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Original Article

Effect of lameness on daily milk yield in dairy cow

Piyanat Prasomsri[1*]

Abstract

Being aware of the impact of lameness on milk production is necessary to encourage farmers to pay more attention to this issue. Therefore, we need evidence that presents the production loss due to lameness. This can be applied to make the farmers realize the importance of lameness. This study aims to examine the impact of lameness on daily milk yield based on data obtained from cow level in a large dairy farm with 2 units in Thailand. The crossbred Holstein Friesian cows were evaluated for the degree of lameness by locomotion score (LS) monthly for 8 consecutive months. Cows were separated into non-lameness (LS1), subclinical lameness (LS2-3) and clinical lameness (LS4-5). The cows' data which included lactation number, days in milk, lameness, mastitis, metritis, other medical records and milk production in kg/day/cow was collected by Dairy Champ software. The data analysis was performed by univariable analysis at $P<0.1$ without correlation with other variables more than 30% and multivariable analysis was performed simultaneously. Variables associated with daily milk yield were examined for interaction at $P<0.05$. The predictability of the equation was examined. 305 days of milk production was simulated by using Monte-Carlo technique. The 856 data sets from 184 cows were recorded for daily milk yield and LS. The non-lameness, subclinical and clinical lameness groups were 49.6, 43.7 and 6.7%, respectively. The average of 305 days milk yield of the non-lameness group in unit 1 and 2 was 6,426.9 ± 1,544.8 and 4,651.6 ± 1,420.1 kg, respectively. The simulation data showed a decrease in 305 days of milk yield (1,266.2 ± 467.5 kg) in cows where lameness occurred throughout the 1st lactation when compared with a healthy cow. The clinical and subclinical lameness in the first three months of the lactation period reduced the daily milk yield by 1.2 ± 0.5 and 0.2 ± 0.6 kg, respectively. In addition, the occurrence of clinical and subclinical lameness with clinical mastitis reduced the daily milk yield by 1.6 ± 0.9 and 0.5 ± 1.0 kg, respectively. This study showed evidence of milk loss caused by lameness. This can motivate farmers to take action on lameness and preventive measures should be planned to reduce the production loss in the farm.

Keywords: Lameness, Locomotion score, Dairy cow, Milk yield

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Introduction

Lameness is a clinical disorder of the legs and hooves. It is considered a major health problem in dairy cows (Ettema and Østergaard, 2005, FAO, 2009) and is widespread in dairy farms. The prevalence of lameness around the world is around 23 – 32% (Hernandez *et al*., 2002, Espejo *et al*., 2006, Sarjokari *et al*., 2013, Popescu *et al*., 2013a). In Thailand, Wongsanit *et al*. (2015) reported the prevalence of lameness in dairy cows as 21.98%. Lameness can be caused by infection and non-infection, lack of regular hoof trimming, traumatic injury and management factors such as nutrition (Faye and Lescourret, 1989). In addition, cow-level factors also affect hoof health, such as lactation numbers, milk production, breed and genetics (Coulon, 1996).

Lameness in high-production cows can affect farm productivity (Nordlund *et al*., 2004). Lameness reduces milk production significantly, both qualitatively and quantitatively (Sulayeman and Fromsa, 2012). Warnick *et al*., (2001) found that the milk yield of a lame cow decreases significantly. In addition, Archer *et al*. (2010), found that durations of severe lameness (locomotion score 4-5) at 4 months, 6 months and 8 months decreased milk yield by 0.5, 0.7, and 1.6 kg/cow/day, respectively.

The best method for examining a lame cow in dairy herds, which is based on lesions found, is examination during routine hoof trimming. However, the disadvantage is that this is labor-intensive and time-consuming and the operator must have good trimming skills. These disadvantages are the cause of farmers' neglect of the lameness problem (Leach *et al*., 2010). Therefore, other methods have been developed to examine lameness that are easier and more convenient. A widely popular method is locomotion scoring techniques (Sprecher *et al*., 1997). This method, which is related to the degree of lameness, is based on gait characteristics. Although the information can be presented to farm owners more easily, one of the major obstacles is the inability to motivate them to realize the importance of lameness. The expression of lameness in the form of milk loss may be able to motivate and realize the decision-making of farmers to take preventive measures for lameness. However, the impact of lameness on milk production in Thailand has not been studied. The objective of this study is to illustrate the impact of lameness on milk yield using data obtained from a Thai dairy farm.

