Insights into lactation performance for automatic milking systems of Holstein dairy cows in Taiwan

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Abstract

Since 2018, Taiwan has introduced automatic milking systems (AMS). However, there has been no detailed investigation or analysis regarding the animal behavior, milk yield variations, and physiological characteristics associated with this new milking mode. This study aims to establish a foundational database for animal behavior, physiological traits, and milk production characteristics of Holstein dairy cows in Taiwan using AMS by collecting basic data. The experiment focuses on analyzing the effects of AMS on the milk production traits of Holstein dairy cows in Taiwan, gaining deeper insights into the production characteristics under AMS.

The study reveals that the average milk yield for cows in their first lactation is 33.02 ± 0.26 kg, for second lactation 42.79 ± 0.44 kg, and for third lactation 41.71 ± 0.80 kg. The average daily milk yield of first-lactation cows is significantly lower than that of second- and third-lactation cows. Cows milked an average of five times daily produce significantly more milk than those milked two or three times daily, but there is no significant difference compared to those milked four times daily. Significant differences are observed among cows milked two to four times daily, with milk yield increasing as the frequency of milking increases. Furthermore, cows with high daily milk yields and short milking intervals have significantly higher 305-day milk yields compared to those with high daily milk yields and long milking intervals.

Conversely, cows with low daily milk yields and short milking intervals have significantly lower 305-day milk yields than those with low daily milk yields and long milking intervals. A deeper understanding of the changes in milk production traits and lactation curves of cows using AMS could help identify cows suited to AMS through new herd grouping models. This could allow for adjustments to overall herd composition and the development of optimized management and selection strategies to enhance equipment utilization efficiency.

Keywords: Automatic milking systems, milk yield, lactation.

Introduction

Automatic milking systems (AMS) have revolutionized dairy farming by enhancing efficiency and reducing labor requirements. Since its introduction in Taiwan in 2018, AMS has provided a new milking paradigm, enabling cows to voluntarily enter the milking station multiple times a day. This has raised questions about how AMS affects milk production traits, physiological responses, and overall dairy management

efficiency. Previous studies have demonstrated that AMS adoption leads to variations in milk yield, milking frequency, and lactation persistency, but research on Taiwanese Holstein dairy cattle under AMS conditions remains limited. This study aims to analyze milk production traits in Holstein dairy cows using AMS, establish a foundational database for lactation characteristics, and evaluate factors influencing milking efficiency and productivity.

Material and methods

Experimental design

This study was conducted to evaluate the effects of automatic milking systems (AMS) on the milk production traits of Holstein dairy cows in Taiwan. The experiment was designed as an observational study on commercial dairy farms equipped with AMS. Data collection focused on individual cow performance across different lactation parities and milking frequencies.

Animals and housing

A total of 30 Holstein dairy cows were selected for the study, stratified by parity into three groups: first-parity (n = 10), second-parity (n = 10), and third-parity or greater (n = 10). Cows were housed in free-stall barns equipped with AMS units.

All cows were fed a total mixed ration (TMR) formulated according to NRC (2001) recommendations, and water was provided ad libitum.

Data collection

Milk yield and milking frequency

Milk yield (kg/day) was recorded for each cow using AMS-integrated sensors. The number of daily milking sessions was automatically logged, and cows were classified into groups based on milking frequency (2, 3, 4, or 5 times/day). Total lactation yield was estimated over a 305-day lactation period (305-DY).

Lactation curve analysis

Lactation curves were constructed based on daily milk yield (DY) and milking interval (MI). Cows were categorized into six groups according to DY (high, medium, low) and MI (short, long). Key parameters calculated included: Peak milk yield (Ppeak, kg/day): Maximum milk production observed in the lactation period. Days to peak yield (Dpeak, days): The number of days from calving to peak yield. Lactation persistency (c-value): The rate of decline in milk yield after peak lactation.

Milk composition analysis

Milk composition was analyzed using a Fourier-transform infrared spectrometer (MilkoScan TMFT+, FOSS, Denmark) for the following parameters: Milk fat (%), Milk protein (%), Lactose (%), Total solids (%), Fatty acid profile (de novo, mixed, and preformed fatty acids).

Data processing and statistical analysis

To ensure data accuracy, records with extreme or biologically implausible values were removed Milking intervals <1 hour or >24 hours were excluded and Incomplete or missing lactation records were omitted.

Differences in milk yield, milking frequency, and lactation parameters were analyzed using a one-way ANOVA, followed by Tukey's post-hoc test. Correlations between milk yield and composition were assessed using Pearson correlation coefficients. All statistical analyses were performed using SAS software (SAS Institute, Cary, NC, USA), with significance set at $P < 0.05$.

