Assessing the impact of automatic milking systems on milk free fatty acid content in Taiwan

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Abstract

Using the Automatic Milking System (AMS) can increase milk yield and reduce labor, but the impact of AMS on the milking behaviour of cows in tropical regions like Taiwan, as well as its effect on the quality of farm raw milk, has not been thoroughly explored. Free Fatty Acids (FFAs) in milk are considered one of the indicators of milk quality, and an increase in FFAs can lead to off-flavours and spoilage in dairy products. This study examines the FFA content in individual cow's milk from different milking systems and investigates the influence of lactation stages and milking frequency on FFAs in raw milk. The experiment monitored milk samples collected from the Conventional Milking Parlour (CMP) and the AMS from 2021 to 2022, totalling 2,936 and 1,726 samples respectively. The FFA content in these samples was measured using Fourier Transform Infrared Spectroscopy (FTIR). The results show that the milk from cows using the AMS had significantly higher FFAs (1.17 mmol/100g milk fat, $P < 0.01$) compared to those using CMP (0.88 mmol/100g milk fat). The FFA levels in the early stage of lactation (0.82 mmol/100g milk fat) were significantly lower ($P < 0.01$) than in the mid (1.10 mmol/100g milk fat) and late stages (1.17 mmol/100g milk fat) of lactation. When comparing different milking frequencies, cows milked 2, 3, and more than 4 times a day in the AMS had FFAs of 0.89, 1.09, and 1.15 mmol/100g milk fat respectively, with the FFAs in milk from cows milked twice a day significantly lower ($P < 0.01$) than those milked 3 times or more. This study indicates that the difference in FFAs between AMS and CMP in Taiwanese farms is particularly evident in the early stages of lactation, which helps in further investigating the physiological changes in cows during this period. The study confirms that the use of AMS in Taiwanese farms affects milk quality, including cow-related factors and other management aspects. Although the introduction of AMS may initially impact parameters related to milk quality, these effects may reduce or disappear as the lactation stage progresses, the cows adapt, and milk volume increases. Additionally, farm managers and dairy farmers need to pay special attention to the cleaning and maintenance of AMS, as well as the proper cooling of raw milk, to maintain high-quality milk.

Keywords: free fatty acids, milk quality, automatic milking system, conventional milking parlour.
Presented at the ICAR Anual Conference 2024 in Bled at the Session 6: Evaluation and presentation of new parameters in herd management for dairy farms

Introduction

Using the Automatic Milking System (AMS) can increase milk yield and reduce labour, but the impact of AMS on the milking behaviour of cows in tropical regions like Taiwan, as well as its effect on the quality of farm raw milk, has not been thoroughly explored. Free Fatty Acids (FFAs) in milk are considered one of the indicators of milk quality, and an increase in FFAs can lead to off-flavours and spoilage in dairy products. Therefore, it is important to assess the impact of AMS on the FFA content in milk in order to understand its effect on milk quality in Taiwanese farms.

In Taiwan, dairy farms have increased their herd size, but labour shortages and aging are causing problems. These issues could be resolved by using an automatic milking system (AMS). Mechanization and automation will be the future management model for dairy farms. This study examines the FFA content in individual cow's milk from different milking systems, and investigates the influence of lactation stages and milking frequency on FFAs in raw milk.

Material and methods

The experiment monitored milk samples collected from the Conventional Milking Parlour (CMP) and the AMS from 2021 to 2022, totaling 2,936 and 1,726 samples respectively. The FFA content in these samples was measured using Fourier Transform Infrared Spectroscopy (FTIR). Recording each day's milk production, milking equipment used, stage of lactation, and milking process.

Statistical analysis was conducted using a mixed-effects model to assess the impact of milking system, lactation stage, and milking frequency on the free fatty acid content in milk. The milking system, lactation stage (early, mid, and late), and milking frequency (2 times, 3 times, and more than 4 times a day) were considered as fixed effects. Individual cows were included as random effects to account for the repeated measures on the same cow.

