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ORIGINAL PAPER

Factors affecting milk yield, milk fat, bacterial score, and bulk tank somatic cell count of dairy farms in the central region of Thailand

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Abstract A study was conducted to determine the effects of season, farm location, and farm size on farm milk yield (FMY), average milk yield per cow (AYC), milk fat, bacterial score, and bulk tank somatic cell count (BTSCC) of dairy farms in the central region of Thailand. Farms were located in the districts of Kaeng Khoi, Muaklek, Pak Chong, and Wang Muang. Collection of data was at the farm level; individual animal records were unavailable. A total of 967,110 daily farm milk yield, 58,575 milk fat and bacterial score, and 24,109 BTSCC records from 1,034 farms were collected from July of 2003 to June of 2006. There were three seasons: rainy, summer and winter. Farms were categorized into small, medium, and large according to the number of cows milked per day. Results showed that FMY and AYC were higher ($p<0.05$) in winter and lower in the summer and rainy seasons. In addition, the majority of small size farms had higher ($p<0.05$) AYC and milk fat values, and lower bacterial score and BTSCC values than medium and large size farms.

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Abbreviations

AYC	average milk yield per cow
BTSCC	bulk tank somatic cell count
FMY	farm milk yield
LBS	natural logarithm of bacterial score
LBTSCC	natural logarithm of bulk tank somatic cell count

Introduction

Since commercial dairying began in Thailand in the early 1960's, the Thai dairy industry has seen tremendous growth and progress. Raw milk production in Thailand rose from 124 tons to 1300 tons per day from 1984 to 1999, and consumption of liquid milk also rose from 6.81 kg per to 29 kg capita per year from 1994 to 2000 (Itsaranuwat and Robinson, 2003). Despite this rapid growth in production, Thailand's dairy industry is unable to produce enough milk products to meet local demand, thus it still remains dependent on importation of large amounts of dairy products. Because of the high demand for dairy products in Thailand, the Thai government has recently put forth new initiatives to increase the productivity of dairy herds. These new initiatives aim at improving quality of feed, milking technology, and proper collection and storage of milk (MOAC, 2005). Thai dairy farmers must overcome many challenges in their production systems to meet these goals. The ability of farmers to provide adequate nutrition and management to high yielding Holstein cattle has become increasingly problematic (Chantalakhana and Skunmun, 2001). In addition, improving the sanitation and milk hygiene of farms is an area of concern of Thai dairy farms and cooperatives. Thus, emphasis needs to be placed on identifying management factors within farms that lead to lower milk yields and a higher incidence of bacteria in milk as well as mastitis in cows. The objective of the current study was to determine seasonal, farm location, and farm size effects on milk yield, milk fat, bacterial score, and bulk tank somatic cell count of dairy farms in the central region of Thailand.

Material and methods

Study area

Location and climate

The study was performed on dairy farms in central Thailand (approx. 15 N, 102 E) in Kaeng Khoi, Muaklek, and Wang Muang districts of Saraburi province, and Pak Chong district of Nakhon Ratchasima province. The climate of Thailand is tropical and can be categorized into three climatic seasons (MD, 2002): winter (cool and dry), from November to February, summer (hot and dry), from March to June, and rainy (hot and humid), from July to October. Historically in Central Thailand, average annual rainfall, temperature and humidity levels have been approximately 900 mm, 28.3°C and 79% in the rainy season, compared to 124 mm, 29.6°C and 69%, and 187 mm, 26.1°C and 70% in winter and summer, respectively (MD, 2002).

Description of farms

Feeding and nutritional management of dairy cattle on most farms of this region vary among seasons. During the rainy season when forage is more abundant, farmers usually grow warm season grasses such as *Brachiaria ruziziensis* (ruzi), *Panicum maximum* (guenni), and *Pennisetum purpureum* (napier), of which typically 30 to 40 kg of fresh roughage is given per day (Suzuki, 1998). Smaller farms may also feed native grass in a cut and carry system or take their cattle off the farm to public grazing areas. The majority of medium and large size dairy farms use a confinement-based dairy system with limited pasture area, thus farmers must purchase forage to supplement their operations (Garcia et al., 2005). Concentrate (12 to 15 kg per milking cow per day) is used to supplement forages. There was no breed information available on the animals in this study. However, according to the Thai government, the majority of dairy cattle in Thailand are 75% Holstein or greater (MOAC, 2005).

