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Research article

First-lactation milk fat-to-protein ratio in tropically-raised dairy cows: environmental and genetic influences

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Abstract

The objective of this research was to determine factors influencing to fat-to-protein ratio (FPR) in the first-lactation of dairy cows raised in tropical climate. The dataset included fat percentage, protein percentage, and FPR values from 160,506 records representing 23,201 first-lactation cows that calved between 1993 and 2017. These cows originated from 508 farms in all regions of Thailand. The data were analyzed using the general linear model procedure in the R program. The models included herd-year-season of records, and breed group as fixed effects, and age at calving and days in milk as covariates. The result showed that the average fat percentage, protein percentage, and FPR were 3.560±0.960, 3.130±0.390 and 1.150±0.330, respectively. Effects of herd-year-season of records, breed group, age at calving, and days in milk were highly significant for all traits (P<0.05). Cows containing less than 87.50% Holstein Friesian (HF) blood gave fat percentage, protein percentage and FPR higher than 93.75%HF and 87.50-93.74%HF. The FPR was highest in the winter and lowest in the summer. In conclusion, present results indicated that fat percentage, protein percentage and FPR are clearly influenced by both genetic and non-genetic factors. Therefore, development of different breed, feeding systems, season of recording and herd is needed to produce quality of fat and protein percentage.

Keywords: Dairy cattle, Milk fat-to-protein ratio, Tropical

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INTRODUCTION

Thailand is in a tropical zone, so the weather there is hot and humid year-round. There is a negative impact on feed intake, reproduction, and milk production in dairy cattle, especially in high lactating cows, because of the stress and discomfort caused by these conditions (Bouraoui et al., 2002).

Milk yield is the most important characteristic for Thai dairy farmers, as it directly correlates with income. The dairy that provided the high milk yield always led to problems in health and fertility traits (Oikonomou et al., 2008; Oltenacu and Broom, 2010). From the health and fertilities problem, many countries interested to select milk composition such as fat and protein percentage have been used as indicators of milk quality and accounted for in the pricing of raw milk sold by producers, with a high fat content in milk being favored by dairy processing plants (Thai Milk Board, 2016). Milk fat are derived from four major pathways: directly from the diet, de novo synthesis in the mammary gland, formation in the rumen via biohydrogenation or bacterial degradation, and release from body fat stores (Chilliard et al., 2000). Changes in milk fat composition during lactation suggest alterations in the activity of these pathways and were associated with variations in the energy status of the cow (van Knegsel et al., 2005). The fat-to-protein ratio (FPR) was proposed as an energy status indicator (Friggens et al., 2007; Buttchereit et al., 2012). A high FPR indicates a low or negative energy balance (NEB), which is the result of a combination of an increased fat percentage and a decrease in milk and protein yield.

Negative energy balance means not enough energy to be used and also affects the amount of milk decreased. More animals will be eliminated from the herd if the lack of energy balance. Therefore, FPR is an easy and low-cost method. When dairy cattle lack energy balance, it leads to increased lipolysis and uptake of fatty acids mobilized from the body, resulting in consequently increased fat synthesis. At the same time, inadequate intake of fermentable feed, energy-spending carbohydrates can cause an insufficient protein synthesis through ruminal bacteria. The flow of amino acids to the udder is compromised and decreased in milk protein content (Tetens et al., 2013). In Thailand, there are several report and investigate the topic of FPR in Thai tropical Holstein dairy cattle. Puangdee et al. (2016) Buaban et al. (2016) Puangdee et al. (2017). In the study of Buttchereit et al. (2011) examining the genetic relationship between daily energy balance and FPR it was shown that the correlation was high at the beginning of lactation and decreased toward zero at 180 DIM. The authors concluded that FPR could be a good indicator of energy balance during early lactation, that is, during the time of energy deficit. Cows with a negative energy balance mobilize fat from body reserves to compensate energy deficiency (Loker et al., 2012)

The objective of this research was to determine the factors affecting fat percentage, protein percentage and FPR in dairy cattle under a tropical climate in Thailand

MATERIALS AND METHODS

Data management

The retrospective data used in the present study were taken from the Bureau of Biotechnology for Livestock Production, Department of Livestock Development (DLD) in Thailand. A total of 160,506 of the test-day records of 23,201 cows from 508 herds in all parts of Thailand were used in the study. Records of test-day fat and protein percentage were used to analyzed, FPR was calculated as the ratio of test-day fat percentage to protein percentage. The ratio of FPR implied to indicated the risk of metabolic disorders of the cows, the fat protein ratio was analyzed interpreted. The data were divided into three groups including acidosis risk (the ratio < 1.0), normal condition (the ratio = 1.0-1.5), and ketosis risk (the ratio > 1.5).