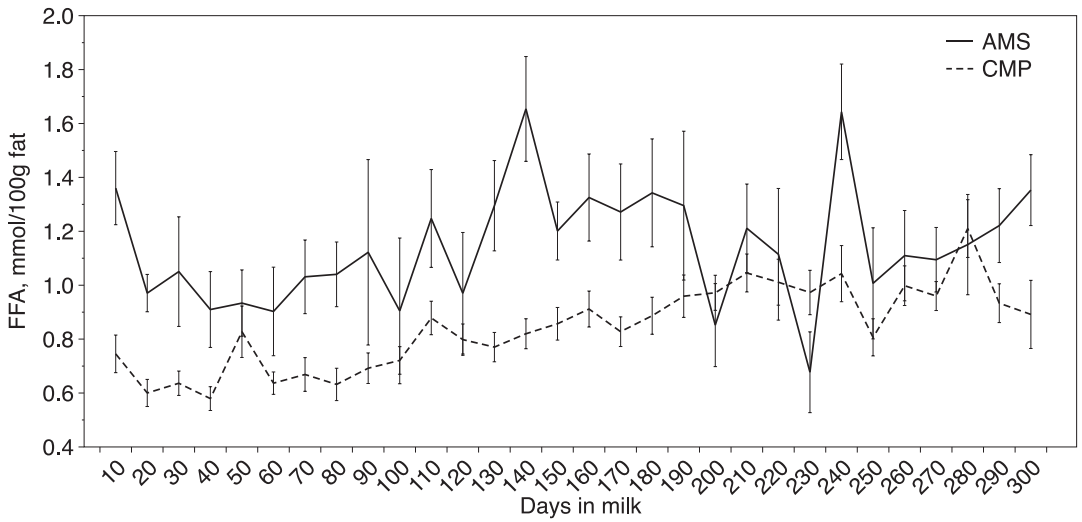

Figure 1. Free fatty acid (FFA) levels (mean ± standard error, mmol/100g fat) for automatic milking system (AMS, solid line) and conventional milking parlour (CMP, dashed line) over 15 days intervals through the entire 305 days of lactation.

The FFA content in milk samples was analyzed as the response variable, and the differences in FFA levels between the milking systems and across lactation stages and milking frequencies were evaluated using ANOVA. Post-hoc pairwise comparisons were conducted to assess specific differences between the levels of each factor. All analyses were performed using the SAS statistical software, and the significance level was set at alfa = 0.05.

Results

The difference between AMS and CMP for FFAs across days in milk is presented in Figure 1. Cows milked with AMS produced milk with greater FFAs content across lactation. The greatest difference between AMS and CMP was detected in 140 days after calving, whereas the smallest differences were observed after 200 days in milk. The milk from cows using the AMS had significantly higher FFAs (1.17 mmol/100g milk fat, $P < 0.01$) compared to those using CMP (0.88 mmol/100g milk fat) (Table 1). The FFA levels in the early stage of lactation (0.82 mmol/100g milk fat) were

Table 1. Least squares means and P-values of fixed effects in the statistical analysis of free fatty acid (FFA) concentration in milk.

Item	Group	FFA (mmol/100g milk fat)	P value
Milking system	AMS	1.17 ± 0.04^{a}	<0.0001
	CMP	0.88 ± 0.05^{b}	
Lactation stage	Early	0.82 ± 0.05^{a}	<0.0001
	Middle	1.10 ± 0.04^{b}	
	Late	1.17 ± 0.05^{b}	
Milkings	Control	0.97 ± 0.03^{ab}	<0.01
	2	0.89 ± 0.04^{b}	
	3	1.09 ± 0.05^{a}	
	4+	1.15 ± 0.08^{a}	
Milking system × Lactation stage	AMS × Early	1.08 ± 0.07^{ab}	<0.05
	AMS × Middle	1.23 ± 0.06^{a}	
	AMS × Late	1.20 ± 0.06^{ab}	
	CMP × Early	0.55 ± 0.11^{c}	
	CMP × Middle	0.97 ± 0.06^{b}	
	CMP × Late	1.13 ± 0.06^{ab}	
Lactation stage × Milkings	Early × Control	0.99 ± 0.08^{bcd}	<0.05
	Early × 2	0.61 ± 0.09^{d}	
	Early × 3	0.77 ± 0.10^{cd}	
	Early × 4+	0.89 ± 0.14^{bcd}	
	Middle× Control	0.97 ± 0.05^{bcd}	
	Middle× 2	1.03 ± 0.07^{abc}	
	Middle× 3	1.26 ± 0.08^{ab}	
	Middle× 4+	1.16 ± 0.12^{abc}	
	Late × Control	0.95 ± 0.05^{bcd}	
	Late × 2	1.05 ± 0.05^{abc}	
	Late × 3	1.26 ± 0.08^{ab}	
	Late × 4+	1.41 ± 0.16^{a}	