Materials and Methods

Farms and dairy cows: A dairy farm was used in this study. This farm had two units and was located in Thailand's central region. The cows in both units were crossbred Holstein-Friesians. The farm structure was identical for both units, including the housing design, environment, udder health and milking protocol, milking machine, treatment procedure, feed materials, feed formulation and feeding management. Total mixed ration (TMR) feeding was used in both units. Each unit, however, necessitated its own set of staff, such as animal husbandry, milkers and workers. Milking cows were fed twice daily and divided into groups based on milk quantity. Cows were milked daily at 4.00 a.m., and 2.00 p.m. The floor of the housing was made of concrete. Dairy Champ® was used to record the farm data (Dairy Champ professional, University of Minnesota, St. Paul, USA).

Data collection: The data collecting period, which was planned for the convenience of all authors, was from March to October 2019. All milking cows in that period, which had never previously been evaluated for lameness, were recruited to score locomotion and gather individual data. All milking cows were examined for locomotion by the first author. The criteria and clinical use to score the lameness have been clearly described by Sprecher *et al*. (1997) (Table 1). After afternoon milking, the cows were scored while walking back to the housing independently on a flat, non-slip concrete pathway covered with rubber that was at least 4-5 meters long and 2-3 meters wide. Each cow was led through the scoring area, one at a time, and locomotion was evaluated based on back posture and gait while standing and walking (Table 1). The scorer was in a position where the cow could be obviously seen. The scoring was done monthly for 8 consecutive months. Milk yield measurement (kg/cow/day) and locomotion scoring were done on the same day. Individual cow data including lactation number, days in milk (DIM) clinical mastitis and endometritis was collected with data from the cattle identification card and the Dairy Champ ®. If any cow showed one or more clinical signs of systemic infection during the examination, such as fever, depression or anorexia, all its data would be excluded from this study.

Data analysis: Data was analyzed by IBM® SPSS® version 22 (SPSS: An IBM Company, New York, United States). The descriptive analysis and continuous data variables were examined to check the normal distribution using the histogram. The correlation was examined among the variables, including unit of the farm, lactation number, day in milk, locomotion score, clinical mastitis and endometritis. Univariable analysis was performed using variables with analytical results correlated with milk yield at $P \leq 0.1$ and there was no correlation with other variables greater than 30% that were further analyzed in a multivariable analysis. In the univariable analysis, endometritis did not correlate with decrease in milk yield. In addition, the number of abortions and other health problems were very low when compared to the total amount of data. Therefore, it did not take further analysis.

In this analysis, milk yield (kg/cow/day) was the response or dependent variable (y) whereas the unit of the farm, lactation number, day in milk, locomotion score, clinical mastitis and endometritis were the predictor or independent variables (x). The data was analyzed using a generalized linear mixed model and it was determined that the fixed effect was the unit of the farm, lactation number and day in milk. The cow identification number was random effect data.

The equation is

$$Y_{ij} = \alpha_{ij} + \Sigma\beta_{ij}X_{ij} + \Sigma\Delta_j Z_j + v_j + e_{ij}$$

$$v_j \sim N(0, \sigma^2_v)$$

$$e_{ij} \sim N(0, \sigma^2_e)$$

where Y_{ij} = milk yield at day i of cow j (test day milk yield; TDY); α_{ij} = intercept value at day i of cow j; $ß_{ij}$ = coefficient of X_{ij}; X_{ij} = exposure at scoring date; Δ_j = coefficient of Z_j; Z_j = exposure of cow j; Σ = sum of exposures at 1-n; v_j = error of the cow; e_{ij} = error from other variables in the equation assuming the error has a normal distribution and the mean of error equal to zero.

Table 1 Scoring criteria used to evaluate a lameness score and clinical description (Sprecher *et al.*,1997).

Lameness score	Clinical description	Assessment criteria
1	Normal	The cow stands and walks with a level-back posture. Her gait is normal.
2	Mildly lame	The cow stands with a level-back posture but develops an arched-back posture while walking. Her gait remains normal.
3	Moderately lame	An arched-back posture is evident both while standing and walking. Her gait is affected and is best described as short-striding with one or more limbs.
4	Lame	An arched-back posture is always evident and gait is best described as one deliberate step at a time. The cow favors one or more limbs/feet.
5	Severely lame	The cow additionally demonstrates an inability or extreme reluctance to bear weight on one or more of her limbs/feet.

