FACTORS AFFECTING MILK YIELD, MILK FAT, MILK QUALITY, AND ECONOMIC PERFORMANCE OF DAIRY FARMS IN THE CENTRAL REGION OF THAILAND

By

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To my love and wife, Kirathirat. Thank you for all of your support and prayers.

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AYC	Average milk yield per cow
BTSCC	Bulk tank somatic cell count
EBV	Estimated breeding value
FMP	Farm milk price
FMR	Farm milk revenue
FMY	Farm milk yield
LBS	Log of bulk tank somatic cell count
LBTSCC	Log of bulk tank somatic cell count

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A study was conducted to characterize the dairy production, educational experiences, decision making practices, and income and expenses of dairy farms and to determine the effects of season, farm location, farm size, and management practices on farm milk yield (FMY), average milk yield per cow (AYC), milk fat, bacterial score, bulk tank somatic cell count (BTSCC) and economics of dairy farms in the central region of Thailand. The farms were located in Lopburi, Nakhon Ratchasima, and Saraburi provinces. Farm groups were identified as farms from the Muaklek dairy cooperative (Muaklek farms) and farms from other dairy cooperatives (Non-Muaklek farms). 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, 24,109 BTSCC and 58,575 milk price records from 1,034 farms were collected from July of 2003 to June of 2006. Additional details of farm management practices and educational experiences were collected through a questionnaire in May of 2006. There were three seasons: rainy, summer and winter. Farm size was defined as the number of cows milked per day. Farms were categorized into small, medium, and large according to their size. Two pricing systems were defined as 1 = base price plus additions/deductions for milk fat percentage, solids-non-fat, and bacterial score, and 2 = same as 1 plus bulk tank somatic cell count (BTSCC).

Results showed that most farms from both groups had a primary or high school educational level, used a combination confinement and pasture production system, gave a mineral supplement, raised their own replacement females, milked approximately 16 cows/day, used crossbred Holstein cows (75% Holstein or more), and mated purebred Holstein sires to their cows. More Non-Muaklek farms (80%; $P < 0.05$) used a combination of genetic and phenotypic information when selecting sires than Muaklek farms (54%).

When looking only at Muaklek farms, 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. Farm milk prices were lower ($P < 0.05$) in pricing system 1 than pricing system 2. Most small farms had higher ($P < 0.05$) milk prices than medium and large farms across both pricing systems. Large farms lost more milk revenue due to deductions from bacterial score and BTSCC than small and medium farms. Farms that kept records on individual animals had higher ($P < 0.05$) milk fat percentages and lower bacterial scores than farms that did not. Farms that used genetic information (EBV) and phenotypes when selecting sires were higher ($P < 0.05$) for milk fat percentage than farms that used only phenotypes and personal opinion. Farms milking cows with a single unit milking machine and by hand, had higher ($P < 0.05$) bacterial scores and BTSCC than farms using only a single or multi unit machine.

Overall small size farms had higher AYC and milk prices and lower losses in milk revenue compared to larger farms. Additionally, farms that kept individual animal records used EBV when selecting sires, used a single method for collecting milk, and used family labor achieved higher performance from their herds than farms that did not.

CHAPTER 1
INTRODUCTION

Beginning in the 1950s the Thai government began organizing and forming government programs and policies towards promoting the dairy industry in Thailand. These policies were further advanced in the 1961 with the introduction of the Holstein breed and a strong advertising campaign by the government in the 1970's, which helped to stimulate milk consumption and growth of the commercial dairy industry (Chinwala and Umrod, 1988). In the 1980's and through the year 2000, government investment through policies and advertisement led to tremendous growth and progress in the Thai dairy industry. From 1992 to the year 2000, raw milk production increased from 215,457 to 480,000 tons, respectively (Itsaranuwat and Robinson, 2003). Additionally the rise in consumption of dairy products from the consumer increased as liquid milk consumption rose from 6.81 kg per capita in 1994 to 29 kg in 2000 (Itsaranuwat and Robinson, 2003). Nonetheless the dairy industry in Thailand is still a developing industry with approximately 95% of dairy farmers being classified as small scale farms (Chantalakhana and Skunmun, 2001). Recent statistics show that there are 408,350 head of dairy cattle raised by about 23,000 dairy farm households, with an average herd size of 17.5 head (MOAC, 2005).

Through genetic selection and improved feeding and management practices, Thai farmers are averaging 305 d milk yield values from 3,000 to 4,000 kg (Chantalakhana and Skunmun, 2001). However despite these improvements, there is still a need to develop improved nutritional value in feedstuffs, milking management practices, genetic selection of animals through use of estimated breeding values (EBV) and crossbreeding by use of complementation of breed types. Selection of an animal with the proper breed type that is adaptable to the environment, from a seasonal and nutrition standpoint, is important towards the success of farms.

Koonawootrittriron et al. (2002) reported 305 d milk and fat yield averages for lactating cows with ≥ 80% Holstein of 4,069 kg 3.67%, while cows with Holstein percentage between 60 and 80% were 4,139 kg and 3.73%, respectively. Additionally, Koonawootrittriron et al. (2002) and other similar studies show that these types of cows may be more adaptable to the climate in Thailand compared to purebred Holstein cows. Nutritionally, Kaewkamcham (2003) has shown the effects where cows fed a diet based on NRC requirements produced significantly higher milk yields than those that were on a lower plan of nutrition. Other management practices of farms, such as record keeping, have also shown to be positively correlated with higher milk yield averages (Suphalux, 2001). Although milk yield is probably the main factor farmers are concerned on improving in their animals, improving milk quality is also critical for dairy producers. Yhoung-Aree (1999) found that dairy farms which had good hygiene practices in feed troughs, milk parlors, and drainage systems had higher milk quality than farms that did not. Milk quality is important for farmers to pay attention to, in that milk prices paid by dairy cooperatives to farmers are often based on quality factors such as bacterial score and bulk tank somatic cell count. Thus, if farmers are producing lower quality milk they may expect to receive less revenue and lower total profits on their farms.

The objectives of this study were 1) to determine seasonal, farm location, and farm size effects on milk yield, milk fat, bacterial score, and bulk tank somatic cell count of Muaklek farms, 2) to determine the effect of pricing system, month and year, district of farm, and farm size on milk price, and to calculate FMR and losses in FMR due to deductions in milk price based on milk fat percentage, bacterial score, and BTSCC of Muaklek farms, 3) to characterize the dairy production, educational experiences, decision making practices, and income and expenses of Muaklek and Non-Muaklek farms and to determine if there are any differences of these practices between Muaklek and Non-Muaklek farms, and 4) to determine record keeping practices, genetic selection, educational experience, and farm management effects on average milk yield per cow, milk fat percentage, bacterial score, and bulk tank somatic cell count of Muaklek farms.

CHAPTER 2
LITERATURE REVIEW

Thailand

Location and Background

Located in the Southeastern part of Asia, Thailand is between 5° 35' to 20° 30' North latitude and 97° 20' to 105° 40' East longitude, and is bordered by Cambodia to the East, Laos to the Northeast, Myanmar to the West, Malaysia to the South and also borders two main bodies of water, the Gulf of Thailand to the South and the Indian Ocean to the west (Royal Thai Embassy, 2004). Thailand is approximately 513,115 sq. km in size, or about the size of Texas, and is comprises of seventy-six provinces that are subdivided into districts, sub-districts, and villages (TAT, 2005). The topography of Thailand is divided into four main regions, the north, a mountainous area, the central plains, the main rice producing area, the Northeast Plateau, an arid region, and the South peninsula, a major rubber producing area in Thailand (PRD, 2006). With a population of 62 million people, Thailand is comprised of 80% ethnic Thai, while the remaining 20% is made up of minority groups, with Chinese making up 10%, Malaysian 3%, and the remaining population made up of other minority groups such as the Mons, Khmers, and hill tribes (TAT, 2005). The national religion in Thailand is Buddhism, which approximately 95% of all Thai people practice, and is richly tied to the culture and history of Thailand (TAT, 2005).

Since 1932 the Thai government has been a constitutional monarchy and is governed by His Majesty King Bhumibol Adulyadej as Head of State, but where official power rests with the government who is headed by the Prime Minister, the Parliament, and an administrative system that flows down to the village level (PRD, 2006). The Parliament is divided into two houses, the Senate and the House of Representatives, where members of both houses are elected to office by the people and the Prime Minister is elected by the government representatives (TAT, 2005).

Climate

The climate of Thailand is tropical and can be divided into three climatic seasons: a rainy season, from mid May to mid October, a winter season, from mid October to mid February, and a summer season, between mid February and mid May (MD, 2002). The winter season is characterized by being cool and dry, summer as hot and dry, and the rainy season as hot and humid. The weather in Thailand is heavily influenced by monsoonal weather patterns. The southwest monsoon, beginning in May brings streams of moist air from the Indian Ocean which results in plenty of rain from May through October (MD, 2002). A second monsoon, the northeast monsoon, begins in October and brings colder air from the north, particularly in the north and northeast areas (MD, 2002). Annual rainfall in most areas of Thailand ranges from 1200 to 1600 mm (MD, 2002).

Agriculture

The Thai agriculture industry dates back to 1257 A.D. in the Sukhothai Period where stories of agriculture were found inscribed on stones (MOAC, 2005). These writings found that King Ramkhamhaeng implemented many national policies to promote agriculture, in particular giving people the right to choose their occupation of work, and that land used for profit purposes would be inherited directly to these people's descendants (MOAC, 2005). During the periods between the 1800's and the early 1900's divisions and departments within the ministry of agriculture went through many changes, in which many new departments were formed and other departments were merged together. In 1943 Kasetsart University was founded in Bangkok by the Kasetsart University Act, which created the University and made it a department in the Ministry of Agriculture (KU, 2003). In 1974 all departments of agriculture, which included the Department of Fishery, Department of Livestock, Department of Forestry, Land Development Department, Department of Agriculture, Department of Agriculture Extension, were merged to form the Ministry of Agriculture and Cooperatives (MOAC, 2005). In addition the Ministry of Agriculture and Cooperatives are in charge of seven state enterprises which include the Dairy Farming Promotion Organization of Thailand (MOAC, 2005).

Thailand ranks number one in the world in natural rubber, canned pineapple, rice production, and also leads the Asian region in chicken meat exports (Wikipedia, 2007). According to the Thailand Ministry of Agriculture and Cooperatives, in 2004 there were 408,350 head of dairy cattle in Thailand raised by 23,000 households, with an average farm size of 17.5 head/farm producing 12 kg of raw milk per cow per/day (MOAC, 2005).

Dairy Industry

Although the first recordings of dairy farming in Thailand were in 1700 AD by Indian farmers, the introduction of developed dairy breeds, such Holstein Friesian in 1961, and the beginning of commercial dairying didn't begin until 1962 (Chinwala and Umrod, 1988). Through cooperation from the Danish and German governments as well as the United Nations in starting many dairy development and school milk programs, dairy production began to develop and expand during the 1970's and 80's (Chinwala and Umrod, 1988). From 1999 to 2003 the Thai milk market increased 21.6% reaching an estimated value of 438 million (USD), a growth rate of 5% per year during that period (Datamonitor, 2004). Additionally consumption of liquid milk rose from 6.81 kg per capita in 1994 to 29 kg in 2000 (Itsaranuwat and Robinson, 2003). The Thai dairy market is segmented into four main areas of milk, yogurt, spreadable fats, cheese, and cream (Datamonitor, 2004). However, in these four market areas, in 2003 milk accounted for 77% and yogurt for 19% of the market value (Datamonitor, 2004). Within the milk market, long life liquid milk, or UHT milk, in 2003 accounted for 44.8% of the market share, powdered milk for 20.8%, fresh liquid milk for 19.5 % and concentrated or condensed milk for 14.9% (Datamonitor, 2004).

Government Policies

Established in 1971, the Dairy farming Promotion Organization (DPO), of the Thai department of agriculture and cooperatives, is responsible for promoting the raising of dairy cattle, training and educating farmers in dairy farming practices, developing the processing of milk in dairy cooperatives, and lastly also plays a part in producing milk and other dairy products through its own dairy business and the Thai-Danish dairy farm (DPO, 2006). The DPO is an important part of government policy in promoting dairy production in Thailand. Not only does the DPO provide training to farmers on dairy production activities, but they also provide artificial insemination services and preventative and treatment of disease of animals to farmers (DPO, 2006). These activities are all part of the government's policies to stimulate and promote not only dairy production but also consumption of dairy products of the Thai population. The DPO training program is diverse and extensive in nature. Every year the DPO provides a two week training course, throughout the year, to any farmers that want to enter into dairy farming, as well as providing training to agricultural vocational college and university students (DPO, 2006). Extension is also a major component of the DPO. From 1999 to 2003 the DPO trained over three thousand farmers and performed over 300,000 artificial inseminations (DPO, 2006).