After extraction, data was edited following conditions; age at first calving ranged from 18to 48 month. Days in milk were restricted to between 5 and 305 d. The first test date was in the interval between 5 and 60 d. Daily milk yield was between 1 and 45 kg. Each cow had at least 5 test-day records, and a minimum of 5 records was defined for each herd-year-season of recording.

Statistical analysis

All consideration traits including %fat, %protein, and FPR of the milk samples were analyzed in this study. The models included herd-year-season of recording, and breed group of cow as fixed effects, and age at calving and days in milk as covariates in the models. Thailand has 3 seasons were defined as summer (March-May), rainy (June-October), and winter (November-February) (Meteorological Department, 2022). In addition, breed groups of cows were classified by HF into three groups, including 1) > 93.75%HF, 2) 87.50 to 93.74% HF, and 3) < 87.50% HF cows (adapted from Buaban, 2015) because the Thai dairy population consists of more than 283,000 crossbred cows in 2018, mostly raised by smallholders (Buaban et al., 2015). On average, to be robust in the tropical environment, each cow has 87.50 to 93.74%Holstein-Friesian (HF) genes and 6.25 to 12.50% Bos indicus, including Sahiwal, Brahman, and Thai native cattle The statistical model was analyzed as follows:

$$y_{ijk} = \mu + HYS_i + BG_j + b_1(Age)_{ijk} + b_2(DIM)_{ijk} + e_{ijk}$$

Where: y_{ijk} is individual observation of consideration traits; μ is overall means; HYS_i is the combination of herd×year×season of recording (i=1, 2,...,22,860); BG is the fixed effect of breed groups of the cow (j=> 93.75%HF, 87.50 to 93.74% HF, and < 87.50%HF); b_1 is the regression coefficients associated with age; b_2 is regression coefficients associated with DIM; $(Age)_{ijk}$ is age at calving as covariate; $(DIM)_{ijk}$ isdays in milk as covariate; e_{ijk} is random effect. The collected data were first analyzed for descriptive statistics analysis. The data was analyzed with Generalized Linear Models by statistical software using the nlme function in R program (R Core Team, 2020) was used to investigate the effects for all traits. It was noticed that a significant difference was reported at $P < 0.05$.

RESULTS

Means and standard deviations of the percentage of fat, protein, and FPR in the first lactation of Thai dairy cow are shown in Table 1. The percentage of fat, protein, and FPR were 3.560 ± 0.960, 3.130 ± 0.390 and 1.150 ± 0.330, respectively.

Table 1 Number of records, mean, standard deviation, for the traits

Traits	Number of records	Mean± SD
% Fat	160,506	3.560 ± 0.960
%Protein	160,506	3.130 ± 0.390
Fat to protein ratio	160,506	1.150 ± 0.330

The FPR reflecting the mobilization of fat from body reserves has been associated with several different metabolic disorders. FPR > 1.5 indicates negative energy balance problems (n = 18,263), whereas rumen acidosis is suspected when FPR is < 1.0 (n = 47,323). According to the results, the average of FPR in this study is still in a normal range (n = 94,940) (Figure 1). Therefore, cows in early lactation have a tendency to mobilize fat from body reserve to cope with insufficient energy from the feeds, which leads to negative energy balance status (Puangdee et al., 2017).

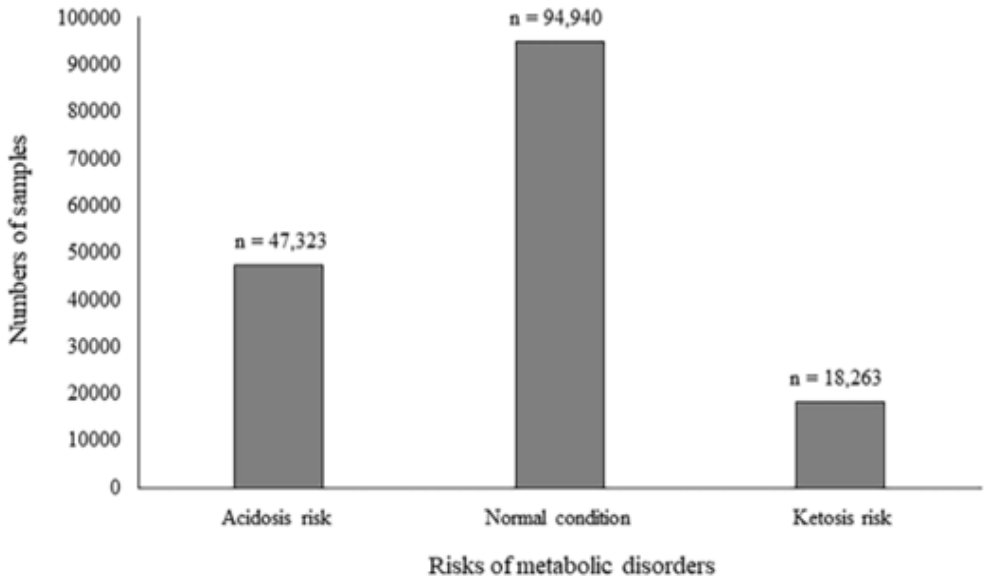

Figure 1 The prevalence of metabolic disorders of dairy cows that consideration form FPR. The data were divided into three groups including acidosis risk (the ratio < 1.0), normal condition (the ratio = 1.0-1.5), and ketosis risk (the ratio > 1.5).