Farmers milk their cows twice daily, once in the morning and once in evening. Primarily single unit milking machines are used to milk cows. Prior to milking, farmers typically clean udders of cows with a chlorine solution. Some farmers also apply an iodine-based dipping agent after milking. The extent to which preventive management techniques, such as teat dipping and dry cow management, are used by farms in this study is largely unknown.

Data collection and records

The farms in the study were members of the Muaklek dairy cooperative. Records were taken from farms that sold milk to the Muaklek dairy cooperative during the time of the study and were collected by dairy cooperative personnel at milk collection centers. Collection of data was at the farm level; individual animal records were unavailable. There were 1034 farms in the dataset. The Saraburi province contained a total of 786 dairy farms, of which 28 farms were in Kaeng Khoi, 737 farms in Muaklek, and 21 farms in Wang Muang. The Nakhon Rachasima province had 248 farms, all in the Pak Chong district. Milk yield from farms was collected on a daily basis from July 1, 2003 through February 28, 2006. Data for milk fat and bacterial score were collected once every ten days from November 1, 2004 through June 30, 2006, and BTSCC records were collected every ten days from October 6, 2005 through June 30, 2006. This study used a total of 967,110 daily farm milk yield, 58,575 milk fat and bacterial score, and 24,109 BTSCC records.

Records on milk yield, milk fat, bacterial score, and BTSCC included day, month, and year of collection date, district where the farm was located, and farm. A season variable was created to account for seasonal environmental differences. There was information from four years (2003, 2004, 2005, and 2006) and three seasons (rainy, winter, and summer). Farm size was determined by a survey administered to farms by the Muaklek cooperative and it was based on the number of milking cows milked per day in January of 2005. The number of milking cows per farm was not regularly recorded and assumed to have remained constant throughout the duration of this study. Farms were classified by size into groups: 1=small (less than 10 cows milked per day), 2=medium (between 10 and 19 cows milked per day), and 3=large (20 or more cows milked per day). There were a total of 517 small, 362 medium, and 155 large farms in the study. Milk yield was analyzed as two separate traits, farm milk yield (FMY) and average milk yield per cow (AYC). Farm milk yield was the yield of all cows milked in a farm. Average milk yield per cow was defined as FMY divided by the number of cows milked per day.

A methylene blue reduction test was used to measure bacteria in milk from farms. Although there are more accurate methods available to measure bacteria in milk, the methylene blue reduction test was chosen by the cooperative because of the low cost of this test. The test was performed by placing drops of methylene blue dye into milk samples, where removal of oxygen from the milk and the forming of reducing elements by bacterial metabolism make the color disappear (Atherton and Newlander, 1977). Scores assigned to milk samples ranged from 1 to 4 based on the number of hours needed for the sample to change color or the dye to disappear; 1 having the fastest rate and least amount of bacteria and 4 the slowest rate and greatest number of bacteria. Scores were defined as: 1=more than 6 hours, 2=between 4 to 6 hours, 3=between 3 to 4 hours, 4=less than three hours (MCDL, 2005).

Statistical analysis

Farm milk yield, average milk yield per cow, milk fat, and BTSCC were analyzed using the mixed model procedure of SAS (SAS, 2004). The mixed linear model used for FMY included the fixed effects of year-season-farm district subclass, number of milking cows as a covariate, and the random effects of farm and residual. The mixed linear model for AYC and milk fat included the fixed effects of year-season, farm district-farm size subclass, and the random effects of farm and residual.

The BTSCC data were not normally distributed. Thus, data were transformed using natural logarithms after which it was approximately normally distributed. The mixed linear model used for LBTSCC was similar to the milk fat model and included the fixed effects of month nested within year of collection date, farm district by farm size subclass, and the random effects of farm and residual. Bacterial scores data followed a Poisson distribution, thus the bacterial score trait was analyzed using a generalized linear model with the GENMOD procedure of SAS (SAS, 2004). To normalize the data, bacterial score was transformed with a log link function. The log-linear model for bacterial score contained the fixed effects of year-season, farm district-farm size subclass, and residual.

Random farm effects were assumed to have mean zero and a common variance σ_{f}^2. Residual effects were assumed to have mean zero and common variance σ_{e}^2. Variances for random effects were estimated using restricted maximum likelihood. Significance of the variance due to farms within farm sizes (σ_{f}^2) was determined using a z-score ratio. Tests for main effects were compared using an F test at an $\alpha=0.05$ level. Least squares means for fixed effects, and differences between subclasses within fixed effects were compared using a t-test in all models except for bacterial score, which used a chi-square test, at an $\alpha=0.05$ level.