Results

Milk composition

The correlation between milk yield and various milk components showed (Figure 1) a weak negative correlation with milk fat (-0.18), milk protein (-0.15), de novo fatty acids (-0.17), mixed fatty acids (-0.18), preformed fatty acids (-0.20), short-chain fatty acids (-0.10), medium-chain fatty acids (-0.23), long-chain fatty acids (-0.11), palmitic acid (-0.23), and oleic acid (-0.22). In contrast, trans fatty acids exhibited a weak positive correlation (0.14).

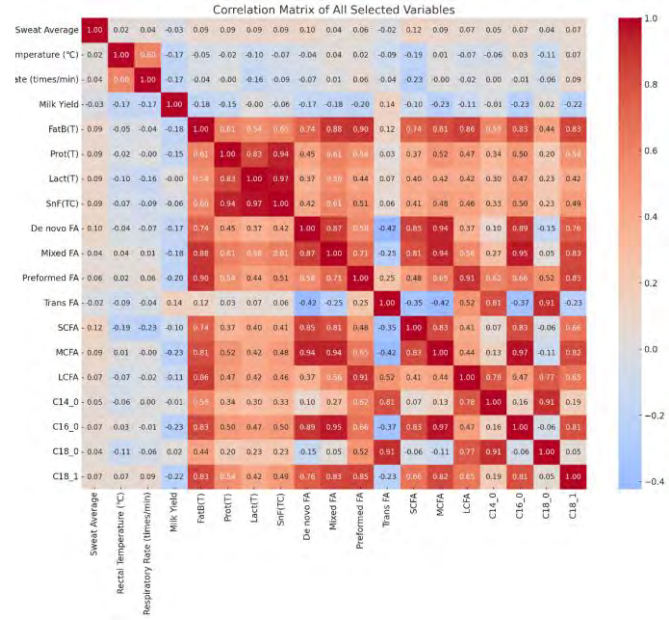

Figure 1. Analysis of the correlation coefficients between milk yield and 15 milk components. FatB (T) : Milk Fat Prot (T) : Milk Protein Lact (T) : Lactose SnF (TC) : Solids-Not-Fat De novo FA: De Novo Fatty Acids Mixed FA: Mixed Fatty Acids Preformed FA: Preformed Fatty Acids Trans FA: Trans Fatty Acids SCFA: Short-Chain Fatty Acids MCFA: Medium-Chain Fatty Acids LCFA: Long-Chain Fatty Acids C14_0: Myristic Acids C16_0: Palmitic Acid C18_0: Stearic Acid C18_1: Oleic Acid.

Milk yield and parity

The milk yield and data distribution of dairy cows using the automatic milking system (AMS) across different parities are shown in **Figure 2.** The average milk yield for first-parity cows was 33.02 ± 0.26 kg, for second-parity cows 42.79 ± 0.44 kg, and for third-parity cows 41.71 ± 0.80 kg (**Table 1**). The results indicate that the daily average milk yield of first-parity cows was significantly lower than that of second- and third-parity cows.

Milk Yield and Milking Frequency

For dairy cows using the automatic milking system (AMS), the average daily milk yield for cows milked twice per day was 34.25 ± 0.38 kg, for those milked three times per day was 39.43 ± 0.37 kg, for those milked four times per day was 42.02 ± 0.56 kg, and for those milked five times per day was 46.61 ± 0.88 kg (**Table 2**). The milk yield of cows milked five times per day was significantly higher than that of cows milked three or two times per day, but there was no significant difference compared to those milked four times per day. Significant differences were observed between cows milked two to four times per day, with milk yield increasing as milking frequency increased.

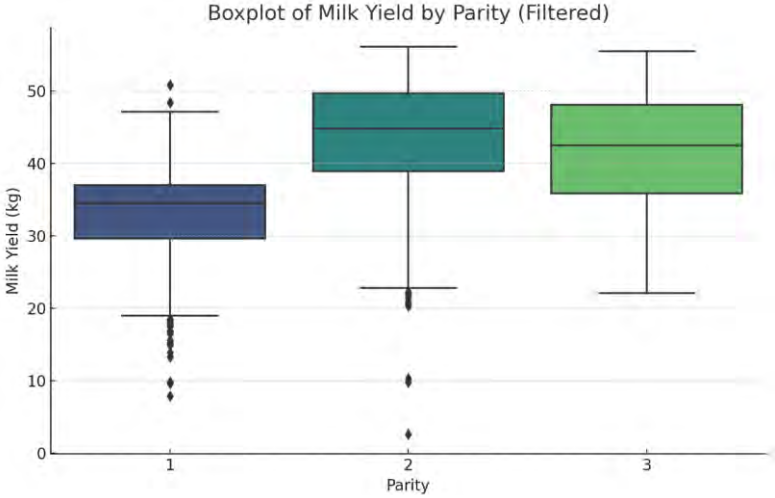

Figure 2. Milk yield and data distribution for dairy cows of different parities using an automatic milking system.

