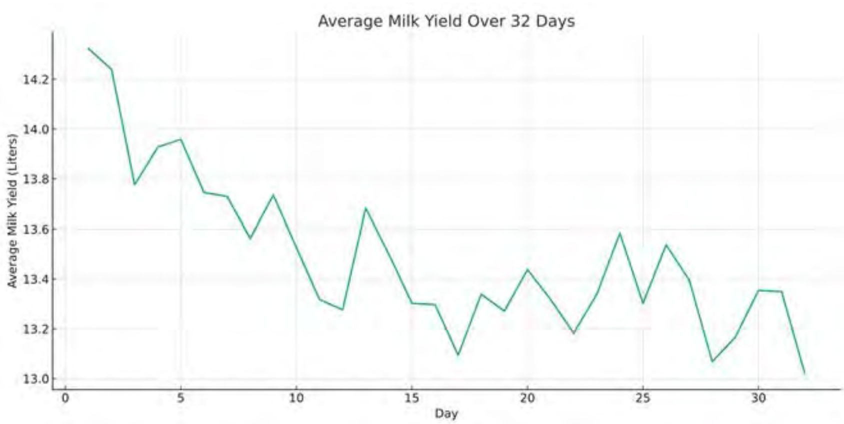

Figure 1 Overall average milk yield during 32 days of measurement in this study

The line plot of average milk yield over the 32 days revealed notable patterns (Figure 1). The daily average milk yield exhibited variability, underscoring the dynamic nature of milk production in dairy cows.

Table 1 The effect of parity and lactation period on the average and total milk yield of cows

Parameters	Parity					Lactation Period			SEM	p-values		
	1	2	3	4	5	Early	Mid	Late		P	LP	P*LP
Average Milk Yield	17.7	14.9	12.3	13.7	15.66	20.1[c]	9.8[a]	14.6[b]	1.1	0.1	<.01	0.5
Total Milk Yield	564.4	479.2	393.1	439.9	499.8	643.9[a]	314.2[a]	467.7[b]	35.3	0.1	<.01	0.5

P, Parity; LP, Lactation Period; SEM, standard error of the means.
[a-c] Values within a row with different superscripts differ significantly at p ≤ 0.05

In the initial phase of the study period, the average milk yield demonstrated a slight increase, reaching a peak around the 10th day. Following this peak, a period of gradual decline was observed, lasting until approximately the 20th day. Beyond this point, the average milk yield seemed to stabilize, showing relatively minor fluctuations through the remainder of the study period.

Table 2 Correlation between parity and lactation period on total and average milk yield of cows

	Total milk yield	Average milk yield
Parity	-0.14	-0.14
Lactation Period	-0.65*	-0.65*

Asterisk (*) indicate significant correlation

This temporal pattern in milk yield might be influenced by several factors, including the cows' lactation period, health status, and changes in feeding or management practices over the 32-day period. The line plot of average milk yield offers a visual summary of these results, providing a clear illustration of the day-to-day changes in milk production. This visualization serves as a valuable tool for understanding the dynamics of milk yield in a dairy farm context.

Our dataset comprised of daily milk yield records for 96 cows over a one-month period. Each cow was characterized by its parity (number of calvings) and its stage in the lactation period (Figure 3). The average milk yield per cow was calculated and used as the dependent variable in our analyses.

The initial exploratory data analysis revealed a negative correlation between both parity and lactation period with average milk yield. Table 2 shows the ANOVA result which revealed that the differences in average milk yield between different lactation periods were statistically significant (p<0.001), while the differences between parities were not (p = 0.073). A Tukey's HSD post-hoc test confirmed significant differences in average milk yield between all pairs of lactation periods (p<0.001 for all comparisons). The correlation coefficient for parity and average milk yield was -0.14, while for lactation period and average milk yield it was -0.67 (Table 3).