Two other government organizations that have an influence on the Thai dairy industry are the department of livestock development (DLD) and the cooperative promotion department (CPD). Although the DLD duties involve and cover all livestock species, they also work in cooperation with dairy farmers to improve areas in animal breeding, nutrition of animals, developing extension activities to farmers, and research and development and transfer technology in animal health and production (DLD, 2007). The CPD is responsible for supporting and strengthening cooperatives in order to increase the influence and reach of their business and the efficiency of their operation (CPD, 2006). In simpler terms, the CPD is an outlet of information and help for dairy cooperatives in Thailand to become a self-reliant, thriving successful business in order to have a better socio-economic standard of living for farmers that are members of cooperatives (CPD, 2006). Other government policies affecting the dairy industry in Thailand include a number of subsidies and the government regulation over milk price. The Thai government currently sets the rate for the price of raw milk in Thailand.

Dairy Cooperatives

Milk collection in Thailand is performed primarily by dairy cooperatives that buy milk from farmers and then sell the milk to milk processing companies, although a few cooperatives such as Nong Pho and Wang Nam Yen process the milk themselves (Rabobank, 2004). Approximately 80% of milk collected at the farm level is by cooperatives, while 20% is collected by private milk collectors (Rabobank, 2004). Based on a report by Rabobank (2004) the Ban Bueng, Muak Lek, Nong Pho, Pak Chong, Phi Mai and Wang Nam Yen cooperatives are among the largest dairy cooperatives in Thailand. In 2001 there were a total of 114 milk collection cooperatives mainly located in the central region of Thailand in the provinces of Saraburi, Ratchaburi, Nakhon Pathom and Chiangmai (Itsaranuwat and Robinson, 2003). The main activities of Thai dairy cooperatives are to operate milk collection centers where cooperatives purchase milk from farmers at a base price, plus price adjustments for milk quality and also sell other services. When purchasing and selling milk, farmers usually receive between 10.5 and 11.5 baht/kg, depending on the quality of the milk, and when selling most cooperatives receive the standard price of 12.5 baht/kg, dictated by the government (Rabobank, 2004).

Current Statistics

According to the Thailand Ministry of Agriculture and Cooperatives, in 2004 there were 408,350 head of dairy cattle in Thailand raised by 23,000 farm households, with an average farm size of 17.5 head/farm producing 12 kg of raw milk per cow per/day (MOAC, 2005).

Additionally, Rabobank (2004) reported that, assuming farmers are replacing animals at a 10% rate, average annual milk yield per cow would be approximately 2,100 kg, which is relatively low compared to most major milk producing countries such as the US with 8,400 kg and New Zealand that averages 3,300 kg (Rabobank, 2004). The result of low yields may be the results of the fact that 70% of Thai Dairy farmers have less than 10 head of cattle, where dairying may be just one of many important farm activities. The small size of farms and other factors such as low nutritional content in feed, less productive management decisions, and keeping cow's for a long time after their peak milk production season has passed may be also the causes of lower milk yields (Rabobank, 2004). However on larger dairy farms in Thailand where farmers have 20 or more cows, reports have shown milk yields per cow up to 4,000 kg per year (Rabobank, 2004). The majority of dairy cattle in Thailand are high percentage, 75% or higher, Holstein Friesian cows (MOAC, 2005), with other percentages coming from breeds such as Red Sindhi, Brahman, Jersey, and Red Dane (Koonawootrittriron et al., 2002).

Dairy Production

Farm Size

In two previous studies in Thailand, Garcia et al. (2005) defined farm size as number of total cows in the herd, while Falvey and Chantalakhana (1999) described farm size by the amount of hectares of farms. Whichever way farm size is defined it can be used to describe the production systems of dairy farms. This is important because differences in labor, feeding and type of management practices in farms can vary across different farm sizes. In the study by Garcia et al. (2005), although all farms across all farm sizes fed a 16-18 % concentrate ration to their cows, the small size farm (total of five cows) fed fresh ruzi grass and rice stalk to their cows compared to a larger size farms (total of 21 cows) that fed only corn stem and rice straw as a source of roughage. Although smaller size farms used only family labor on their farms, a very large farm (total of 117 cows) depended almost solely on hired labor for their farm (Garcia et al., 2005). These factors may have influenced differences seen in lactation length and culling rate, where the farm with 14 cows had a lactation length of 280 and culling rate of 7% compared to the larger farm with 117 cows that had a lactation length of 300 and culling rate of 25% (Garcia et al., 2005). When examining farm size by number of hectares, Falvey and Chantalakhana (1999) reported farms with 12.3 hectares had less cows (9 cows) but were similar in total milk production of 2,303 kg/milk/cow/year compared to smaller farms with 1.3 hectares and 15cows where cows produced 2,254 kg/milk/year. Thus, when studying and researching farms in Thailand, it is important to understand farm size and its relation to a farm's feeding practices, labor, and overall care and management.

Record Keeping

Record keeping is an important part of any dairy farm enterprise. Keeping records allows farmers to improve production in areas such as milk yield, fat and protein yield, fertility in cows, decrease levels of mastitis, and also management practices such as culling, feeding, and methods used to milk cows. Due to the limited amount of information available in Thailand, it is uncertain what effect record keeping had on the performance of dairy farms. However, Suphalux (2001) reported that average milk yield was significantly positively correlated to dairy farms keeping records in the Muaklek region of Thailand. Additionally, from previous research performed in other parts of the world, it would seem that those farms keeping records, and more importantly keeping records on individual animals, may have more efficient and higher producing animals than farms that do not keep records. Losinger and Heinrichs (1996) found that farms that kept records on individual animals had higher fat yields and rolling herd milk averages than farms that did not keep records. Since there is limited literature in the area of record keeping practices of dairy farms, the review on this topic is brief. In order to determine the effects record keeping has on dairy farms in Thailand more research will need to be conducted in this area.

Factors Affecting Milk Yield

For dairy producers, milk yield is one main factor that drives economic profitability in dairy farms. Striving to increase milk yield per animal, while decreasing feed and other expenses, can lead to economic gains in farms. In different regions of the world dairy cattle milk yields differ due to many factors such as environment, season, nutrition and difference in genetic makeup of animals. In 2004 Thailand, The Ministry of Agriculture and Cooperatives (MOAC, 2005) reported the average milk yield was 12kg/d per cow while, the Dairy Promotion Organization (DPO, 2005) reported average 305 d milk yield to be 3,958.47 kg or approximately 12.98 kg/milk/d.

Breed

Over the past sixty years there have been many dairy breeds used in Thailand for dairy production, including Red Danish cattle, of which were some of the first dairy cattle used in Thailand. Early Red Danish studies showed that purebred Red Danish cattle had difficulty adapting to the environment in Thailand, as shown by high mortality rates (Madsen, 1977). However, through crossbreeding Red Danish cattle to Sahiwal, Red Sindhi and Thai native zebu breeds adaptation showed to increase while mortality rates substantially decreased (Madsen, 1977). Today the Holstein breed is the predominant breed used in Thailand, with the majority of cattle being 75% or more Holstein (MOAC, 2005). In a previous study in Thailand 305 d milk yield for purebred Holstein cattle were 3,824.60 ± 104.41 kg, while cattle between 70-80 % Holstein had a 305 d milk yield of 4,075.69 ± 67.97 kg (Koonawootrittriron et al., 2006). Rengsirikul et al. (1999) found similar results in Nakhon Pathom Province where cattle that were greater than 75% Holstein had significantly higher 305 d milk yields of 2,874 kg compared to cattle that were less than or equal to 75% Holstein which were 2,677 kg. In a ten year study performed by Prasanpanich et al. (1999), cows that were equal or greater than 87.5% Holstein exhibited the highest 305 d milk yield of 3,653 kg compared to the other two groups of equal to or greater than 75 and 50% Holstein that had 305 d milk yields of 3,482 and 3,353 kg, respectively. However, Prasanpanich et al. (1999) also reported that even though the cattle that were equal to or greater than 87% Holstein had the highest 305 d milk yield, they also were the longest for number of days open, with 190 compared to only 140 d for cattle that were equal to or greater than 75% Holstein. Thus, when looking at the effects of breed on milk yield, it is important to also consider how milk yield and other factors may be affecting other important traits such as fertility.

From these previous studies in Thailand, it seems that the cattle with the higher milk yields were those that were at or around 75% Holstein compared to purebred Holstein or cattle that only contain approximately 50% Holstein. As seen in the Red Danish studies, the fact that purebred Holsteins have shown to have lower milk yields that the 75% Holstein cattle may be to a lack of adaptation to the tropical hot and humid tropical environment in Thailand, and possibly lower plane of nutrition from the given environment. The following sections of climate and nutrition effects on milk yield will further address these issues.

Climate

In many environments climatic seasons can have an effect on various aspects of dairy production. Tropical regions of the world, such as Thailand, usually have a distinct dry and rainy season where temperature and humidity values are very large. These situations in tropical climates make it difficult for some temperate related dairy breeds, such as Holstein to adapt to. Ravagnolo et al. (2000) indicated that the two most important variables to measure when assessing heat stress in Holstein cattle were maximum temperature and minimum relative humidity, which can be represented in the THI (Thermal Humidity Index) index. In their study, Ravagnolo et al. (2000) found that for each unit of increase above a THI level of 72, purebred Holstein cattle a decrease in milk production by 0.2 kg.

In Thailand, Wilairat (1996) reported differences in heat tolerance for three groups of Holstein crossbred cows of 50% Holstein, between 75 and 87.5%, and between 90 and 100%. Results showed that the 50% Holstein cows ranked significantly higher for milk yield, and lower for respiration rate, pulse rate, and rectal temperature, where between the other two percentage Holstein groups there was no difference for heat tolerance or milk yield (Wilairat, 1996). In an additional study in Thailand, differences for heat stress in dairy cattle were measured using three treatments of clipping the coats of cows, shade supplement only, and the combination of shade and coat clipping effects on milk yield (Chareonpojana, 2001). Results showed that cows in the coat clipping treatment had an increase in milk yield of 21%, shade treatment of 21.5%, and combination of shade and coat clipping had an increase of 31.5% (Chareonpojana, 2001). In a similar experiment ¾ Holstein Friesian ¼ Sahiwal cows in the Saraburi province of Thailand were evaluated for heat tolerance in two groups of clipped hair and non-clipped hair (Boonprong, 1999). Boonprong (1999) found that the clipped animals had significantly lower body temperature, respiration rate, pulse rates, and plasma cortisol concentration but higher average daily milk yield than animals that were not clipped. However, Prasananich (2001) showed no significant differences in rectal temperature and milk yields for lactating cows in clipping and non-clipped treatment groups.

Climatic seasonal effects have also have shown to have effects on reproductive performance and fertility in dairy cows. Chanartaepraporn (1995) looked at the effect of season in Thailand on conception rates of 80 heifer’s ages 18 to 30 months at the Dairy farming

Promotion Organization farm. The study had three treatment groups: a control group, a second group injected with $PGF_{2\alpha}$, and a third group injected with Progestagen (SMB) (Chanartaepraporn, 1995). Results of the study showed that in the rainy season conception rates were 45.5, 25, and 41.7% whereas in the summer season (hot and dry season) conception rates were 53.3, 40, and 40% for the control, $PGF_{2\alpha}$, and Progestagen (SMB) treatments, respectively (Chanartaepraporn, 1995). Reproductive rates are important in that they are directly related to overall annual milk yield performance of lactating cows. Cows that take longer to get bred and thus have greater days open, are more likely to remain in the herd for a shorter period of time and have lower total milk output over their lifetime.

Nutrition

As in any livestock production system nutrition plays a vital role in allowing animals to produce to their maximum potential. Proper nutrition is vital for maximizing milk yield and production in dairy cattle production systems. Nutritional recommendations for a 454 kg cow, producing 10 kg of milk a day in mid lactation, is to have a total of 12.4 kg of dry matter intake with diet crude protein level of 12.6 %, 10% in rumen digestible protein (NRC, 2001). The diet used to meet these requirements was feeding 44% of a mid-mature legume, 27% corn silage, 23% dry cracked corn, and 8% soybean meal (NRC, 2001). Depending on stage of lactation, where early in lactation nutritional requirements are the highest and late the lowest, and weight and daily milk production changes, diets of dairy cattle may need to be changed. However, a 454 kg cow that is producing 10 kg of milk a day is similar to many dairy cows in Thailand (MOAC, 2005). Thus, one could expect that the nutritional requirements stated by the National Research Council (2001) should be somewhat applicable to cattle in Thailand. If farmers are not meeting their dairy cows' nutritional requirements, a drop in daily milk production is likely to take place (NRC, 2001).