Table 1. Using an automatic milking system, the milk yield of dairy cows for each parity.

Parity	Mean *	SE
1	33.02[a]	0.26
2	42.79[b]	0.44
≥3	41.71[b]	0.80

*Least squares means, within a row were significantly different (P < 0.05).

Lactation curve

The dairy cows using the automatic milking system (AMS) were grouped based on daily milk yield and milking interval, and a 305-day lactation curve was plotted. The raw data points are shown in Figure 3, while the processed and calculated lactation curves are presented in Figure 4. The results indicate that the high daily yield + short milking interval group had a significantly higher 305-day milk yield than the high daily yield + long milking interval group. In contrast, the low daily yield + short milking interval group had a significantly lower 305-day milk yield than the low daily yield + long milking interval group (Table 3).

Table 2. Using an automatic milking system, the average number of milkings per day and the average milk yield per milking for dairy cows.

Milking Frequency	Mean	SE
2	34.25[a]	0.38
3	39.43[b]	0.37
4	42.02[c]	0.56
5	46.61[bc]	0.88

*Least squares means, within a row were significantly different (P < 0.05).

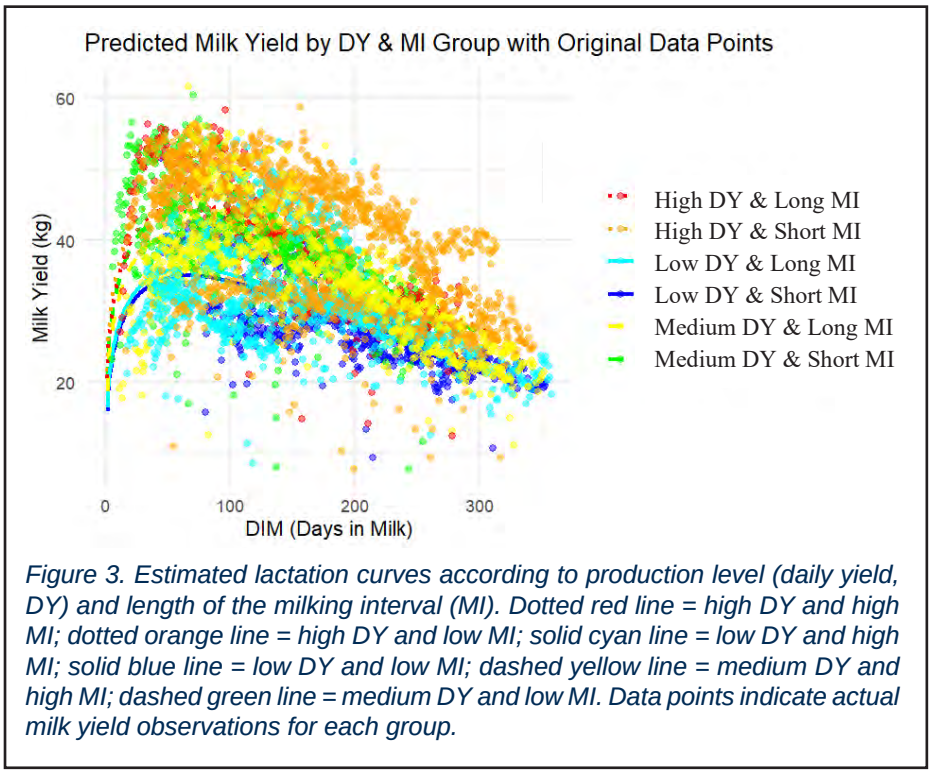

Figure 3. Estimated lactation curves according to production level (daily yield, DY) and length of the milking interval (MI). Dotted red line = high DY and high MI; dotted orange line = high DY and low MI; solid cyan line = low DY and high MI; solid blue line = low DY and low MI; dashed yellow line = medium DY and high MI; dashed green line = medium DY and low MI. Data points indicate actual milk yield observations for each group.

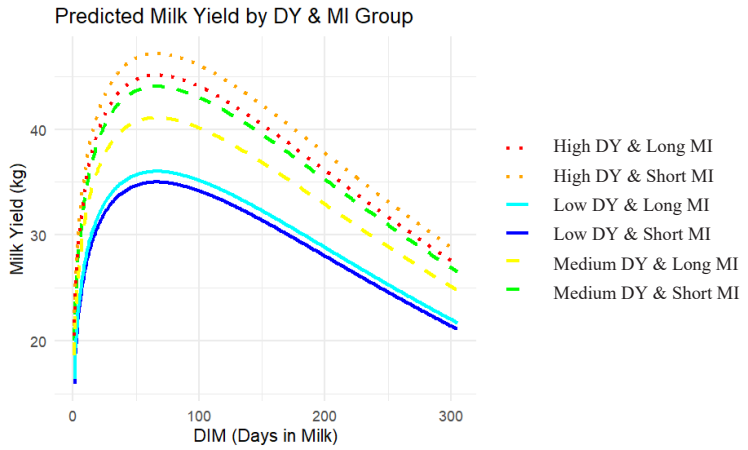

Figure 4. Estimated lactation curves according to production level (daily yield, DY) and length of the milking interval (MI). Dotted red line = high DY and high MI; dotted orange line = high DY and low MI; solid cyan line = low DY and high MI; solid blue line = low DY and low MI; dashed yellow line = medium DY and high MI; dashed green line = medium DY and low MI.