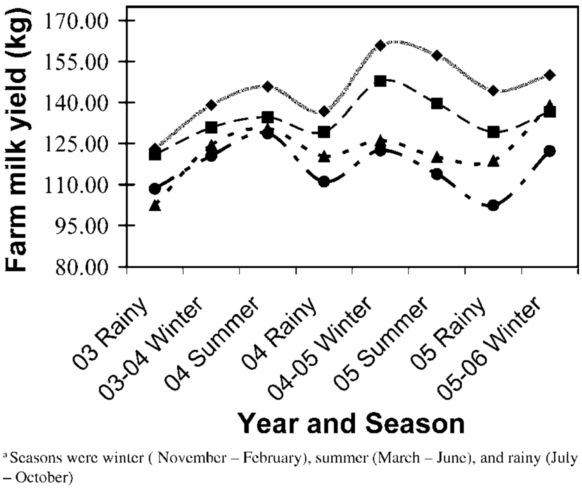

Fig. 1 Least square means for farm milk yield by farm districts Muaklek (♦), Pak Chong (■), Kaeng Khoi (●) and Wang Muang (▲) and year and season. [a] Seasons were winter (November – February), summer (March – June), and rainy (July – October)

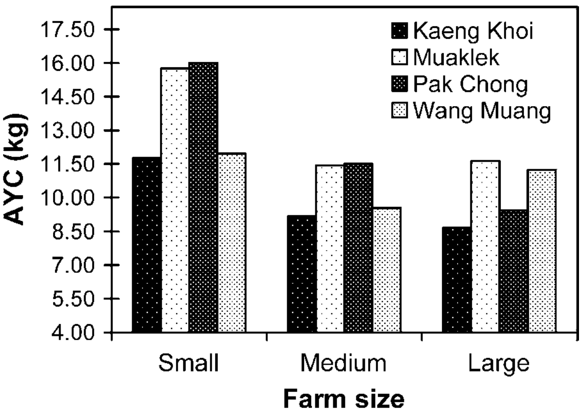

Fig. 2 Least square means of average milk yield per cow (AYC) by farm size and farm district

Results

Farm milk yield and average milk yield per cow

The year-season by farm district subclass and milking cow effects were important sources affecting FMY ($p<0.001$). Farm milk yield was lower ($p<0.05$) in the rainy season than the summer and winter seasons of each year in the Kaeng Khoi, Muaklek, and Pak Chong districts (Fig. 1). The FMY was higher ($p<0.05$) in winter than the rainy and summer seasons in all districts and years.

Year-season and farm district by farm size subclass variables affected AYC ($p<0.001$). The 2003 rainy season had the lowest AYC (9.55±1.07 kg, $p<0.05$), while the 2004–2005 winter season had the highest (12.63±1.07 kg, $p<0.05$). Average milk yield per cow was lower ($p<0.05$) in the rainy season than either in summer or winter. In the Kaeng Khoi and Wang Muang districts, there were no differences ($p=0.61$) across farm size for AYC (Fig. 2).Small farms in the Muaklek district were higher ($p<0.05$) for AYC (15.76±0.63 kg) than medium (11.44±0.74 kg) and large farms (11.63±1.09 kg). In the Pak Chong district, small farms had higher AYC (16.01±1.04 kg, $p<0.05$) than both medium (11.50±1.32 kg) and large farms (9.43±2.09 kg).

Milk fat percentage

Year-season was an important ($p<0.001$) source of variation affecting milk fat % of farms, while farm district by farm size subclass approached significance ($p=0.07$). Milk fat values for the 2005 summer (3.88±0.01%) and rainy (3.87±0.01%) seasons were almost identical ($p=0.12$), however every other season group combination did differ ($p<0.05$). In the Kaeng Khoi and Wang Muang districts, large farms had the highest milk fat values (3.91±0.07% and 3.85±0.01%, respectively), but these were not different from those of small and medium farms ($p=0.52$; Fig. 3). Small farms had higher milk fat (3.88±0.007%; $p<0.05$) than medium (3.85±0.008%) and large farms (3.83±0.01%) in the Muaklek district. In the Pak Chong district, small farms had the highest value (3.85±0.01%) for milk fat, but were not different from medium ($p=0.29$) and large ($p=0.76$) farms.