The variables correlating with milk yield in the final equation were examined. The interaction between the variables was examined individually by pairs of variables. The interaction that was statistically significant at $P \leq 0.05$ was kept in the equation. If there was no supportive or counter influence, the confounding of each variable was further examined by experimenting with each variable entering and exiting the equation one by one. The effect of the remaining variables in the final equation did not change milk yield more than 20%. The fitting of the model was checked for predictiveness by the distribution curve. The normality of the error and the graph between error value and milk yield (kg/cow/day) were estimated from the equation.

The effect of the influence of variables that were related to the milk yield in the final equation were collected and the Yij value was estimated by the Monte-Carlo simulation technique by the @Risk® program (Palisade Corporation, Ithaca, New York, USA). Yij was used to generate the lactation curve in any circumstances based on the impact of different factors on milk yield. Milk yields in each unit, non-lameness, subclinical lameness and clinical lameness group were compared for each lactation. The lactation was separated into three stages: the first, second and greater than or equal to the third. Lactation curves were generated under non-lameness, subclinical lameness, clinical lameness and clinical mastitis scenarios.

Results

The 966 initial data sets were filtered down to the 856 final data sets from 184 cows. They were separated into two units: 128 cows in unit 1 and 56 cows in unit 2. The first lactation included 80 cows, accounting for 43.48 percent of the total (391/856). There were 51 cows in the second lactation, accounting for 27.72% (222/856) and 53 cows in the greater than or equal to third lactation, accounting for 28.80% (243/856). The distribution of lactation is shown in Fig. 1. From the locomotor score (LS) data, 49.6% (425/856) were LS1 (non-lameness), 43.7% (374/856) were LS2-3 (subclinical lameness), and 6.7% (57/856) were LS4-5 (clinical lameness). There was data of cows with mastitis as 8.9 % (76/856). The lactation curve of the non-lameness cow in each lactation and each unit were simulated (Fig. 2-3). The peak milk yield (kg/cow/day) in unit 1 was 25.8 ± 5.8, 26.9 ± 6.2 and 25.5 ± 6.0 and the 305-day milk yield (kg) was 6,093.9 ± 1,746.6, 6,426.9 ± 1,544.8 and 5959.3 ± 1,373.5 in, the first, second, and greater than or equal to third lactation, respectively. The peak milk yield in unit 2 (kg/cow/day) was 18.6 ± 5.7, 19.7 ± 5.8 and 18.2 ± 5.4 and the 305-days milk yield (kg) was 4,348.7 ± 1,360.1, 4,681.6 ± 1,420.1 and 4,214.1 ± 1,245.1 in the first, second, and greater than or equal to third lactation, respectively. The average daily milk yield (kg/cow/day) was 18.9 ± 0.5 in unit 1 and 13.1 ± 0.9 in unit 2.

The variables in the final multivariable analysis equation were farm unit, lactation number, days in milk, lameness and clinical mastitis. The inter-variable interactions were significantly associated with daily milk yield ($P<0.05$) as shown in Table 2. A residual plot of the final equation from the analysis revealed that the equations used in this study were suitable. (Fig. 4).

Cows in the first lactation with clinical lameness on all 305 milking days had the greatest loss in milk yield (1,266.2 ± 467.5 kg. or 4.1 ± 1.53 kg/cow/day) (Fig. 5). The differences in milk yield between lactation, degree of lameness and lactation number are shown in Fig. 6. The milk yield (kg) in the first, second and greater than or equal to third lactation was 4,820.4 ± 1596.2, 6,207.9 ± 1602.1 and 5,990.9 ± 1532.7, respectively.

Furthermore, the amount of milk loss will be affected by the duration of lameness (Table 3). Clinical mastitis had a variable effect on milk yield in each lactation, with the greatest milk loss averaging 319.0 ± 926.0 kg when compared to a healthy cow.

Cows usually reach their peak milk yield during the first three months of lactation. Clinically lame cows, on the other hand, reduced milk yield by 1.2 ± 0.5 kg/cow/day. When clinical lameness coincided with clinical mastitis, the milk yield lost 1.6 ± 0.9 kg/cow/day. Cows with subclinical lameness lost 0.2 ± 0.6 kg of milk per day. When subclinical lameness coincided with clinical mastitis, the milk yield lost 0.5 ±1.0 kg/cow/day. As illustrated in Fig. 7, the early lactation cow with only lameness, only clinical mastitis and lameness with clinical mastitis had an effect on milk yield loss.