$^{a–d}$ Groups that do not share a common superscript letter are significantly different in their FFA levels (P<0.05).
AMS: automatic milking system; CMP: conventional milking parlour.
Early, Middle, and Late corresponds to 7 to 100 DIM (days in milk), 101 to 200 DIM, and 201 to 305 DIM, respectively. The 2, 3, and 4+ represent daily milking frequencies with AMS, while Control refers to twice daily milking using CMP.

significantly lower ($P < 0.01$) than in the mid (1.10 mmol/100g milk fat) and late stages (1.17 mmol/100g milk fat) of lactation.

When the milking frequencies of cows were compared, it was observed that cows milked twice a day had lower levels of FFAs in their milk fat (0.89 mmol/100g) compared to those milked three times per day (1.09 mmol/100g) and more than four times per day (1.15 mmol/100g) in an AMS system. This difference was found to be statistically significant with a p-value of less than 0.01. The results of the study indicate that the use of an automatic milking system can have a significant impact on the FFA.

Discussion

In previous study (Marchi *et al*., 2017), cows milked with AMS produced milk with greater FFA content across lactation. The greatest difference between AMS and CMP was detected within the first 80 days after calving, whereas the smallest differences were observed after 260 days in milk. This result is similar to our study, the smallest differences were observed during the late lactation in both experiments.

In this study, FFAs content was greater (+0.29 mmol/100 g milk fat) in milk from cows milked in AMS than CMP. The results show a similar trend to previous studies. Marchi *et al*. (2017) indicates the FFAs content in milk in AMS is higher than in CMP by 0.16 mmol/100 g milk fat. FFAs are produced through the degradation of milk fat into glycerol and FFAs via lipolysis reactions. Cooling and mechanical treatments of milk can disrupt the membrane of fat globules, leading to an increase in FFAs levels. This increase in FFAs is primarily associated with higher milking frequency or shorter milking intervals (Klei *et al*., 1997; Justesen and Rasmussen, 2000). Wiking *et al*. (2019) indicated that when the milking interval was less than 585 minutes, FFA levels increase as the milking interval shortens. More frequent milking leads to lower milk yield per milking. This is because the increased frequency of milking results in a higher air-to-milk ratio in the pipeline, reducing the stability of milk fat globules (MFG). When milk is pumped or agitated, mixing with air occurs, causing MFG rupture upon collision with air bubbles. As a result, membrane material and core fat are released into the milk plasma when air bubbles collapse or merge. Additionally, low quarter milk yields are linked to elevated (FFA) levels (Rasmussen *et al*., 2006). Additionally, milk from cows milked more than twice daily tends to have larger fat globules, which are more susceptible to lipolysis compared to smaller fat globules. Wiking *et al*. (2006) stated that the increase in FFA content at higher milking frequencies in AMS is attributed to both biological and mechanical factors. However, biological factors may have a greater impact, as spontaneous lipolysis is heightened. These findings suggest that the use of an automatic milking system, combined with a higher milking frequency, may contribute to increased levels of FFAs in milk.

This study suggests that there is a noticeable disparity in free fatty acids between automated milking systems and conventional milking parlors in Taiwanese farms, especially during the initial phases of lactation. This finding opens up opportunities for delving deeper into the physiological transformations occurring in cows during this specific period. Furthermore, exploring these differences may provide insights into potential improvements or adjustments to enhance milk quality and overall efficiency within dairy farming operations.

Conclusions

The use of AMS in Taiwanese farms may have a long-lasting impact on milk quality. Certain cow-related factors and management aspects may continue to be affected even as cows adapt and milk volume increases. Furthermore, farm managers and

dairy farmers need to pay special attention to the cleaning and maintenance of AMS, as well as the proper cooling of raw milk, to maintain high-quality milk.

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