Kaewkamcharn (2003) reported that differences in milk yield when cows of different Holstein percentages (<75, 75, 87.5, and >87.5%) were fed two different diets. Results showed that cows fed a standard diet based on the NRC's nutrient requirement averaged 15.9 k/d, which was 2.02 k/d higher than cows fed the substandard diet (Kaewkamcharn 2003). In addition to increased milk production, cows in the standard diet group also had significantly higher milk fat percentages (4.37 vs. 4.12%), protein (3.43 vs. 3.27%), and lactose (4.88 vs. 4.81%), as compared to cows fed the substandard diet (Kaewkamcharn 2003). In another study (Rattananupong, 1988), Red Dane cows were fed 1kg of 14.2 % crude protein concentrate for each 2 kg of milk and roughage ad lib, coupled with four different forage diets of Rhodes grass, rice straw with 1.5% urea and 7.5% molasses, rice straw with 2.5% urea and 10.0% molasses, and lastly rice straw with 7.5% molasses and 2.5 kg/d of Leucaena leaves. In this study, Rattananupong (1988) found that animals fed the Rhodes grass diet and rice straw supplemented with leucaena leaves diet were significantly higher dry matter intake during the three months of the trial and a significantly milk yield than cows fed the other diets. Pichet (1989) looked at cattle grazing only high quality planted grass pastures compared to animals fed a ration that consisted of 15.5% crude protein with a TDN of 70%. Results showed that cattle on the grazing system by itself averaged 10.5 kg of milk production per day while the cows on the ration produced 17 kg a day (Pichet, 1989).

Thus, from the research that has been performed in the previously discussed studies, it is clear that if nutritional requirements are being met, then one can expect the dairy cattle to reach their genetic potential for milk production. However, if diets that farmers are feeding their cattle are below requirements then a decrease in performance can be expected.

Factors Affecting Milk Fat

Breed

Genetics of different breeds of dairy cattle vary for milk fat. The predominant breed of dairy cattle in Thailand, are high percentage Holstein cattle (MOAC, 2005). Thus the genetics of the Holstein breed have a major influence on milk fat in Thailand. Previous studies in Thailand have shown milk fat percentage levels for Crossbred cattle ≥75% Holstein having milk fat values of 3.77 %, with a protein content of 3.17 (Garcia et al., 2005). However, due to the hot and humid climates in Thailand, a majority of cattle have some percentage of *Bos indicus* influence which effects milk fat. Breeds such as Sahiwal and Red Sindhi have milk fat values of between 4.3-5.2 % and 4.5-5.2%, respectively (Taneja, 1999). Australian Frisian Sahiwal cattle (50% Holstein; 50% Sahiwal) have reported 305 d fat yields of 115 kg compared to 141 kg for the Australian Holstein Friesian (Taneja, 1999). In addition to *Bos indicus* breeds having an influence on dairy cattle milk fat yields in Thailand, there are other *Bos taurus* breeds such as Red Danish that have also had an impact on the Thai dairy industry. Red Danish have been shown to have 305 d milk fat yield of 133 kg, and when crossed with Red Sindhi (F1 Red Danish and Red Sindhi) up to 152 kg (Madsen, 1977). Thus, based on the moderate heritability of milk fat and selection from the use of different genetics and breed types, dairy farmers are able to achieve a target level for milk fat based on the market they are selling to.

Nutrition

Nutrition also can have a major affect on milk fat. Research has shown that with increase feeding of concentrate, there is also an increase in milk protein components up to a point where if dry matter in the diet is more than 50% concentrate, the increase in starches shows to decrease milk fat percentage (Palmquist and Bealulieu, 1993). In a large review of many studies on milk fat depression, Bauman and Griinari (2003) reported the two main causes of milk fat depression, one being a high grain low forage diet, and two large amounts of plant and/or marine oils in the diet. However, Bauman and Griinari (2003) also stated that even though plant oil supplements in the diet may be high, if roughage intake is high, leading to normal rumen function, then milk fat will not be depressed. Thus, when looking at feeding practices, diets and their affect on milk fat yields, the amount of dietary fiber from forages, in particular green grasses are important for normal rumen function and avoiding milk fat depression (Bauman and Griinari, 2003)

When reviewing studies involving the effects of nutrition on milk fat in Thailand, the literature is limited. In a study of Red Danish crossbred cows, animals fed Rhodes grass hay had higher milk fat yields than those that were fed molasses treated rice straw as their source of roughage (Rattananupong, 1988). In another study Kaewkamcharn (2003) fed Holstein crossbred cows (≥75% Holstein) two diets based on NRC requirements and a substandard diet below NRC requirements. Results showed that cows fed the NRC diet had milk fat percentages of 4.37% compared to those cows fed the substandard diet which had values of 4.17% (Kaewkamcharn, 2003). In addition Kaewkamcharn (2003) reported that milk components were lower in the hot and dry season as compared to the rainy and winter season. This may be due to the lack of forage availability that many farmers face during the dry season in Thailand. The dairy farming promotion organization of Thailand has previously stated that lack of available high quality forage is a concern for farmers (DPO, 2006). Although the literature is somewhat limited in this review, findings from the previously reported studies, there is a clear need for an improvement of forages that farmers feed their cattle. Thus continued research is needed in identifying and training farmers in growing higher quality forages to feed to their animals, in particular in the dry season

Factors Affecting Somatic Cell and Bacterial Counts

Management Practices

Somatic cell count is often a topic of discussion in the dairy industry. Somatic cell counts are not only highly correlated with udder infections, such as mastitis or udder inflammation, but they are also highly correlated with lower milk yield as well. Research has shown that a cow with a somatic cell count of below 100,000/ml usually have no type of udder infection, while a cows with a somatic cell count of 200,000/ml show a low amount of infection, and cows with somatic cell counts between 400,000 and 800,000/ml are found with infection (Ingalls, 1998). Somatic cell count is important for farmers to keep records of because they have shown to decrease milk yield in cows. Research has shown that cows measuring 200,000/ml have a decrease in milk yield equivalent to .68 kg/d, which doubles for every 200,000/ml increase so that cows with counts of 400,000/ml would have a decrease in milk yield of 1.5 kg/d (Ingalls, 1998).

Yhoung-Aree (1999), in a study that involved two hundred and four farms in Central Thailand, examinedt differences in somatic cell and bacterial plate counts among dairy farms. Results showed that in the combined areas median scores for somatic cell count were 41.7% of the farms had a somatic cell count of ≤200,000/ml milk, regarded as a good quality, 12.2% had scores between 200,001 and 250,000/ml with acceptable quality and 46.1 % of the farms had a median score larger than 250,000/ml and marked as poor quality (Yhoung-Aree, 1999). Additionally, in the study farmers that used a single method in milking (either by hand or machine) had significantly lower bacterial counts than those that used more than one method (Yhoung-Aree, 1999). Also, farms that paid attention to hygiene in the trough, milk parlors, and drainage systems had higher milk quality than farms that did not (Yhoung-Aree, 1999).

However, because the measuring of bulk tank somatic cell counts among dairy cooperatives in Thailand is a new technology and not widely practiced, there is limited data on how it is affected by farm management practices. Additionally, although many dairy cooperatives are measuring bacterial scores in Thailand, the technologies used to measure bacterial counts, such as the methylene blue reduction test, are out of date and not precise in their measurements (MDCL, 2005). Nonetheless, from previous studies in other countries there is a vast amount of literature on the subject. In a study looking at factors affecting total bacterial count in raw milk, results showed that farms that frequently cleaned milk containers, cleaned their containers immediately after milking, used boiled water to clean containers and equipment, and had shorter elapsed time from when milk was collected to when it was refrigerated, had lower total bacterial counts (Kivaria et al., 2006). In another study, Mungube et al. (2004) found that farms that kept cows in good body condition, practiced drying off cows and using dry cow therapy, and used separate towels when drying off teats and udders had significantly lower mastitis levels in their herds than farms that did not use these practices. From previous research, implementing simple management practices such as improving cleaning of milk containers, equipment, and keeping a hygienic environment will improve milk quality and decrease mastitis.

Climate and Season

The majority of rainfall in Thailand takes place during the rainy season (May to October), which can receive as much as 900 mm of rain. In many cases this poses a problem for farmers in controlling the amount of mud in pens and cattle resting areas. As a result farmers may have more trouble keeping cattle clean, in particular keeping udder and teats clean more during the rainy season than during other parts of the year. However, there is limited information on how this seasonal effect affects bulk tank somatic cell and bacterial counts in raw milk of farms in Thailand. In a study in the state of California in the United States, results showed that farms had the highest incidence of mastitis in the rainy season, mostly due to problems controlling mud in pens and on cattle (Gonzalez et al., 1990). The findings of Gonzalez et al. (1990) may be similar to what is taking place in Thailand. However in order for this to be confirmed additional research is needed.

Extreme heat and humidity levels also have shown to have an effect on bulk tank somatic cell and bacterial counts in dairies. Research has shown that as temperature and humidity levels rise, mastitis and somatic cell counts also increase (Jordan et al., 2001). These increases in mastitis are due to the heat stress which limits the immune system and immune response in the body (Jordan et al., 2001). Due to the fact that in Thailand most farmers are raising cattle with some *Bos indicus* influence perhaps temperatures where heat stress takes place may be higher than what would be expected of purebred Holstein cattle in temperate environments. However in order to determine if in fact heat stress is leading to increased levels of mastitis in Thailand, additional research will need to be performed.

Educational Experiences of Farmers

Formal and Non-Formal Education

Formal and non-formal education can be described by their environment, audiences, teaching methods and orientations, and overall atmosphere of an education program. Non-formal education is seen as outside of the classroom education programs, such as on-farm training activities or field days, where participants are trying to gain an applied skill such as a farmer taking an artificial insemination course (Merriam et al., 2007). Conversely, formal education has traditionally been seen as public school systems (primary, middle and high school), and higher education institutes such as community colleges, universities, and vocational schools (Merriam et al., 2007). Formal education is usually seen in a structured environment and classroom setting where the school has an actual location and building in which students/participants attend classes (Merriam et al., 2007). In many instances in formal education audiences may be young adults or single adults that are not fully functioning as independent adults, whereas in non-formal education, audiences could be older, have full time jobs, and families of their own. However, this is an area where audiences of both formal and non-formal education could overlap and intermix with one another.

According to the Thailand Ministry of Education, in 2005 there were a total of seventy eight institutes of higher education and forty-four agricultural and technology vocational colleges In Thailand (MOE, 2005). In 2005, the forty-four agricultural and technical colleges had over 39,000 students and 2,000 instructors (MOE, 2005). However, In Thailand many farmers formal education may be only through the primary or the high school level. Elsey and Sirichoti (2001) reported average education levels of Thai durian farmers of 78% with a primary, 18.3% having a high school education level, and 3% with a college education level. As a result of a small percentage of farmers pursuing and receiving higher education, many educational programs, in particular with dairy farmers, consist of non-formal educational methods and settings. In Thailand there are many government departments, dairy cooperatives, and private companies that provide non-formal extension training to dairy farmers. For example, in 2002 the Department of Agricultural Extension began using agriculture clinics that provide training to farmers on animal disease diagnosis, treatment and vaccination, farm accounting, and how to form a cooperative (Department of Agricultural Extension, 2003). Although there are a number of non-formal educational training opportunities for Thai dairy farmers, the Dairy Farming Promotion Organization of Thailand (DPO) insists that there is not enough collaboration and cooperation between the different organizations (DPO, 2006). Each government organization working with dairy farmers in Thailand has their own objectives and programs, making it difficult to integrate different areas, ideas, and personnel together in order to achieve government set goals for the dairy industry (DPO, 2006). Also there is not a great amount of literature concerning how much dairy farmers look to government organizations or dairy cooperatives for their training on dairy farming activities. More research is needed in order to determine what organization dairy farmers receive most of their information regarding dairy production in Thailand. Additionally, information regarding current management practices, practiced by dairy farmers will be helpful in planning and implementing future non-formal educational training programs for dairy farmers in Thailand.