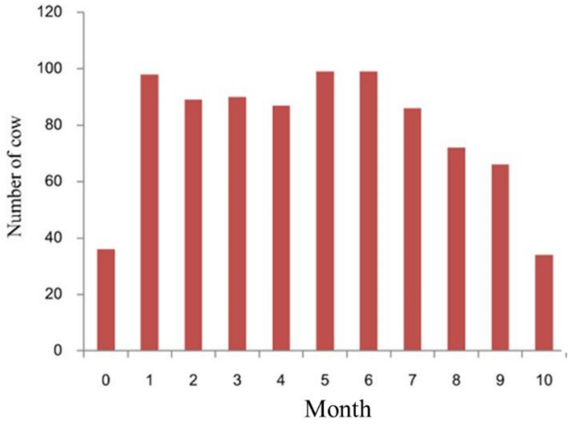

Figure 1 Cow distribution by Days in milk.

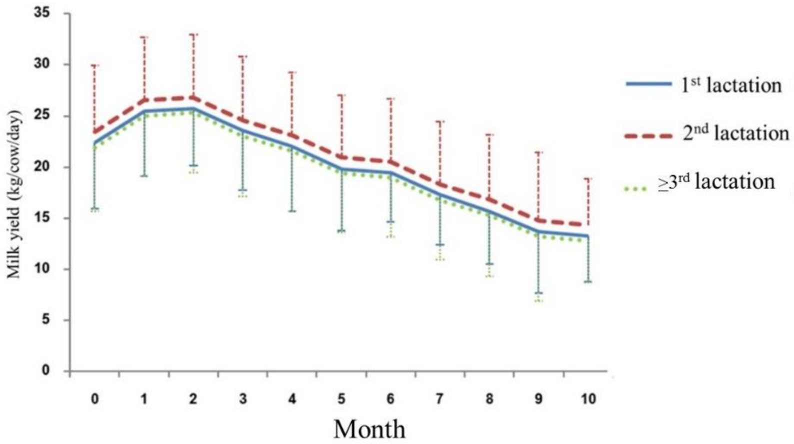

Figure 2 The lactation curve of the cows without lameness in Unit 1. In the first (continuous line), second (dash line) and greater than or equal third lactation (dotted line) of cows by days in milk from calving to 10 months postpartum.

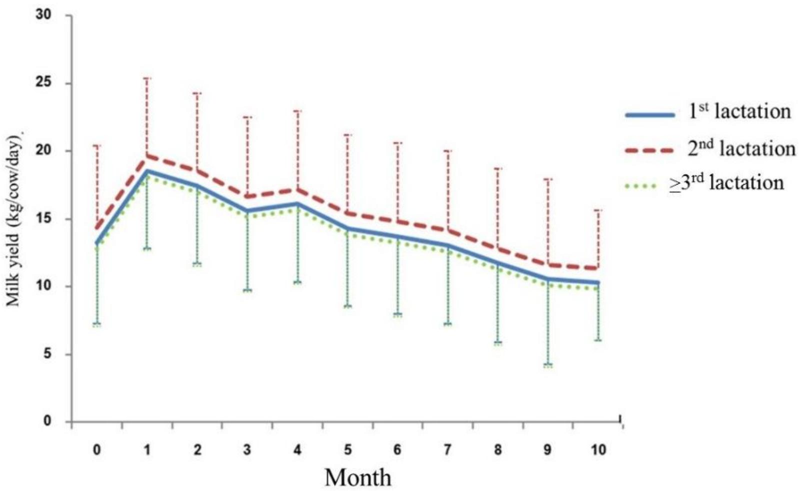

Figure 3 Lactation curve of cattle without lameness in Unit 2. first (continuous line), second (dash line) and greater than or equal to third lactation (dotted line) of the cows by day in milk from calving to 10 months postpartum.

Table 2 Association between different variables on milk yield (kg/cow/day) from generalized linear mixed model. Cows were randomly assigned into the equation.