A linear regression model was trained to predict the average milk yield from the parity and lactation period. The model was trained on 80% of the data, and its performance was evaluated on the remaining 20% of the data. The model achieved a mean squared error of 12.60 and an R^2 score of 0.658 on the test set.

The equation for the model is as follows:

$$Average\ Milk\ Yield = 25.57 - 0.46 \times Parity - 4.71 \times Stage\ of\ Lactation_{Ordinal}$$

This equation can be used to estimate the average milk yield for a cow given its parity and stage in the lactation period. However, the model is a simplification and other factors not included in the model may also influence milk yield.

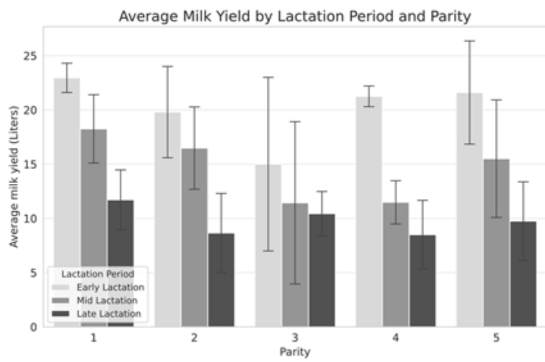

Figure 2 Covariance between the lactation period and parity on average milk yield in this study

DISCUSSION

Our findings indicate a significant relationship between the lactation period and average or total milk yield in cows, consistent with previous research that suggests milk yield varies depending on the lactation period (Sinha et al., 2021; Vijayakumar et al., 2017). The negative correlation coefficient of -0.67 suggests that as a cow progresses through its lactation period, the average milk yield decreases. This was substantiated by the ANOVA and Tukey's HSD post-hoc test, both of which revealed statistically significant differences in average milk yield across the lactation periods. This finding is in line the study of (Sabek et al., 2021; Yoon et al., 2004), which reported that the milk yield decreased in increasing the lactation period. The parity of a cow, although negatively correlated with average milk yield, did not show a statistically significant effect. This suggests that while there is a trend of decreasing milk yield with increasing parity, the effect is not strong enough to be statistically significant in this dataset. This might be related with different numbers of cows in each parity in this dataset.

The linear regression model constructed in this study offers a methodology for predicting the average milk yield of a cow based on its parity and lactation period. Although the model's R^2 value of 0.658 suggests that it accounts for a significant proportion of the variance in milk yield, it is imperative to acknowledge that milk production is a complex trait influenced by numerous factors not incorporated in this model, such as genetics, nutrition, and health status. As such, while the model can provide valuable estimates, its applicability to other populations may be limited and warrants further investigation.

Furthermore, the model serves as a foundation for future research. By utilizing more comprehensive datasets that incorporate additional influencing factors, more sophisticated models could be developed to enhance the accuracy of milk yield predictions. This could have substantial implications for the management of dairy production and the optimization of yield, particularly in dairy farms with similar characteristics.

CONCLUSION

This study provided an in-depth analysis of average milk yield over a 32-day period in a dairy farm. Our findings highlighted the dynamic nature of milk production, with daily averages showing notable variability. The patterns observed in the data suggest that milk yield is influenced by various factors, potentially including the cows' lactation period, health status, and changes in feeding or management practices.

Despite the observed variability, the data also demonstrated periods of relative stability in milk yield. This suggests that, while daily fluctuations are common, longer-term trends in milk production can be relatively consistent under stable conditions. These findings underscore the value of ongoing monitoring and data collection in managing milk yield effectively.

The predictive model developed in this study, based on parity and lactation period, provides a valuable tool for forecasting milk yield. By integrating such a model into farm management practices, stakeholders can make more informed decisions and potentially enhance productivity. However, while the model can provide valuable estimates, its applicability to other populations may be limited and require further investigation.

Future research should continue to explore the factors influencing milk yield, with a particular focus on understanding the causes of the observed day-to-day variability and a larger dataset. Further refinement and validation of predictive models will also be crucial in optimizing milk production in dairy farming.

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