Table 3. Parameter estimates of lactation curves according to cow production level (DY) and length of the milking interval (MI).

			Cow for AMS	
Parameter	**DY**	**MI**	**Mean ± SE**	**Difference, %**
Ppeak, kg/d	High	Short	47.16 ± 0.15[a]	34.70
	High	Long	45.12 ± 0.18[b]	28.88
	Medium	Short	44.04 ± 0.13[c]	25.79
	Medium	Long	41.10 ± 0.24[d]	17.40
	Low	Short	35.01 ± 0.16[e]	Referent
	Low	Long	36.02 ± 0.17[f]	2.88
Dpeak, d	High	Short	66.65 ± 0.01	
	High	Long	66.65 ± 0.01	
	Medium	Short	66.65 ± 0.01	
	Medium	Long	66.65 ± 0.01	
	Low	Short	66.65 ± 0.01	
	Low	Long	66.65 ± 0.01	
305-DY, kg	High	Short	12,069 ± 13[a]	34.72
	High	Long	11,545 ± 12[b]	28.87
	Medium	Short	11,270 ± 7[c]	25.81
	Medium	Long	10,517 ± 10[d]	17.40
	Low	Short	8,958 ± 23[e]	Referent
	Low	Long	9,217 ± 17[f]	2.89
c	High	Short	0.0036 ± 0.0001	
	High	Long	0.0036 ± 0.0001	
	Medium	Short	0.0036 ± 0.0001	
	Medium	Long	0.0036 ± 0.0001	
	Low	Short	0.0036 ± 0.0001	
	Low	Long	0.0036 ± 0.0001	
Lactation, %	High	Short	26.66	
	High	Long	6.66	
	Medium	Short	13.33	
	Medium	Long	20.00	
	Low	Short	6.66	
	Low	Long	20.00	

Discussion

The results of milk composition were similar to those of Castro et al. (2022), showing a negative correlation between milk yield and fatty acids. As milk yield increased, the dilution effect led to a decrease in de novo fatty acids, mixed fatty acids, and preformed fatty acids. Regarding the differences in milk yield across parities, De Marchi et al. (2017) reported a significant interaction between milk yield and parity. Between the first and third parities, the average milk yield gradually increased, reaching its peak at the third parity. For cows beyond the third to fifth parities, the average milk yield remained stable at 31.3–32.4 kg. In the present study, the highest milk yield was observed in second-parity cows; however, there was no significant difference between the second and third parities.

Previous studies have suggested that the use of automatic milking systems (AMS), allowing cows to voluntarily choose their milking time and be milked more than twice a day, may help protect udder health and maintain high milk yield as parity increases. Stelwagen (2001) reported that compared to milking twice per day, milking three or more times per day could increase milk yield by 18%, with the highest yield observed at three and four milkings per day. This result is consistent with the findings of the present study. Previous research also indicated that changes in milking frequency have short-term effects by altering cellular activity to regulate milk secretion, while long-term effects involve changes in the number of mammary epithelial cells. As milk yield changes, the lactation curve is also affected.

The results of the lactation curve were consistent with those of Masía et al. (2020). Their study suggested that cows in the high daily yield + long milking interval group may have a larger udder capacity, allowing them to store more milk, or may be less sensitive to serotonin, enabling mammary epithelial cells to continuously synthesize milk, thus exhibiting high milk yield potential. This group accounted for approximately 7% of the population in both the present study and previous research. In the future, adjusting the herd structure to increase the proportion of this group while reducing the proportion of low-yield cows with short milking intervals could potentially increase 305-day milk yield by 28%, thereby improving the overall efficiency of automatic milking systems (AMS).

Conclusions

The automatic milking machine provides cows with multiple milking sessions per day, introducing a new parameter, milking interval, to the lactation curve. This results in a new grouping pattern for the cows. By gaining a deeper understanding of the milk production traits and lactation curve changes in cows using the automatic milking machine, it may be possible to identify cows best suited for the system through the new grouping model. This would allow for adjustments to the overall herd composition and the development of optimized management and selection strategies to improve equipment efficiency.

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