Parameter	Mean effect	SE	Significant	Lower 95% CI	Upper 95%
Fixed effect					
Intercept	2.91	3.32			
Farm					
1	2.97	1.72	0.08	-0.40	6.34
2	Baseline	.	.	.	.
Lactation					
1	-3.82	1.56	0.01	-6.88	-0.76
2	0.71	1.70	0.68	-2.62	4.04
3+	Baseline	.	.	.	.
Month of lactation					
0	12.72	3.63	0	5.60	19.84
1	15.17	3.27	0	8.76	21.58
2	11.09	3.29	0.001	4.63	17.55
3	11.54	3.34	0.001	4.97	18.10
4	14.40	3.32	0	7.88	20.91
5	12.38	3.26	0	5.97	18.79
6	5.66	3.33	0.09	-0.87	12.19
7	6.61	3.39	0.05	-0.05	13.28
8	7.63	3.48	0.03	0.80	14.45
9	10.50	3.95	0.01	2.74	18.26
10	Baseline	.	.	.	.
Lameness					
1 (Normal = 1)	-0.11	1.07	0.92	-2.21	1.99
2 (Subclinical lameness = 2,3)	0.12	0.97	0.91	-1.80	2.03
3 (Clinical lameness = 4,5)	Baseline	0	.	.	.
Mastitis					
0	7.06	2.69	0.01	1.78	12.33
1	Baseline	0	.	.	
Farm*Month of lactation[a]			0.01		
Lameness*Lactation[a]			0.01		
Mastitis*Month of lactation[a]			<0.001		
Random effect		Variance		SE	
Resudual		9.35		0.52	
Cow		23.77		2.68	

[a]Detailed information is not presented.

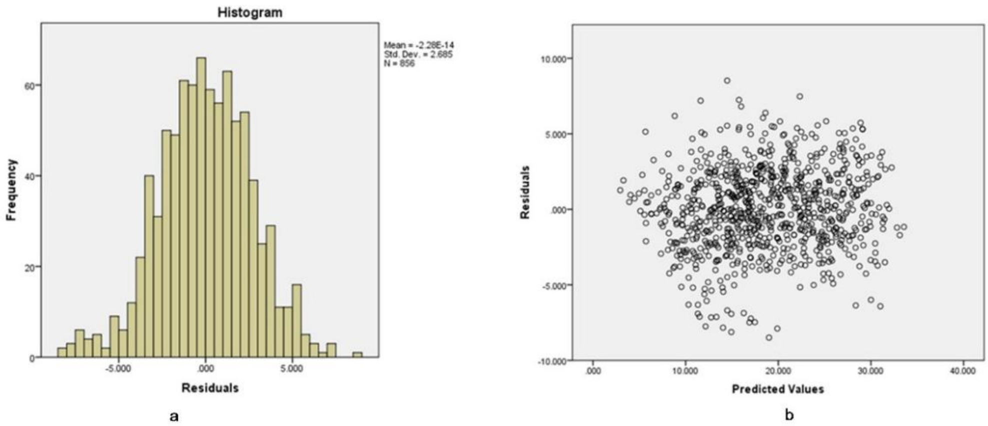

Figure 4 The normal distribution curve of the residual values (a) and the graph showing the relationship between the residual values and the estimated daily milk yield from equation (b).

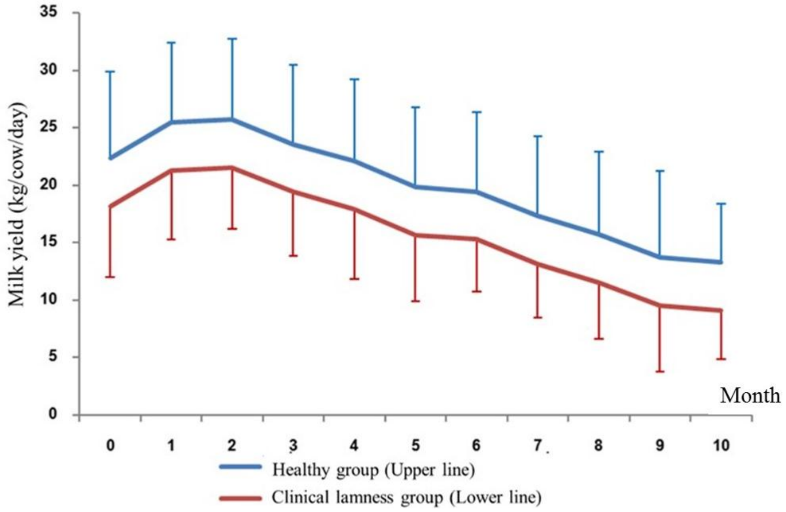

Figure 5 Lactation curve of the first lactation in Unit 1 between Clinical lameness group (LS3; lower line) and healthy group (LS1; upper line).