Adoption of Programs and Participatory Learning

The measured success of any educational program aimed at training farmers could be the adoption rate. Adoption rate is the percentage of participants who participated in the educational program that actually went to their farm and implemented these newly learned skills and/or technologies. Since many farmers in Thailand may not receive their training in dairy production from formal educational institutes, many programs aimed at reaching dairy farmers in Thailand are usually non-formal in nature. However, within non-formal education there are many different teaching and learning methods which may affect the rate of adoption of training programs. Depending on the learners themselves, their background and characteristics these learning and teaching methods may vary as to how they affect the adoption of training programs. In Southern Thailand Srinoy et al. (1999) interviewed 114 dairy farmers in order to determine the adoption of practices supported by the Thai government. Results of the study showed that farmers were very diverse in their adoption of certain dairy practices, with their main problems still being low fertility rates and a lack of roughage during the dry season (Srinoy et al., 1999). The inconsistency of adoption of programs by farmers as reported by Srinoy et al. (1999) may be due to the method of training used. Participatory training, where farmers have opportunities to train with hands on experience has shown to be successful in Thailand. In a study aimed at improving local feedstuffs and forages of dairy farmers in Northeast Thailand, farmers were trained through demonstration sites, visiting farms where farmer to farmer interaction and learning took place, and follow up visits to farms by extension agents and researchers were also practiced (Wanapat et al., 2000). Results showed that through the participatory learning methods these new technologies and practices were readily adopted, leading to increased milk yield and a higher income returned to farmers (Wanapat et al., 2000).

In addition to using teaching methods used by trainer and the learning styles of participants, the method of disseminating information can also play a large role in adoption of programs. In a study aimed at fish farmers Turongruang and Demaine (1997) used audio-visual materials as well as leaflets for disseminating information to farmers. Due to the fact that Turongruang and Demaine (1997) target audience had low levels of formal education and spoke a different dialogue, the leaflets and audio-visual material was produced in a way that could be easily understood by the farmers. Scientific and complex words were replaced by pictures and easy to understand descriptions. Results of the study showed that adoption of the program reached towards 70% among farmers (Turongruang and Demaine, 1997). Thus, understanding the audience of farmers extension workers and dairy organizations are trying to reach is also a critical component in adoption of programs. As further training programs are developed to train dairy farmers in Thailand, dairy organizations and cooperatives may need to continue to implement the successful practices noted by previous studies.

Economics of Dairy Farms

Pricing System

Milk pricing systems in Thailand are comprised of a base price plus additions and deductions that dairy cooperatives give, usually based on milk quality. The base price of milk in

Thailand is sold per kilometer of raw milk sold and is not market driven, but rather determined and set by the National livestock committee of Thailand (MOAC, 2006). The national livestock committee is made up of dairy cooperatives, dairy processing factories and government authorities in Thailand (MOAC, 2006). From 1998 to 2006 the standard price for one kilogram of raw milk sold was 12.5 baht. However, the base price that farmers' actually receive may be may be lower than this, mainly due to administration and transportation costs of milk collection centers (MOAC, 2006). For example, in 2006 the Muaklek Dairy Cooperative Limited base price given to farmers was set at 11 kg per kilogram of raw milk sold (MDCL, 2005). In addition to the base price, the Muaklek dairy cooperative gives its members additions and deductions based on milk fat percentage, solids non-fat, bacterial score (measure of bacteria in raw milk) and bulk tank somatic cell count (MDCL, 2005).

Depending on what companies and products dairy cooperatives are marketing their milk too, determines in a large part the emphasis of the pricing system. However as seen in the Muaklek dairy cooperative, the emphasis on milk quality in the area of bacteria in milk and somatic cell count, are more and more becoming an important issue for dairy cooperatives and other private milk collection centers in Thailand.

Expenses

Since most dairy farms in Thailand use some form of a confinement based operation, they rely on concentrate as a major source of an animals' diet. Therefore feed expenses can make up a large portion of a farm's monthly and annual expenses. However, other expenses such as health and veterinary, semen, equipment and building, and loan costs also are part of a farms budget. Average expenses by category of farms in Lopburi province reported by Suzuki (1998) were lower than other studies where annual feed expenditures were 48% for feed, 2% for A.I and medicine, and 8% for loan repayment. Overall expenses accounted for an average of

58% of total average farm revenue (Suzuki, 1998). In another study looking at both grazing and grazing and confinements production systems, Pichet (1989) reported that cows grazing on improved pasture on a 300 d lactation, had grass expenses of 1,440 baht and lactation compared to cows on a 3:1 ration of concentrate to improved pasture with concentrate and feed expenses of 4,290 and 1,220 baht, respectively. In the same study, when cows moved to a diet where concentrate was fed on an ad libitum diet with no grazing on improved pasture, concentrate costs rose to 14,850 baht per 300 d lactation/cow (Pichet, 1989).

Like many other farmers across the globe, Thai dairy farmers require capital in order to make large purchases such as buildings, cattle, and equipment. This capital usually can either come through a loan from a bank or from personal assets. Itsaranuwat and Robinson (2003) reported that 46% of farmers used or had their own source of capital for investment while the remaining 54% used loans from banks or other sources of capital for investment in dairy farming. Of the 54% of farmers that used loans from banks, 70% of the loan came from the bank of Agriculture and Cooperatives while 25% where from commercial banks (Itsaranuwat and Robinson, 2003). Itsaranuwat and Robinson (2003) also found that approximately 70% of all loans were used to buy cows, while 25% was used by farmers to build barns and milking facilities. Although farmers may repay loans by themselves, if the farmer borrowed money from the cooperative the loans will be automatically taken out from the revenue in milk sales each month by the cooperative itself (MOAC, 2006).

Revenue and Profit

Dairy farm revenues in Thailand are mainly comprised of the sale of milk to milk collection centers owned by dairy cooperatives or businesses. However a portion of farm revenue also comes from the sale of calves, in particular bull calves, mature or cull cows, and in some farms the sale of manure for fertilizer. In a study of farms with an average 9 milking cows per farm in Central Thailand, average revenues for the control group of farms were 301,933, 600, 41,980, and 6,986 baht for milk sales, sales of calves, sale of mature animals, and sale of manure, respectively (Hall et al., 2004). Suzuki (1998) reported dairy farms in Lopburi province with an average of 5.3 milking cows had average revenues and profits of 179,483 and 73,642 baht, respectively.

Other sources of revenue for dairy farms in Thailand come from either other on farm agriculture activities or off-farm income. In a study of farms in Thailand, Yhoung-Aree (1999) found that families whose workers worked in only dairy farming or in other on farm agricultural activities had significantly higher income than those families who also worked on non-farm jobs. However, in the same study Yhoung-Aree (1999) found that smaller farms that had land and capital constraints showed to increase their income by working in both farm and non-farm jobs. This study may indicate that there is a level of scale of farm size and constraints that individual farms have which directly relates to total income of farms and where this income comes from.

Although most dairy farms in Thailand feed concentrate as the major source of feed, there is some literature that shows farmers using a grazing system on improved pasture (planted grasses) have been profitable in their operations. Pichet (1989) reported cows that produced a 300 d lactation of 3,150 kg on improved pasture only had a profit of 19,605 baht per lactation. When cows on a 3:1 ration of concentrate to grazing on improved pasture, milk production increased to 3,900 kg, with a 300-d lactation, with profits increasing to 20,620 baht per lactation (Pichet, 1989). However when cows were fed to appetite on a concentrate diet with no grazing, although milk yield increased o 5, 100 kg per 300 d lactation, profits decreased compared to the other diets to 18,150 baht per lactation (Pichet, 1989). The study by Pichet (1989), although performed more than fifteen years ago and included only ten cows per feeding group, showed that there is an optimum for level of feed costs versus the total amount of milk production given per cow and how these factors affect profit per cow/lactation. Based on the type of cattle dairy farms are raising, farmers should try and find that optimum level of feed and total feed costs and milk yield of animals, versus the overall profit of the cows per lactation.

CHAPTER 3

FACTORS AFFECTING MILK YIELD, MILK FAT, BACTERIAL SCORE, AND BULK TANK SOMATIC CELL COUNT OF DAIRY FARMS LOCATED IN THE CENTRAL REGION OF THAILAND

Introduction

Since commercial dairying began in Thailand in the early 1960's, the Thai dairy industry has seen tremendous growth and progress. From 1984 to 1999 raw milk production in Thailand rose from 124 tons to 1300 tons per day and from 1994 to 2000 consumption of liquid milk also rose from 6.81 kg per to 29 kg capita per year (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. As a result of the increased 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). Recent statistics show that there are approximately 400,000 dairy cattle raised in 22,000 farms, with an estimated 70% of farms being considered smallholders because they have less than 10 dairy cows (Rabobank, 2004). The 2005 DPO dairy sire and dam summary indicated that cattle in that population had an average lactation length of 343 d, a milk yield of 3,958 kg / per 305 d, a fat yield of 152.12 kg / per 305 d, and fat percent of 3.84 % / per 305 d (DPO, 2005). In order to continue the past success of the industry and meet the demand for milk production and milk quality, there is a need to develop more in depth research to determine the factors affecting milk production and milk quality in Thai farms.

Tropical countries such as Thailand face seasonal climate patterns that provide unique challenges to dairy farmers. In the rainy season, Thailand can receive as much as 900 mm of rain and reach THI levels of up to 79, which provide challenges such as heat stress and keeping the stalls and resting areas clean that are difficult for farmers to control. Likewise, in winter when there is little rain and green forage available, providing adequate amounts of quality forage to cattle is also a challenge. The ability of farmers to provide adequate nutrition and management to high yielding, Holstein cattle has become an increasing constraint and problem for Thai dairy farmers (Chantalakhana and Skunmun, 2001) . In addition, improving the sanitation and milk hygiene of farms is an increasing concern of Thai dairy farms and cooperatives. Thus, emphasis needs to be placed on identifying management factors within farms that are leading to lower milk yields in cows 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

Location

The study was performed in the country of Thailand, located between latitudes 5° 37'N to 20° 27'N and longitudes 97° 22'E to 105°, in Southeast Asia (MD, 2002). The size of Thailand is 513,115 km^2 and has a population of approximately 62 million people (TAT, 2005). The farms in the study were located in the central region of Thailand, in the provinces of Saraburi and Nakhon Ratchasima which are approximately 3,576 and 25,494 km^2 in area, respectively (TAT, 2005). The Saraburi province is in the northeast central region of Thailand and has a topography ranging from plains to plateaus, while Nakhon Ratchasima, which borders Saraburi to the northeast, is made up mostly of plateaus and mountain terrain (TAT, 2005). Within Saraburi province, dairy farms were located in three districts of Kaeng Khoi, Muaklek, and Wang Muang. Dairy farms in Nakhon Ratchasima province were located in the district of Pak Chong. The

Saraburi province contained a total of 786 dairy farms, of which 28 farms were in Kang Koi, 737 farms in Muaklek, and 21 farms in Wang Muang. The Nakhon Rachasima province contained 248 farms, all in the Pak Chong district.

Climate

The climate of Thailand is tropical and can be categorized into three climatic seasons (MD, 2002): winter (November to February), summer (March to June), and rainy (July to October). The winter season is characterized by being cool and dry, summer as hot and dry, and the rainy season as hot and humid. The weather in Thailand is heavily influenced by monsoonal weather patterns. The southwest monsoon, beginning in May brings streams of moist air from the Indian Ocean which results in plenty of rain from May through October (MD, 2002). A second monsoon, the northeast monsoon, begins in October and brings colder air from the north, particularly in the north and northeast areas (MD, 2002). Annual rainfall in most areas of Thailand ranges from 1200 to 1600 mm (MD, 2002). Table 3-1 shows the average temperature, relative humidity, rainfall and calculated THI values by season in the central region of Thailand from 1971 to 2000.

Description of Farms

Nutrition

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 a limited pasture area (Garcia et al., 2005).

Many farmers in Central Thailand do not have enough land to produce sufficient forage for their cattle and they cannot afford to buy more land because of the high cost of land in this region. Thus, these farmers must purchase forage to supplement their operations. Purchased forages include corn silage, cassava and cassava silage, rice straw, and hay. In the winter and summer seasons, when forages are less abundant, rice straw is fed on an unlimited basis as the major source of roughage (Suzuki, 1998). Concentrate is used to supplement forages. Typical ingredients include corn, soybean meal, cottonseed, rice bran, and cassava by-products. Concentrate amounts given to milking cows range from 12 to 15 kg per day. Larger amounts of concentrate are typically given to higher yielding cows. Dairy farmers usually provide a mineral supplement to their cattle.

Breed of cattle, breeding, and healthcare.

There was no breed information available on the animals of farms in the study. However, according to the Thai government, the majority of dairy cattle in Thailand are 75% Holstein or greater (MOAC, 2005). Farms primarily use artificial insemination (AI) to breed cows. Cooperatives provide veterinary services to farms which include AI and health care for animals. Two other organizations, the Dairy Farming Promotion Organization (DPO) and the Department of Livestock Development (DLD), also provide veterinary, healthcare, and AI services to farmers. Most farms use semen of high percentage Holstein crossbred bulls to AI their cows. However, some farms use semen from beef breeds such as Brahman or Charolais. Farmers use the EBV of bulls and suggestions from government and cooperative advisors to select sires. Semen comes from sires in Thailand and it is also imported from countries such as Canada, the United States, and New Zealand. Vaccinations, including that to prevent Foot and Mouth Disease, are given to cows on farms annually by government veterinarians. Other health care concerns of cattle are either treated by the farmers themselves or through cooperative veterinary services. Antibiotics are typically given to treat infections, such as mastitis.