The breed group significantly influenced the percentage of fat, percentage of protein, and FPR was significantly different (P<0.05) (Table 2). The FPR in Thai dairy cow: > 93.75%HF, 87.50 to 93.74%HF and <87.50%HF were 1.153±0.002, 1.155±0.002 and 1.160±0.002, respectively. The cows with HF levels below 87.50%HF gave FPR were significantly higher than those with HF levels between 87.50 and 93.74% (P<0.05).

Table 2 Least square means and standard error for the effect of breed groups and season of recording on fat percentage, protein percentage and fat to protein ratio traits

Factors	Number of records (records)	Number of cows (heads)	%Fat	%Protein	Fat to protein ratio
Breed groups					
>93.75 %HF	47,500	6,890	3.550±0.006[b]	3.117±0.002[b]	1.153±0.002[b]
87.50 to 93.74%HF	74,307	10,588	3.558±0.005[b]	3.118±0.002[b]	1.155±0.002[b]
<87.50%HF	38,699	5,723	3.608±0.006[a]	3.147±0.002[a]	1.160±0.002[a]

[a, b, c] Subscripts with different letters within columns significantly (P<0.05). The data were presented as LSMean±SE.

The herd-year-season of recording effects on percentages of fat, protein, and FPR was significantly different ($P<0.05$). All herds were located in different parts of the country, so each one was influenced by the different effects of environment, management, and feed (Amimo et al., 2007). Effect of year of calving, similar conclusions were reached by Atasever and Stadnik (2015) determined that calving year on daily milk yield, fat yield and protein yield were significantly important in Holstein cows. Adediran et al. (2010) found that the year of calving has a very big effect on the amount of protein and fat in the Holstein breed. On the contrary, Sekerden (2002) reported that the effect of calving year did not influence on fat yield and protein yield in Holstein cow. This difference between studies may be related to different environmental, nutritional, management and barn conditions (Cobanoglu and Ertugrul, 2019). Due to the abundance of forage during the rainy season, the cows received a lot of roughage which caused an increase in the synthesis of fat in milk to increase, resulting in an increased fat in milk. Milk fat and protein percentages were lower by 0.2 to 0.4 in summer than in winter (Garamu, 2019). Because forage was abundant during the rainy season, cows received an adequate amount of roughage, which is essential for milk fat synthesis. This led to an increase in the milk fat content (Garamu, 2019). Moreover, Veerasak et al. (2021) reported that the research about most of the dairy cooperatives showed an increasing trend for milk production. The milk productions from all dairy cooperatives had a similar seasonality pattern as the highest milk production was found in the period of March to May.

Percentage of fat, protein, and FPR were all significantly affected by age at calving ($P< 0.05$.

The number of days in milk had different effects on fat, protein, and FPR ($P<0.05$). The FPR reached a peak at the starting of the lactation (around DIM 35) and steady declined afterwards to the end of lactation (Figure 2).

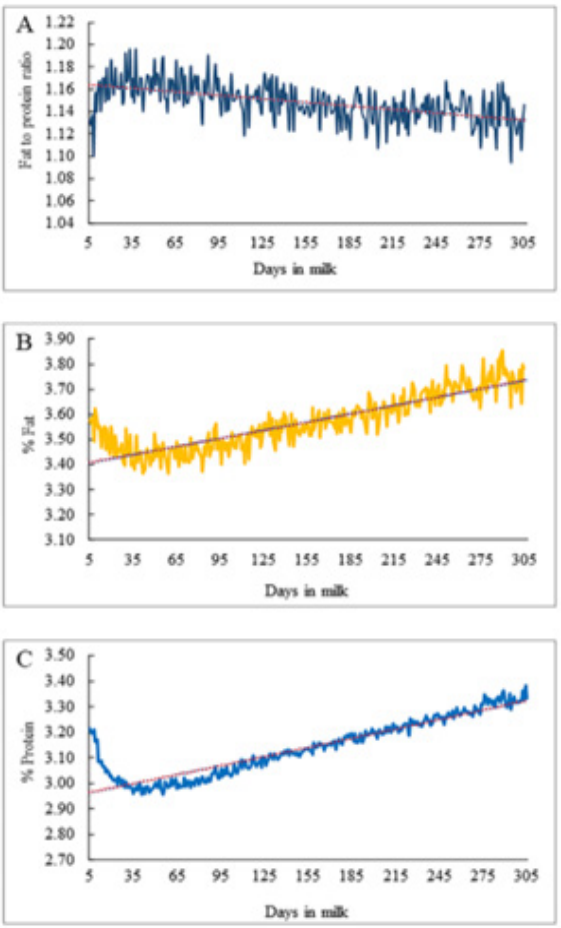

Figure 2 The average trend of, percentage of fat (B), and percentage of protein (C) FPR (A) in dairy cows raised under tropical climate.