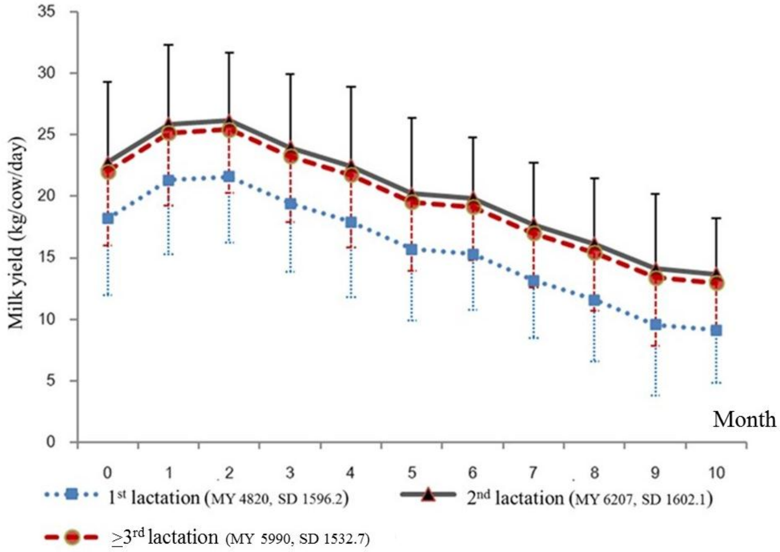

Figure 6 Lactation curve of clinical lameness (LS3) in Unit 1. The first (continuous line), second (dash line) and greater than or equal to the third (dotted line). Milk yield (MY) represents the mean 305-days milk yield (kg).

Table 3 Cumulative milk loss in 305 days (min- max at 95% CI) calculated from clinical lameness (LS3) with duration of lameness (months) in the first lactation in Unit.

	Months of chronic lameness						
	1	2	3	4	5	6	7
Milk production loss (Kilograms)	127.2 (54.18-199.41)	254.3 (108.35-398.82)	381.5 (162.53-598.23)	508.6 (216.71-797.64)	635.8 (270.88-997.05)	762.9 (325.06-1196.46)	890.1 (379.24-1395.88)

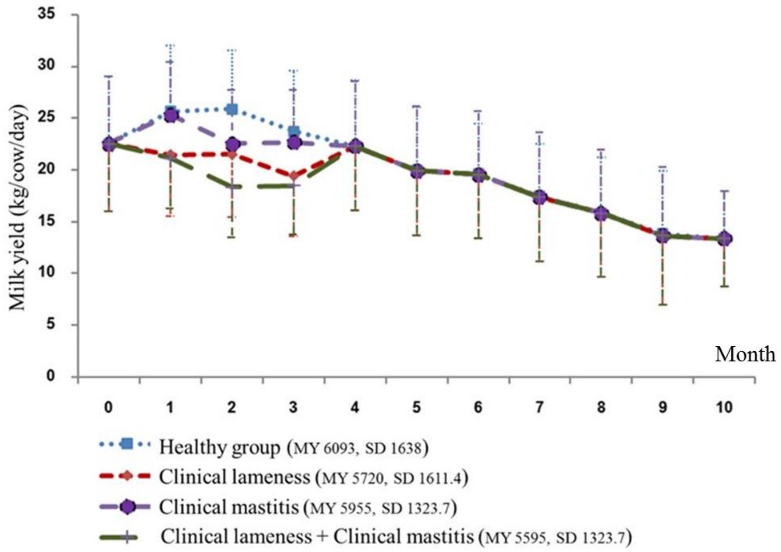

Figure 7 Lactation curve of healthy and lameness group. Healthy group (dotted line), clinical lameness (diamond with dash line), clinical mastitis (square with dash lines) and clinical lameness with clinical mastitis (largest dash line).

Discussion

Both units reached their peak milk yield in the first to second month after calving, according to the lactation curves in this study. These findings were consistent with the study of Kamidi (2005), which reported that the peak milk yield of Holstein-Friesian cows occurred 4 to 8 weeks after calving. Cows in the second lactation of both units produced more total milk than others, followed by the first and third or more lactations, respectively. However, no statistically significant differences in persistency were found between lactations or farm units.