Milking management

Farmers milk their cows twice daily, once in the morning and once in evening. Primarily single unit milking machines are used to milk cows. Extra milk is used to bottle feed calves and also is consumed by family members. Farmers send their milk to one of the Muaklek dairy cooperative milk collection centers between 6:30 to 8:30 am in the morning and from 4:30 to 6:30 pm in the evening (MDCL, 2005). Farmers either deliver the milk to the milk collection centers themselves, or pay a fee to the cooperative to come to their farm and pick it up. 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 data for this study were collected from 1,034 dairy farms. Farms were members of the Muaklek dairy cooperative. Records were collected by Muaklek dairy cooperative personnel at milk collection centers. Collection of data was at the farm level; individual animal records were unavailable. 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. There were 4 farm districts: Muaklek, Kaeng Khoi, Pak Chong, and Wang Muang. A season variable was created to account for seasonal environmental differences. Years were assigned based on the collection year, and seasons were defined as winter and rainy. There was information from four years (2003, 2004, 2005, and 2006) and three seasons (rainy, winter, and summer). Because data were available from the rainy season of 2003 to the summer of 2006, a total of 9 year-season groups were represented. 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). 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.

Bacterial scores were assessed using a methylene blue reduction test. The test was administered by Muaklek Dairy Cooperative personal at milk collection centers. Administration of the test was performed by placing drops of methylane 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 were then assigned to milk samples ranging from 1 to 4 based on the number of hours needed for the sample to change colors 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).

Descriptive Analysis

To describe the bacterial score and BTSCC values for farms, farms were assigned to categories using thresholds based on the Muaklek dairy cooperative milk pricing levels. Price increases and deductions were given per kilogram of milk based on bacteria and BTSCC levels found in milk samples. Categories for bacterial score were: 1, 2, 3, and 4. Categories for BTSCC were: BTSCC ≤ 200,000; 200,001 ≤ BTSCC ≤ 1,000,000; 1,000,001 ≤ BTSCC ≤ 1,500,000; 1,500,001 ≤ BTSCC ≤ 2,000,000; 2,000,001 ≤ BTSCC ≤ 2,500,000; and BTSCC > 2,500,000. General means, standard deviations, number of observations, and percentages of observations in each category by season of collection date were calculated for bacterial score and BTSCC using the frequency procedure of SAS (SAS, 2004).

Statistical Analysis

The farm milk yield, average milk yield per cow, milk fat, and BTSCC were analyzed using the mixed model procedure of SAS, with least squares means being used to determine differences within a class (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 model can be represented as follows:

$$y = Xb + Z_f u_f + e$$

where

y = vector of FMY records,

b = vector of fixed effects of year-season-farm district subclass, and number of milking cows covariate

u_f = vector of random farm effects,

X = incidence matrix relating FMY records to elements of b,

Z_f = incidence matrix relating FMY records to elements of u_f.,

e = vector of residual effects.

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 model can be represented as follows:

$$y = Xb + Z_f u_f + e$$

where

y = vector of AYC or milk fat records,

b = vector of fixed effects of year-season and farm district-farm size subclass,

u_f = vector of random farm effects,

X = incidence matrix relating AYC or milk fat records to elements of b,

Z_f = incidence matrix relating AYC or milk fat records to elements of u_f,

e = vector of residual effects.

The BTSCC data was not normally distributed. Thus, data was 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 farm-size subclass, and the random effects of farm and residual.

Random farm effects in the above models were assumed to have a mean of zero and a common variance σ_f^2. Random residual effects were assumed to have mean zero and common variance σ_e^2. Variances for random effects were calculated using restricted maximum likelihood estimation (REML). Least squares means for fixed effects were compared using a t-test following a significant F-test for these effect using $\alpha = 0.05$ level. Differences of subclasses within fixed effects were calculated using a t-test using an $\alpha = 0.05$ level. Significance of the variance due to farms within farm sizes (σ_f^2) was determined using a z-score ratio.

Bacterial scores included categories 1 to 4, and it followed a Poisson distribution. Therefore, a generalized linear model of the bacterial score trait was analyzed using 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. The model can be represented as follows:

$$\log (u_i) = X_i'b + e$$

where

u_i= vector of means of LBS

b= vector of year-season, and farm district-farm size subclass,

X_i= incidence matrix relating LBS records to elements of b,

e = vector of residual effects.

Least squares means for fixed effects were compared using a chi-square test following a significant F-test for effects using $\alpha = 0.05$ level. Residual effects in the LBS model were assumed to have mean zero and common variance σ_e^2.

Results

Descriptive Analysis

Tables 3-2 and 3-3 contain the percentages of bacterial scores and BTSCC by threshold and season, respectively. Across season, the summer season had the greatest amount of bacteria samples that were score 1 (82.75%) and least amount of score 4 (2.62%). The rainy season had the highest combined percentage of samples with a BTSCC greater than 1,000,000 cells/ml of 11.11%, as compared to the winter and summer seasons (9.51 and 10.47%, respectively).

Regression Analysis

Farm milk yield

The year-season farm district subclass and milking cow effects were important sources affecting FMY (P < 0.0001). The variance estimates for random effects of farm and residual were 4025.83 kg^2 and 1998.95 kg^2, respectively. Least square means for FMY by year-season and farm district are presented in Table 3-4. 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. In all districts FMY was higher (P < 0.05) in the winter season than the rainy and summer season of each year. Every district showed an increase (P < 0.05) in FMY from the 2003 rainy season to the 2005-2006 winter season, of which Wang Muang had the greatest FMY increase (36.51 kg) and Kang Koi the lowest (13.78 kg).

Average milk yield per cow

Year-season and farm district - farm size subclass variables affected AYC (P < 0.0001). The variance estimates for farm and residual were 144.92 kg^2 and 35.21 kg^2, respectively. 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 the summer or winter seasons. Least square means for AYC by farm size and farm district are presented in Figure 3-1. In the Kaeng Khoi district, AYC for small farms (11.76 ± 2.92 kg) was higher, but not different (P > 0.05) from medium (9.18 ± 4.25 kg) and large farms (8.68 ± 6.95 kg). Small farms in the Muaklek district were significantly higher for AYC (15.76 ± 0.63 kg) than medium (11.44 ± 0.74 kg) or large farms (11.63 ± 1.09 kg). In the Pak Chong district, small farms were higher for 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). Thvere was no difference for

AYC ($P > 0.05$) among small (11.96 ± 4.01 kg), medium (9.54 ± 4.01 kg), and large (11.24 ± 6.95 kg) farms in the Wang Muang district.

Milk fat percentage

Year-season was an important ($P < 0.0001$) source of variation affecting milk fat % of farms, while the farm district - farm size subclass approached significance ($P = 0.07$). The variance estimates for farm and residual were 0.01676 $\%^2$ and 0.1275 $\%^2$ respectively. Least square means for milk fat % by year-season are in Figure 3-2. Milk fat percentage in the 2004-2005 winter had the largest value (3.92 ± 0.01 %) and was higher ($P < 0.05$) than all other year-season groups, while the 2006 summer had the lowest milk fat value (3.77 ± 0.01 %) and was lower ($P < 0.05$) than all other year-seasons. The milk fat values for the 2005 summer (3.88 ± 0.01 %) and 2006 rainy (3.88 ± 0.01 %) seasons were not different from one another ($P = 0.12$), while every other season group combination did differ ($P < 0.05$). Least square means for milk fat percentage by farm size and farm district are shown in Figure 3-3. In the Kaeng Khoi and Wang Muang districts, large farms had the highest milk fat value (3.91 ± 0.07 and 3.85 ± 0.01 %, respectively) but these were not different ($P > 0.05$) from those of small and medium farms. Small farms had the highest (3.88 ± 0.007 %, $P < 0.05$) milk fat in the Muaklek district and were significantly higher than both those of medium (3.85 ± 0.008 %) and large farms (3.83 ± 0.01 %). In the Pak Chong district, small farms had the highest value (3.85 ± 0.01 %) for milk fat, but were not different ($P > 0.05$) from medium and large farms (3.83 ± 0.01 and 3.84 ± 0.02 %, respectively). Across farm sizes and districts, medium farms in the Kaeng Khoi district had the highest value for milk fat (3.91 ± 0.07 %), while large farms in the Muaklek district had the lowest (3.83 ± 0.01 %). Within districts, small farms in the Muaklek district were higher for milk fat ($P < 0.05$) than both medium and large farms, while in all other districts there was no difference ($P > 0.05$) among farm sizes for milk fat.

Bacterial score

Year-season and the farm district - farm size subclass both affected LBS ($P < 0.0001$). Least square means results of LBS for year-season and farm district by farm size are presented in Figures 3-2 and 3-4, respectively. The 2004-2005 winter had the highest LBS value (0.355 ± 0.007) which was higher ($P < 0.05$) than those of all other seasons, while the 2006 summer had the lowest value (0.268 ± 0.007) and was lower ($P < 0.05$) than all other seasons. 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, small farms had the highest LBS value of 0.189 ± 0.01 but were not different ($P > 0.05$) from medium and large farms (0.131± 0.02 and 0.174 ± 0.04, respectively). Small farms were lower ($P < 0.05$) for LBS (0.231 ± 0.003) than all other farm sizes in the Muaklek district. Medium farms in the Muaklek district had a lower value (0.268 ± 0.004) for LBS than large farms (0.283 ± 0.006) and approached difference, but were not different ($P = 0.05$). In the Pak Chong district, all farms sizes were different from one another ($P < 0.05$) for LBS with small farms having the lowest value of 0.212 ± 0.006, medium farms intermediate at 0.265 ± 0.007 and large farms having the highest value of 0.313 ± 0.01. In the Wang Muang district, all farm sizes were different ($P < 0.05$) from one another with small farms having the lowest LBS value of 0.303 ± 0.02, medium farms of 0.624 ± 0.01, and large farms the largest of 0.762 ± 0.03. Across districts and farm sizes, the large farms in the Wang Muang district had the highest LBS value whereas medium farms in Kaeng Khoi district had the lowest. In the Muaklek, Pak Chong, and Wang Muang districts, small farms had lower LBS values than large farms ($P < 0.05$).

Bulk tank somatic cell count

Month nested within year and farm district by farm size subclass both affected LBTSCC ($P < 0.0001$). Variance estimates for farm and residual were 0.3202 and 0.4737, respectively. Least square means for LBTSCC by farm district and farm size are contained in Figure 3-5. 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. There were no differences ($P < 0.05$) for LBTSCC among the months of January (12.83 ± 0.05), February (12.81 ± 0.05), March (12.82 ± 0.05), April (12.81± 0.05), and June (12.85 ± 0.05).

In the Kaeng Khoi district, small farms had the highest value for LBTSSC (12.76 ± 0.15) but they were not different ($P > 0.05$) from those of medium or large farms (12.72 ± 0.23 and 12.65 ± 0.33, respectively). 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 ($P > 0.05$) between small (12.30 ± 0.19) and medium farms (12.69 ± 0.20) for LBTSCC. Across farm districts and sizes, farms in the Wang Muang had the highest LBTSCC value while small farms in Wang Muang had the lowest. In the Muaklek, Pak Chong, and Wang Muang districts, large farms were higher ($P < 0.05$) than small farms for LBTSCC.

Discussion

The lower FMY values during the rainy and summer seasons are likely due to heat stress and its effects on milk production. Although breed composition of animals was unavailable in this study, the Thailand Ministry of Agriculture and Cooperatives (2005) claims that the majority of dairy cattle in Thailand are 75% or more Holstein. If cattle in farms are primarily high percentage Holstein, heat stress due to high THI levels (76 or more) could contribute to lower milk yields in the summer and rainy seasons (West, 2003). 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 (Kitpipit et al., 2003; Wilairat, 1996). Koonawootrittriron et al. (2001) found that Holstein cattle had lower 305 d milk yields in the rainy season as compared to the winter and summer seasons. They also showed that milk yields of ¾ Holstein: ¼ Red Sindhi dairy cows produced more milk than both Holstein and ½ Holstein: ½ Red Sindhi cattle, indicating that ¾ Holstein cattle may be appropriate to the environment in Central Thailand. A similar study also revealed that ¾ Holstein: ¼ Sahiwal cows in Thailand exhibited no difference in milk yield between the rainy and winter seasons, indicating that the hot and humid climate in the rainy season had little effect on milk yield (Umpapol, 2001).