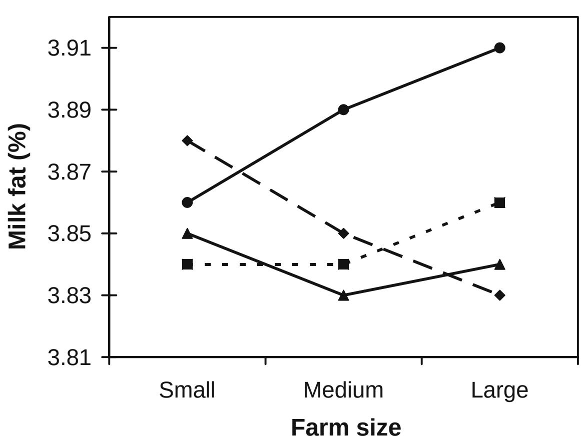

Fig. 3 Least square means for milk fat percentage by farm size and farm districts Kaeng Khoi (●), Muaklek (♦), Pak Chong (▲), and Wang Muang (■)

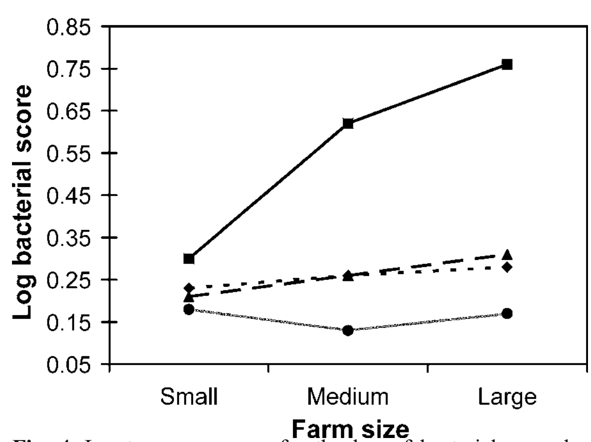

Fig. 4 Least square means for the log of bacterial score by farm size and farm districts Kaeng Khoi (●), Muaklek (♦), Pak Chong (▲), and Wang Muang (■)

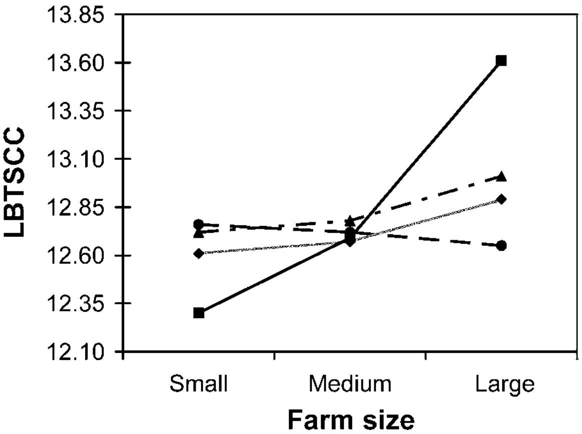

Fig. 5 Least square means of log bulk tank somatic cell count (LBTSCC) by farm size and farm districts Kaeng Khoi (●), Muaklek (♦), Pak Chong (▲), and Wang Muang (■)

Bacterial score and bulk tank somatic cell count

Year-season and the farm district by farm size subclass both affected LBS ($p<0.001$). The 2005 rainy season had a value of 0.34±0.007, and was higher ($p<0.05$) than the previous year-season of 2005 summer (0.300±0.007) and following year-season of the 2005–2006 winter (0302±0.007). In the Kaeng Khoi district, there were no differences ($p=0.08$) across farm sizes for LBS (Fig. 4). Small farms in Muaklek were lower ($p<0.05$) for LBS (0.231±0.003) than medium (0.268±0.004) and large farms (0.283±0.006). In the Pak Chong and Wang Muang districts, farms sizes had different LBS ($p<0.05$); small farms had the lowest values (0.212±0.006 and 0.303±0.02, respectively) and large farms the highest values (0.313±0.01 and 0.762±0.03 LBS, respectively).

Month nested within year and farm district by farm size subclass both affected LBTSCC ($p<0.0001$). For LBTSCC, May of 2006 had the highest value (12.94±0.05) which was higher ($p<0.05$) than those of all other months (Fig. 5). In the Kaeng Khoi district, there were no differences across farm sizes for LBTSCC ($p=0.67$). Large farms in the Muaklek district exhibited higher (12.89±0.05; $p<0.05$) LBTSCC than those of both small (12.61±0.03) and medium farms (12.67±0.03). In the Pak Chong district, large farms had the highest LBTSCC of 13.01 and were higher ($p<0.05$) than small farms (12.72±0.05), but not medium farms ($p = 0.05$). Large farms, in the Wang Muang district, were higher (13.53±0.37, $p<0.05$) for LBTSCC than all other farms, while there was no difference ($p=0.15$) between small (12.30±0.19) and medium farms (12.69±0.20) for LBTSCC.