In this study, clinical lameness was shown to have the greatest decrease in 305-day milk yield at 1,266.2 ± 467.5 kg in the first lactation as compared to the non-lameness group. Sulayeman and Fromsa (2012) reported that lameness had a significant impact on milk production in regard to both quantity and quantity. Warnick *et al*. (2001), showed a decrease in milk production after clinical lameness had occurred for approximately 2 weeks or more in comparison to non-lameness cows, particularly in the second lactation and beyond. Furthermore, Hernandez *et al*. (2002), reported that cows with lameness produced less milk than healthy cows. In comparison to the study of Archer *et al*. (2002), on the association between milk production and locomotion score, lameness had an effect on decreasing milk yield and it was going to decline gradually if lameness was not resolved. This study found that cows in the first lactation with clinical lameness produced 4,827.7 ± 1,614.4 kg of milk per lactation, whereas healthy cows produced 6,093.9 ± 1,746.6 kg of milk per lactation. According to these findings, cows with a high locomotion score produced less milk and appeared to continue losing as long as lameness persisted. Laven (2006) revealed that cows with chronic lameness had hoof pain caused by hyperalgesia. This discomfort was causing problems walking to the feed bunk and leading them to reach at the feed bunk more slowly than the other cows. In addition, the cows lost their appetite due to the high release of prostaglandin at the peripheral nerve ending. Bach *et al*. (2006), found that a high locomotion score had no effect on eating time at the feed bunk but it did alter the position from which cows accessed the feed bunk. However, high locomotion scores, particularly those with locomotion score 3 or higher, were associated with lower dry matter intake, which can result in negative energy balance, decreased milk production and involuntary culling (Collard *et al*., 2000). Moreover, farmers may have to spend more money on labor and lameness treatment (Enting *et al*., 1997).

According to the findings of this study, the milk yield of clinically lame cows in the first lactation was lower than the second and greater than or equal to the third lactation (Fig. 6). Plaizier *et al*. (2007), reported that young cows were susceptible to subacute ruminal acidosis (SARA). Li *et al*. (2013), found that cows in first lactation were at a higher risk of subacute ruminal acidosis than those in subsequent lactations due to a critical change in their nutrition. Oetzel (2007) revealed that the first lactating cows were stressed due to hormonal and physiological changes caused by having to shift to a new cow group and changing feed management. Furthermore, Fyksen (2001) reported that subacute ruminal acidosis, which was the cause of laminitis and milk loss, was more susceptible in the first lactation than in older cows.

Although the cows produced their peak milk in the first three months of lactation, they can be severely affected if any disorder occurs, particularly in the first lactation. This study found that cows with clinical lameness or clinical lameness combined with clinical mastitis produced less average milk than healthy cows throughout the same period. According to the study of Rajala-Schultz *et al*. (1999), cows with clinical lameness showed a 1.5 - 2.8 kg/cow/day decrease in milk yield in the first two weeks after lameness was identified. In comparison to this study, cows lost 0.2 ± 0.6 kg/cow/day in milk yield due to subclinical lameness during the first three months of lactation. When subclinical lameness coincided with clinical mastitis, milk yield loss increased by up to 0.5 ± 1.0 per kg/cow/day. Cows with clinical lameness lost 1.2 ± 0.5

kg/cow/day in milk yield. If clinical lameness occurred concurrently with clinical mastitis, milk yield loss increased by up to 1.6 ± 0.9 kg/cow/day.

This study found that clinical mastitis was a cofactor that was influenced by decreasing milk production. Milk production loss in 305-day of cows that clinical mastitis occurred in early, middle and late lactation were 131.5 ± 257.9, 62.4 ± 279.0, and 30.3 ± 285.0 kg, respectively. Clinical mastitis significantly reduced milk yield in early lactation when compared to healthy cows.

There might be some missing farm management information related to farm productivity in this study. Although both units had the same farm management, the staff in each unit might have differed in terms of policymaking or farm management skills. As a result, there were differences in three main health issues consisting of reproductive health, udder health and hoof health in each unit. Staff in the dairy farm was more than just having an employee in each position. Ideally, it was having productive, high-performing employees and engaged employees (Dust *et al*., 2018). Individual technical skills and knowledges of employees in each position were required and important in livestock production (Bitsch *et al*., 2007). This aspect could explain the difference in the characteristics of lameness, mastitis and milk yield between the two units in this study. According to the authors' opinion, the staff of unit 1 exhibited better skills and knowledge in their job than unit 2. This study, however, did not scientifically investigate the level of knowledge, expertise and skill in dairy farm management of the staff in both units.

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