DISCUSSION

In this study, the means were within the ranges reported in previous studies in Thailand. (Buaban et al., 2016; Puangdee et al., 2016; Wongpom et al., 2017) and similarly the result from Satola and Ptak (2019) in Polish HF.

Variation of HF breed in dairy cow affect to fat and protein percentage. Because cows contained with high HF levels tend to have high milk yield but gave less fat and protein than other breeds. The result was similar to a report by USDA-AIPL (2018), who found that fat percentage, protein percentage and FPR were 3.65, 3.06 and 1.19 in HF, 3.86, 3.18, and 1.21 in Ayrshire, 4.04, 3.08 and 1.20, in Brown Swiss, respectively. The solid content of cow milk is approximately 3 to 4 percent fat, 3.5 percent protein, and 5 percent lactose, but the gross chemical composition of cow milk varies depending on the breed. For example, the fat content is usually higher in *Bos indicus* than *B. taurus* cattle. The fat content of milk from *B. indicus* cattle can be as much as 5.5 percent (FAO, 2022).

Herd-year-season of recording influenced to the study traits. Due to all herds were located in different parts of the country, so each one was influenced by the different effects of environment, management, and feed (Amimo et al., 2007). Effect of year of calving, similar conclusions were reached by Atasever and Stadnik (2015) determined that calving year on daily milk yield, fat yield and protein yield were significantly important in Holstein cows. Adediran et al. (2010) found that the year of calving has a very big effect on the amount of protein and fat in the Holstein breed. On the contrary, Sekerden (2002) reported that the effect of calving year did not influence on fat yield and protein yield in Holstein cow. This difference between studies may be related to different environmental, nutritional, management and barn conditions (Cobanoglu and Ertugrul, 2019). Due to the abundance of forage during the rainy season, the cows received a lot of roughage which caused an increase in the synthesis of fat in milk to increase, resulting in an increased fat in milk. Milk fat and protein percentages were lower by 0.2 to 0.4 in summer than in winter (Garamu, 2019). Because forage was abundant during the rainy season, cows received an adequate amount of roughage, which is essential for milk fat synthesis. This led to an increase in the milk fat content (Garamu, 2019). Moreover, Veerasak et al. (2021) reported that the research about most of the dairy cooperatives showed an increasing trend for milk production. The milk productions from all dairy cooperatives had a similar seasonality pattern as the highest milk production was found in the period of March to May.

Effect of age of calving was found that both milk fat and protein declined as the dairy cows aged. Milk fat decreased approximately 0.2% each year from the first to fifth lactation, likely as a result of higher production and more udder infections. Protein decreased by 0.02–0.05% each lactation as the animal's age increased (Heinrichs et al., 1997). The reason that supported the decline in the older cows was that the tissues around the breast began to deteriorate and may be affected by mastitis due to the increased vascular permeability caused by inflammation (Ramos Garcia et al., 2015).

Effect of days in milk was found similar to reported by Buaban et al. (2015), Puangdee et al. (2017), and Negussie et al. (2013), but different from the previous reports by Satola and Ptak (2019), who found a peak yield of the first lactation around DIM 7 and tended to decrease in DIM 65, the stabilized at 1.15 to the end of the lactation (DIM305). Jamrozik and Schaeffer (2012) also reported that the highest value of the FPR was found immediately after calving and decreases as lactation.

CONCLUSIONS

Factors influencing fat percentage, protein percentage and FPR in first lactation of Thai dairy cattle raised under tropical climate were both genetic and non-genetic factors. Genetic factor was breed group considered as HF fractions in cows. Non-genetic factors were herd-year-season of recording, age at calving, and days in milk. The cow that contained HF blood < 87.50% gave fat percentage, protein percentage and FPR higher than >93.75%HF and 87.50 to 93.74%HF cows. Seasons of recording affected the FPR which was the highest in the winter and the lowest in summer.

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AUTHOR CONTRIBUTIONS

PK and WK conceived and designed the experiments. PK, SB, and WK collected the data, analyzed, and interpreted the data. WM and WK wrote the paper. All authors read and approved the final manuscript.

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