Discussion

The lower FMY and AYC values during the rainy and summer seasons are likely due to heat stress and its effects on milk production. Previous studies in Thailand have shown that high relative humidity and temperature negatively affected ($p<0.01$) daily milk yield of 75% or greater Holstein cattle, whereas crossbred cattle with less than 50% Holstein showed lesser responses to climatic change (Wilairat, 1996). Furthermore, Koonawootrittriron et al. (2001) found that Holstein cattle had lower 305 d milk yields in the rainy season than in winter and summer. They also showed that milk yields of 3/4 Holstein: 1/4 Red Sindhi dairy cows produced more milk than both Holstein and 1/2 Holstein: 1/2 Red Sindhi cattle, indicating that 3/4 Holstein cattle may be appropriate to the environment in Central Thailand.

In addition climate, seasonality of mating may also contribute to lower milk yields during the rainy season in Central Thailand. Chanartaeparporn (1991) reported lower conception rates for Holstein heifers (45.5%) in the rainy season than in summer (53.3%). Thus, if dairy cattle have higher conception rates in winter when temperatures are cooler, a higher percentage of cows would reach their later stages of lactation at the end of the summer and during the rainy seasons. Cows in late lactation during the summer and rainy seasons would have lower milk yields than in winter, as found here.

Previous research in Thailand reported daily milk yields of 12 kg/d (MOAC, 2005) and 12.97 kg/305d (DPO, 2005), which are lower than the AYC of small farms in Muaklek (15.76 kg) and Pak Chong (16.01 kg), but higher than that of large farms across all districts in this study. The greater milk yields in small than in large farms in the Muaklek and Pak Chong districts are consistent with a previous study that found farms milking 9 cows per day had higher yearly milk yields per cow than larger farms (Pichet, 1998). Typically small farms in Thailand are diversified in their agriculture activities which may allow them to feed higher quality by-products and forages to their cattle compared to larger farms (Chinwala and

Umrod, 1988). Small farms also often use public grazing areas or use a cut and carry system where fresh forage is cut, brought back to the farm and fed to animals. However, larger dairy farms may not have sufficient land to grow their own forages or have the time to cut and carry enough high quality forage from their own or public lands (Garcia et al., 2005). If animals in small farms were in fact receiving higher quality forages, this might be one of the reasons for them to have higher AYC.

The reason that small farms in Muaklek had higher ($p<0.05$) milk fat percentage than medium and large farms was likely because small farms fed a greater amount of green fresh cut forage, whereas larger farms in many instances fed a higher quantity of lower quality forage such as rice straw. Although milk fat decreased over the time period of the study, the change was small. Milk fat percentage remaining at approximately the same level during the summer and rainy season could be due to the greater amount of higher quality forage available and fed during the rainy season compared to the dryer weather of the winter and summer seasons (Garcia et al., 2005).

The higher LBS values seen in the rainy season may have been due to poorer floor hygiene, insufficient drainage from pens, and muddy resting areas as found by Yhoung-Aree (1999). Because detailed information on management at the farm level was unavailable for this study, reasons for larger farms to have higher LBS and LBTSCC values than smaller farms are unclear. However, small farms in Central Thailand typically have more area per cow than larger farms, an advantage for controlling mud and water in pens, resulting in a cleaner environment for cows. In addition, most small farms are run by family members whereas larger farms may be managed by hired labor, possibly leading small farms to have better management than larger farms. Lack of knowledge on the part of farmers in the area of hygiene and proper milking and dry cow treatment was likely a relevant factor across all farm sizes. These factors could be more accurately described with a newer method of measuring bacteria in milk, such as total plate count, as performed in the study of Yhoung-Aree (1999). Thus, the Muaklek cooperative may need to move from the methylene blue reduction test to a more accurate bacterial test that can specifically identify and quantify bacteria in milk of farms. Additionally, increased training to farmers in farm hygiene and sanitation, and dry cow management will help improve milk quality at a farm level.

Results here suggest that heat and humidity stress may be lowering milk yields during the summer and rainy seasons, while at the same time affecting the breeding cycle of cows throughout the year. Differences in management and care of animals may be the main factors responsible for small farms to have higher AYC, milk fat and lower LBS and LBTSCC than medium and large farms. However, detailed information on genetic composition of animals, breeding, nutrition and management, and health care, as well as climate information are needed to fully identify and explain seasonal and farm size differences for milk yield, AYC, milk fat, LBS, and LBTSCC. This field information will need to be systematically collected and analyzed to provide a more accurate and complete explanation on factors affecting dairy production in Central Thailand.

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