In addition to the effect of climate on milk yield, seasonality of mating in Central Thailand may also contribute to lower milk yields during the rainy season. Cartmill et al. (2001) found that when THI levels are greater than 72, fewer cows are detected in estrus and conception rate is lower. Similarly, Chanartaeparporn (1995) reported lower conception rates for Holstein heifers (45.5 %) in the rainy season compared to the summer season (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 as compared to the winter season, 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 that farms milking 9 cows per day had higher yearly milk yields per cow than larger farms (Pichet, 1989). However, only limited research has been conducted to investigate the effect of the size of dairy farms in Central Thailand. Typically small farms in Thailand are diversified in their agriculture activities, where in addition to dairying, farmers produce other crops and forages and use crop residues and forages as feed for their animals (Chinwala and Umrod, 1988). These diverse activities may allow small farmers to feed higher quality by-products and forages to their cattle compared to larger farms. 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, whereas 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. Another characteristic of small farms is that they are primarily run by family members, while larger dairy farms in many instances are run by hired labor (Garcia et al., 2005). As a result, nutritional and health care of dairy cattle may be better in small farms, possibly helping them to have higher AYC than those of medium and large farms. Although the majority of small farms were higher for AYC than larger farms, it is important to note that the variability of AYC in medium and large farms was much larger than that of small farms. This was partly due to the smaller sample size of medium and large farms, but also due to the wide range in performance of cows in medium and large farms.

The reason that small farms in Muaklek had higher ($P < 0.05$) milk fat percentage than medium and large farms was likely due to the differences in the quality of forage fed to animals. Small farms fed a greater amount of green fresh cut forage, where 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).

Only 28.3% of samples from farms had ≤ 200,000 cells/ml BTSCC, which is much lower than the 41.7% reported by Yhoung-Aree (1999) in Central Thailand. The average BTSCC here was also much higher than the desired BTSCC levels indicated by NMC (1996), suggesting that mastitis levels of farms in this study may have been relatively high. Inadequate knowledge and training of farmers regarding proper pre and post milking of lactating cows, and dry cow management are a few areas that have been identified as factors that could be leading to high levels of mastitis in dairy farms in the Southeast Asia region (Thirapatasakun, 1999). Lack of hygiene becomes even more of a problem with the large amounts of rain that fall in the rainy season, increasing the challenge for dairy farmers to control mud and water in areas where cattle stand and rest. Poor floor hygiene, insufficient drainage, and muddy resting areas may substantially contribute to the high LBS values seen in the rainy season (Yhoung-Aree, 1999). Further, stall and milking equipment cleanliness, frequency of cleaning milk containers, and water quality used on farms can help to increase the amounts of bacteria in milk (Thirapatsakun, 1999; Kivaria et al., 2006). In addition, elapsed time from milking to transporting of milk to milk cooperatives also influences bacteria levels in milk (Yhoung-Aree, 1999).

Detailed information on management at the farm level was unavailable for this study. Thus, 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. Increased training to farmers in these areas will help improve of 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 effecting 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.

Table 3-1. Rainfall, temperature, and relative humidity averages by season from 1971 to 2000 for the central region of Thailand

Season[a]	Rainfall (mm)	Temp (°C)	Relative humidity (%)	THI[b]
Winter	124.4	26.1	70	75.52
Summer	187.1	29.6	69	80.6
Rainy	903.3	28.3	79	79.95
Average	113	-[c]	75	-

a Seasons were winter (November – February), summer (March – June), and rainy (July – October)

b Thermal heat index = td – (0.55 - 0.55 RH) (td - 58), where td is dry bulb temperature (°F) and RH is relative humidity, presented as a decimal

c Data unavailable

Table 3-2. Bacterial score samples in percentages by threshold level[a] within season

	Bacterial score (%)			
Season[b]	1	2	3	4
Rainy	78.43	13.91	4.13	3.54
Winter	79.17	13.55	4.01	2.62
Summer	82.75	11.56	3.07	2.62
Average	80.11	13.00	3.73	2.92

[a] Threshold levels were based on the milk pricing system of the Muaklek Dairy Cooperative. Deductions and premiums are given per kg of milk based on high and low bacterial score

[b] Seasons were winter (November – February), summer (March – June), and rainy (July – October)

Table 3-3. Bulk tank somatic cell count (BTSCC) samples in percentages by threshold level[a] within season

	Season[b]			
BTSCC (cells/ml)	Rainy[c]	Winter	Summer	Average
1 to 200,000	33.90	27.85	23.42	26.33
200,001 to 1,000,000	54.99	62.64	66.11	63.26
1,000,001 to 1,500,000	6.59	6.12	6.69	6.42
1,500,001 to 2,000,000	2.26	1.88	2.20	2.06
2,000,001 to 2,500,000	1.24	0.67	0.73	1.07
> 2,500,000	1.02	0.84	0.85	0.86

[a] Threshold levels were based on the milk pricing system of the Muaklek Dairy Cooperative. Deductions and premiums are given per kg of milk based on high and low BTSCC

[b] Seasons were winter (November – February), summer (March – June), and rainy (July – October)

[c] Rainy season only contains records from October of 2005

Table 3-4. Farm milk yield by farm district, year and season in least square means (LSM), standard errors (SE) and number of records (n)

Farm district	Year	Season	n	LSM	SE
Kaeng Khoi	2003	Rainy	3171	108.47	12.03
Kaeng Khoi	2003-2004	Winter	3255	120.55	12.02
Kaeng Khoi	2004	Summer	3375	128.69	12.02
Kaeng Khoi	2004	Rainy	3164	111.07	12.02
Kaeng Khoi	2004-2005	Winter	2803	122.45	12.03
Kaeng Khoi	2005	Summer	2866	113.83	12.03
Kaeng Khoi	2005	Rainy	2866	102.40	12.03
Kaeng Khoi	2005-2006	Winter	2720	122.25	12.03
Muaklek	2003	Rainy	85353	123.05	2.34
Muaklek	2003-2004	Winter	87441	139.05	2.34
Muaklek	2004	Summer	88844	145.83	2.34
Muaklek	2004	Rainy	89856	136.75	2.34
Muaklek	2004-2005	Winter	87505	160.86	2.34
Muaklek	2005	Summer	86914	157.24	2.34
Muaklek	2005	Rainy	85547	144.35	2.34
Muaklek	2005-2006	Winter	80348	150.04	2.34
Pak Chong	2003	Rainy	28856	120.94	4.04
Pak Chong	2003-2004	Winter	29098	130.83	4.04
Pak Chong	2004	Summer	29652	134.57	4.04
Pak Chong	2004	Rainy	30311	129.25	4.04
Pak Chong	2004-2005	Winter	29263	147.91	4.04
Pak Chong	2005	Summer	29661	139.65	4.04
Pak Chong	2005	Rainy	28493	129.24	4.04
Pak Chong	2005-2006	Winter	25924	136.60	4.04
Wang Muang	2003	Rainy	2488	102.44	13.87
Wang Muang	2003-2004	Winter	2541	124.43	13.87
Wang Muang	2004	Summer	2562	130.43	13.87
Wang Muang	2004	Rainy	2583	120.43	13.87
Wang Muang	2004-2005	Winter	2399	126.12	13.87
Wang Muang	2005	Summer	2428	120.08	13.87
Wang Muang	2005	Rainy	2428	118.75	13.87
Wang Muang	2005-2006	Winter	2280	138.95	13.87

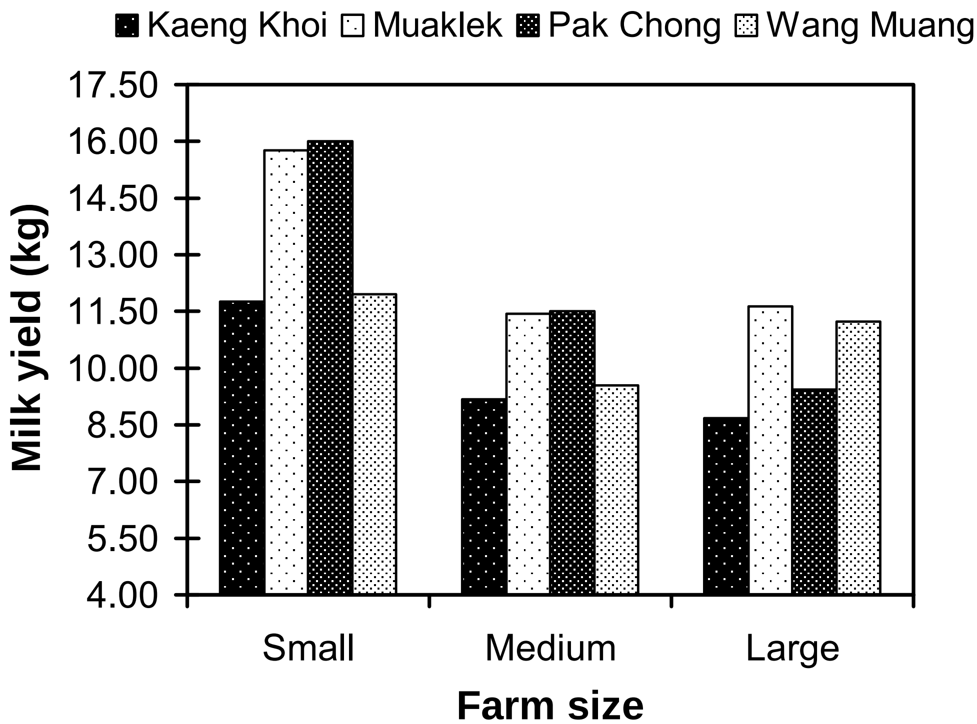

Figure 3-1. Average milk yield per cow by farm size and district in least square means

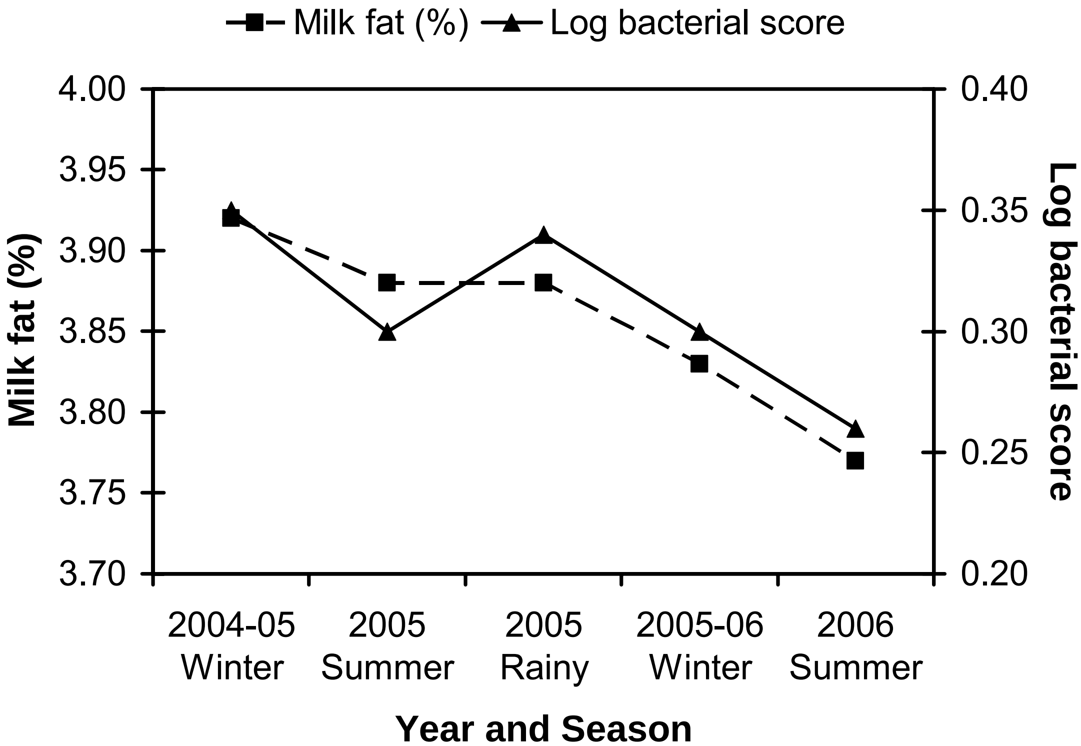

Figure 3-2. Milk fat percentage and log bacterial score by year and season in least square means

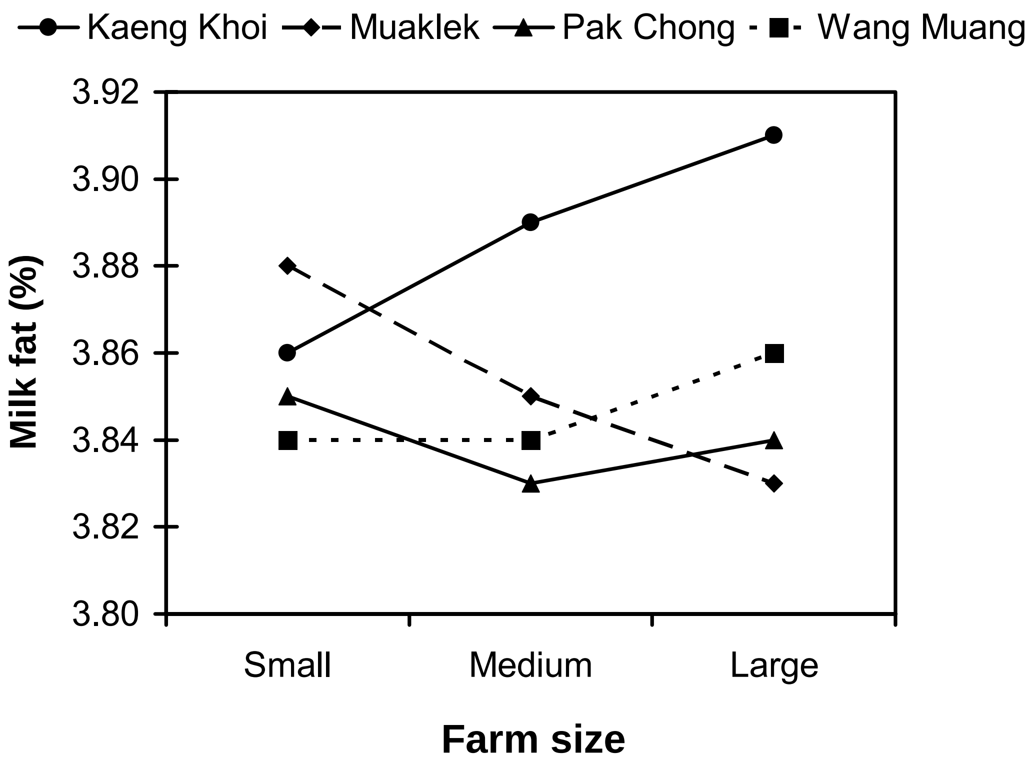

Figure 3-3. Milk fat percentage by farm size and farm district in least square means

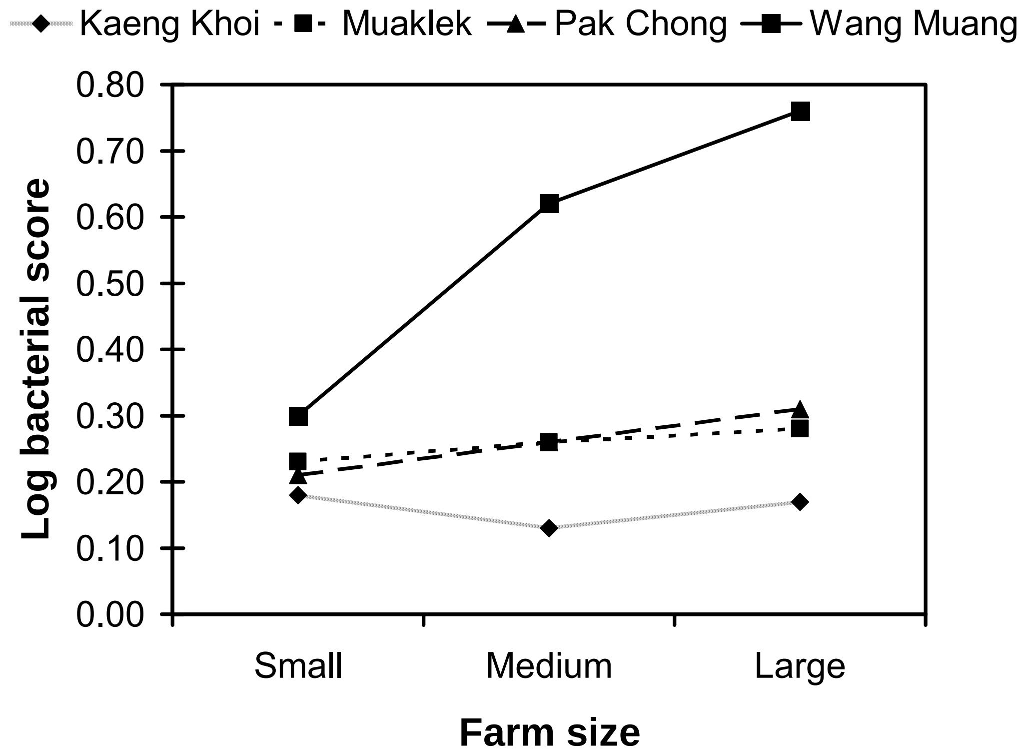

Figure 3-4. Bacterial score (log) by farm district and farm size in least square means

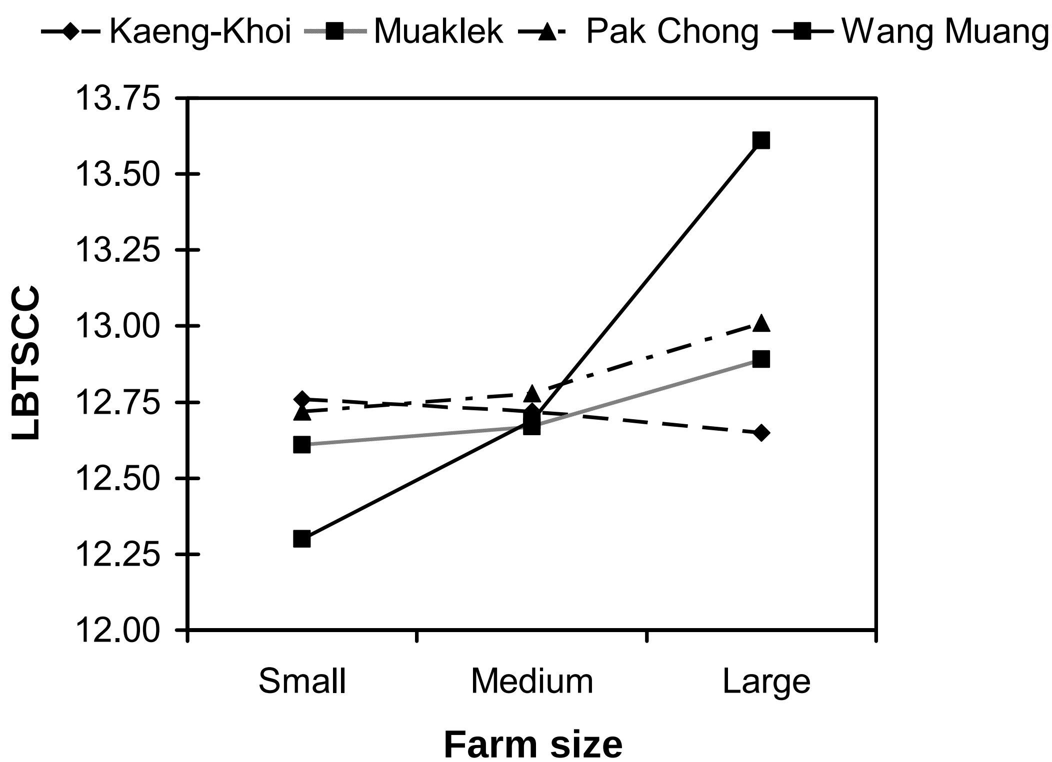

Figure 3-5. Log of bulk tank somatic cell count (LBTSCC) by farm district and farm size in least square means

CHAPTER 4

COMPARISON OF TWO MILK PRICING SYSTEMS AND THEIR EFFECT ON MILK PRICE AND MILK REVENUE OF DAIRY FARMS IN THE CENTRAL REGION OF THAILAND

Introduction

Historically cattle in Thailand were primarily used for draft and meat production purposes, consequently until the 1950's there had been no tradition of consuming dairy products in Thailand (Suzuki, 1998). However, beginning in the 1960's the Thai government, in cooperation with the United Nations, began a school milk program, whose purpose was to increase nutritional levels in children, and mothers and infants by providing powdered and fresh milk. As the demand for milk and other dairy products increased, the Thai government began to promote dairy programs aimed at generating income opportunities for small farmers and reducing the dependency on milk imports from other countries (Suzuki, 1998). Currently, most dairy farms in Thailand are considered small size farms, with an average herd size of twenty animals, and they are typically members of a local dairy cooperative (Garcia et al., 2005). Thai dairy cooperatives serve similar roles as dairy cooperatives in other countries, where cooperatives purchase, and market milk from farms, as well as provide technical assistance to farms. Milk prices are determined by the Thai government, and during the time of this study (2004-2006) milk price was 12.5 baht per kilogram (Moran, 2005). Even though milk prices are set by the government, they still differ across cooperatives due to additions or deductions assigned by the cooperative. Typical additions/deductions specified by cooperatives to farms are based on milk components such as milk fat, solids-non-fat, and milk quality factors such as bacterial score and BTSCC. Through these additions and deductions, farms can either lose or gain milk revenue that may determine whether they make a profit in a given year. Milk yield, milk composition, and milk quality depend on health, nutrition, and herd management. Consequently, herd health, nutrition of animals and other management factors play an important role in influencing revenues of dairy farms. For example, farms with good sanitation practices that control mud and water in pens and resting areas of cattle may have milk with low levels of bacteria and fewer cows with mastitis, benefiting from additions in milk price due to low bacterial scores and low BTSCC.

The objectives of this study were 1) to determine the effect of pricing system, month and year, district of farm, and farm size on milk price, and 2) to calculate FMR and losses in FMR due to deductions in milk price based on milk fat percentage, bacterial score, and BTSCC of dairy farms in the Central region of Thailand.

Material and Methods

Data

Data were from 1034 farms located in the provinces of Saraburi and Nakhon Ratchasima in Central Thailand. All farms were members of the Muaklek dairy cooperative. The Saraburi province contained 786 dairy farms, of which 28 were in the Kaeng Khoi district, 737 in the Muaklek district, and 21 in the Wang Muang district. The Nakhon Rachasima province had 248 farms, all in the Pak Chong district. There were 58,575 FMP records collected every ten days from November 1, 2004 to June 30, 2006, and 813,636 FMY records collected daily from November 1, 2004 to February 28, 2006. Data were collected by Muaklek dairy cooperative personnel at milk collection centers.

Data on FMY and FMP included day, month, and year of collection date, district where the farm was located, and farm identification. A farm size variable was created to group farms into three size categories and it was based on the number of cows milked per day in each farm in January of 2005. The number of cows milked per farm was not regularly recorded, thus it was assumed to have remained constant throughout the duration of this study. Farms size groups were classified as follows: 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 517 small, 362 medium, and 155 large farms.

The Muaklek dairy cooperative used two separate pricing systems for FMP over the duration of this study. A pricing system variable was created to account for changes in the calculation of FMP. The two Muaklek dairy cooperative pricing systems were calculated using a base price of 11 baht/kg, plus additions/deductions based on components and quality of milk (Table 4-1). The two pricing system groups were defined as: 1) standard base price of 11.0 baht/kg plus additions/deductions for milk fat percentage, solids-non-fat, and bacterial score, and 2) standard base price of 11.0 baht/kg plus additions/deductions for milk fat percentage, solids-non-fat, bacterial score, and BTSCC. Pricing system 1 was in place from February 2004 to September 30, 2005, and pricing system 2 from October 2005 to June 2006. The maximum milk price that farms could have received in pricing systems 1 and 2 were 11.7 baht/kg and 11.8 baht/kg, respectively.

Statistical Analysis

The FMP data was not normally distributed. Thus, data were normalized using a logistic transformation. Results from the statistical analysis were back transformed to the original scale of the data. FMP was analyzed using the GLM procedure of SAS (SAS, 2004). The FMP model included the fixed effects of pricing system, month nested within year of collection date by pricing system subclass, farm district by farm size by pricing system subclass, and residual. The model can be represented as follows:

$$y = Xb + e$$

where

y = vector of FMP records,

b = vector of fixed effects of pricing system, month nested within year of collection date by pricing system subclass, and farm district by farm size by pricing system subclass

X = incidence matrix relating FMY records to elements of b,

e = vector of residual effects.

Residual effects were assumed to have mean zero and a common variance σ_e^2. Least squares means for fixed effects and differences between subclasses within fixed effects were compared using a t-test at an $\alpha = 0.05$ level.

Farm milk revenue was calculated as the product of the average FMY and the average FMP the farm received during that period. Maximum FMR was calculated by taking the product of the maximum achievable milk price (pricing system 1: 11.7 baht/kg; pricing system 2: 11.8 baht/kg) by the average FMY a farm received during that period. Loss in FMR was the difference between maximum FMR and actual FMR. Losses in FMR were summed across all months, years, and within farm districts, to compute the average loss in FMR per district. Subsequently, average district FMR losses were added to obtain total average loss in FMR for the Muaklek dairy cooperative during the time of this study.

In order to determine the causes of loss in FMR, histograms of loss in milk revenue were created for milk price observations during each pricing system. Causes for losses in FMR during pricing system 1 were due to lower milk fat, solids-non-fat, and higher bacterial score (Table 4-1). Causes of loss in milk revenue during pricing system 2 were due to discounts from higher bacterial score, BTSCC, or a combination of higher bacterial score and BTSSC. Deductions due to milk fat percentage and solids-non-fat were found to have negligible effect on losses is FMR during pricing system 2, thus, they were not included.

Results

Farm Milk Price

Pricing system, month nested within year by pricing system subclass and farm district by farm size by pricing system effects were important sources affecting FMP ($P < 0.0001$). In pricing system 1, FMP (11.68 baht/kg) was lower ($P < 0.05$) than FMP in pricing system 2 (11.71 baht/kg; Table 4-2). All months within year across pricing system 2 were greater ($P < 0.05$) for FMP than all months within year for pricing system 1 (Figure 4-1). Within pricing system 1, the FMP for June, July, and August of 2005 were similar, but they were lower than in April and May of 2005 ($P < 0.05$). In pricing system 2, FMP in December of 2005 was higher ($P < 0.05$) than all months within year for FMP, while May of 2005 was lower ($P < 0.05$) than all other months within year.

When comparing FMP for farm size within each district and pricing system, all farm sizes in each farm district had lower ($P < 0.05$) for FMP in pricing system 1 than pricing system 2 (Table 4-2). In pricing systems 1 and 2, there were no differences among farm sizes for FMP in Kaeng Khoi. In Muaklek, all farm sizes were different from one another ($P < 0.05$) for FMP, with small farms having the highest FMP and large farms the lowest FMP, in both pricing systems. Small farms in Pak Chong and Wang Muang had greater ($P < 0.05$) FMP than medium and large farms during pricing system 1, whereas medium and large farms had similar FMP ($P = 0.79$). During pricing system 2 in Pak Chong large farms had lower ($P < 0.05$) FMP than small and medium size farms, which in turn were not different from one another. Small farms had greater ($P < 0.05$) FMP than both medium and large farms under both pricing systems in Wang Muang.

Farm Milk Revenue and Loss in Farm Milk Revenue

Results for FMR are presented in Figure 4-2. Across all months and within each year, farms in Muaklek had the highest milk revenues, while farms in Kaeng Khoi had the lowest. Farms in Wang Muang had the highest loss in milk revenue in every month within each year, whereas farms in Kaeng Khoi had the lowest (Table 4-3). Farms in each district had lower losses in milk revenue during pricing system 1, and higher losses in milk revenue during pricing system 2. Across farm sizes, large farms had the largest amount of losses in FMR in every month and year, whereas small farms had the lowest (Figure 4-3). Total losses in milk revenue from November 2004 through February 2006 were 4,038.7, 9,940.7, 7,887.9, and 19,122.6 baht for farms in Kaeng Khoi, Muaklek, Pak Chong, and Wang Muang, respectively. The combined loss in FMR of all farms including both pricing systems was 40,990.0 baht.

During pricing system 1, 79.23 % of milk price observations were at the maximum milk price of 11.7 baht, while 13.2 % were between 11.69 and 11.50 baht (Figure 4-4). Additionally in pricing system 1, 20.2 % of milk price observations received deductions due to bacterial score, compared to 0.4 % due to milk fat, solids-non-fat. During pricing system 2, 22.8 % of FMP were at the maximum price 11.8 baht, while 49.93 % of FMP were between 11.79 and 11.7 baht (Figure 4-5). All FMP between 11.79 and 11.7 baht were from deductions due to BTSCC. A total of 19.9 % of FMP observations were between 11.69 and 11.5, of which 12.33 % and 7.28 % where from deductions due to a combination of bacterial score and BTSCC and BTSCC only, respectively.

Discussion

Results for monthly total FMR for all districts were much higher than previous annual milk revenues of 342,876 baht (milking an avg. of 8.5 cows/day) in dairy farms of the Thaluang dairy cooperative in Central Thailand (Suzuki, 1998). This large difference in revenue was primarily due to an increase in milk price over the past 10 years. However, this increase was also due to an increase in average milk yield per cow from previous years, as seen in small farms in Muaklek district that had an average milk yield of 15.76 ± 0.63 kg per day (Rhone at al., 2007). The higher milk revenues of farms in Muaklek and Pak Chong, compared to Wang Muang and Kaeng Khoi, were due to higher FMY and average milk yields per cow, as reported in Rhone et al. (2007). A longer history of commercial dairy production in the Muaklek region, where farms have more productive animals and operations, may have contributed to these higher milk yields (Chantalakhana and Skunmun, 2001).

The higher FMP during pricing system 2 (11.71 baht) versus pricing system 1 (11.68 baht) suggest that there were farms in the Muaklek cooperative that were benefiting from additions in FMP due to low BTSCC (less than 200,000 cells/cm3) under pricing system 2. This statement is supported by the fact that during pricing system 2, 22.8 % of FMP achieved the maximum price of 11.8 baht, while 72.7 % were at or above 11.7 baht (Figure 4-5). Since the majority of small farms during both pricing systems had higher FMP ($P < 0.05$; Table 4-2) than medium and large farms, it is clear that small farms were benefiting economically from having lower bacterial scores and BTSCC compared to medium and large farms. Conversely, the lower FMP of medium and large farms were due to higher ($P < 0.05$) bacterial scores and BTSCC than small farms (Results from Chapter 1). These lower FMP of medium and large farms account for the greater losses in FMR during pricing system 2. This statement is substantiated by farms having a combined total of 77.2 % of FMP that were at or below 11.7 baht/kg during pricing system 2, indicating that the majority of farms had a BTSCC greater than 200,000 cells/cm^3 (Figure 4-5). If farms under pricing system 2 can maintain a BTSCC of less than 1,000,000 cells/cm^3, farms will be able to achieve or exceed the maximum milk price (11.70 baht/kg) from pricing system 1. However, the current situation of most medium and large dairy farms is that they are struggling to maintain low bacterial scores and BTSCC and, as a result, they are receiving lower FMR and profits.

Overall results here showed that high bacterial scores and BTSCC were linked to lower economic performance of farms. In many instances low production performance alone may not provide enough incentive for farmers to adopt improved management practices. However, linking low production performance to lower economic gains has been shown to motivate farmers to adopt improved practices at the farm level (King and Rollins, 1995). Although in this study specific farm management data were unavailable, muddy resting areas of cattle, cleaning of milking equipment, and proper cooling of milk are factors that have been found to affect bacteria in milk and mastitis in cows (Yhoung-Aree, 1999). Consequently, future work is needed to determine specific factors affecting high bacterial scores and BTSCC of farms. Once these factors have been identified, information from this study can be used to help design and implement a program to train and motivate farmers to adopt desirable farm management practices that will improve quality of milk and decrease mastitis levels of cows.

Table 4-1. Rules for milk price based on additions and deductions for bacterial score and bulk tank somatic cell count (BTSCC) of the Muaklek dairy cooperative

Factor	Grade	Effect on price	Price (baht/kg)
Milk fat percentage	Less than 3.5%	Deduction	0.2
Solid non-fat	Less than 8.4%	Deduction	0.1
Bacterial score	1	Addition	0.7
	2	Addition	0.5
	3	-	0
	4	Deduction	1
	Previous test was 4	Deduction	2
	Two previous tests were 4	Deduction	3
BTSCC (cells/cm3)	Less than 200,000	Addition	0.1
	200,001 to 1,000,000	-	0
	1,000,001 to 1,500,000	Deduction	0.05
	1,500,001 to 2,000,000	Deduction	0.1
	2,000,001 to 2,500,000	Deduction	0.15
	2,500,001 to 3,000,000	Deduction	0.2
	More than 3,000,000	May reject milk until the quality is better	

Table 4-2. Farm milk price by pricing system and farm district–farm size subclass for pricing system 1 and 2 in least square means (LSM) and standard errors (SE)

Farm district	Farm size[a]	Pricing system 1 LSM (baht)	SE	Pricing system 2 LSM (baht)	SE
		11.689	0.044	11.715	0.045
Kaeng Khoi	small	11.695	0.119	11.729	0.124
Kaeng Khoi	medium	11.697	0.179	11.741	0.187
Kaeng Khoi	large	11.697	0.281	11.706	0.286
Muaklek	small	11.693	0.026	11.741	0.027
Muaklek	medium	11.692	0.031	11.728	0.031
Muaklek	large	11.691	0.045	11.705	0.045
Pak Chong	small	11.694	0.043	11.729	0.044
Pak Chong	medium	11.691	0.054	11.724	0.055
Pak Chong	large	11.691	0.085	11.683	0.087
Wang Muang	small	11.687	0.163	11.760	0.165
Wang Muang	medium	11.653	0.163	11.650	0.168
Wang Muang	large	11.570	0.281	11.581	0.300

[a] Farm size was defined as the number of cows milked per day of farms. Categories were: small = less than 10 cows milked per day; medium = between 10 and 19 cows milked per day; and large = more than 20 cows milked per day.

Table 4-3. Averages loss in farm milk revenue due to deductions in milk price by farm district, and across month, year, and pricing system

Category	Farm district Kaeng Khoi loss (baht)	Muaklek loss (baht)	Pak Chong loss (baht)	Wang Muang loss (baht)
Pricing system 1				
Nov-04	92.74	424.41	286.54	793.48
Dec-04	168.50	669.18	398.19	1792.34
Jan-05	193.11	623.99	572.70	1744.73
Feb-05	133.28	458.02	343.45	1199.42
Mar-05	119.49	565.24	422.34	837.70
Apr-05	224.14	432.84	237.85	681.18
May-05	109.31	400.10	400.46	753.81
Jun-05	161.55	480.03	459.61	1256.23
Jul-05	278.56	566.56	338.57	2281.10
Aug-05	144.11	549.33	336.75	945.98
Sep-05	117.22	581.06	371.25	1634.79
Total loss in pricing system 1 (baht)	1742.01	5750.76	4167.71	13920.76
Pricing system 2				
Oct-05	569.27	1005.01	768.41	1437.88
Nov-05	441.17	834.46	874.24	809.72
Dec-05	240.98	786.36	668.86	768.43
Jan-06	373.56	879.02	761.73	1134.22
Feb-06	671.73	685.08	647.03	1051.66
Total loss in pricing system 2 (baht)	2296.71	4189.93	3720.27	5201.91
Combined total loss (baht)		40990.06		

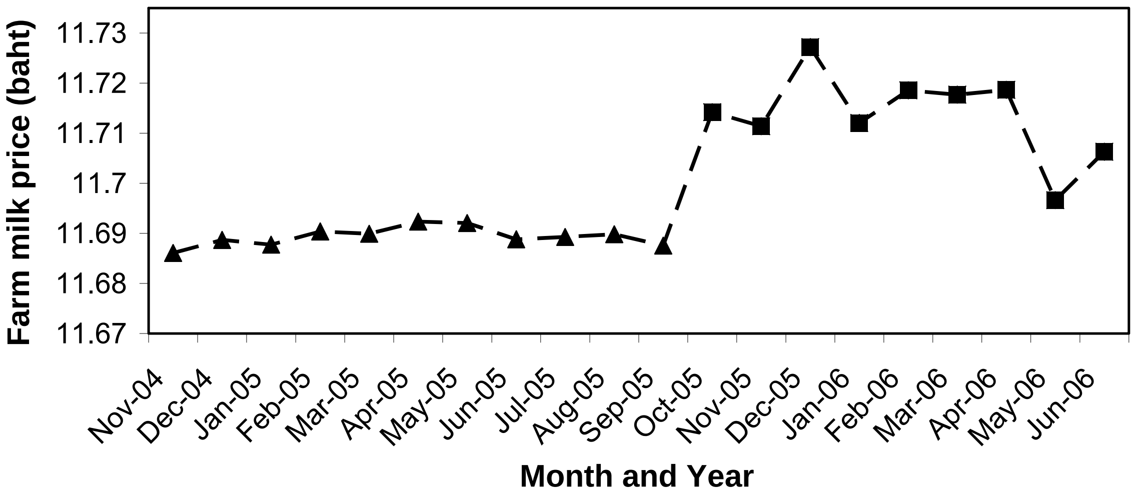

Figure 4-1. Farm milk price by pricing system 1 (▲) and 2 (■) and month and year in least square means

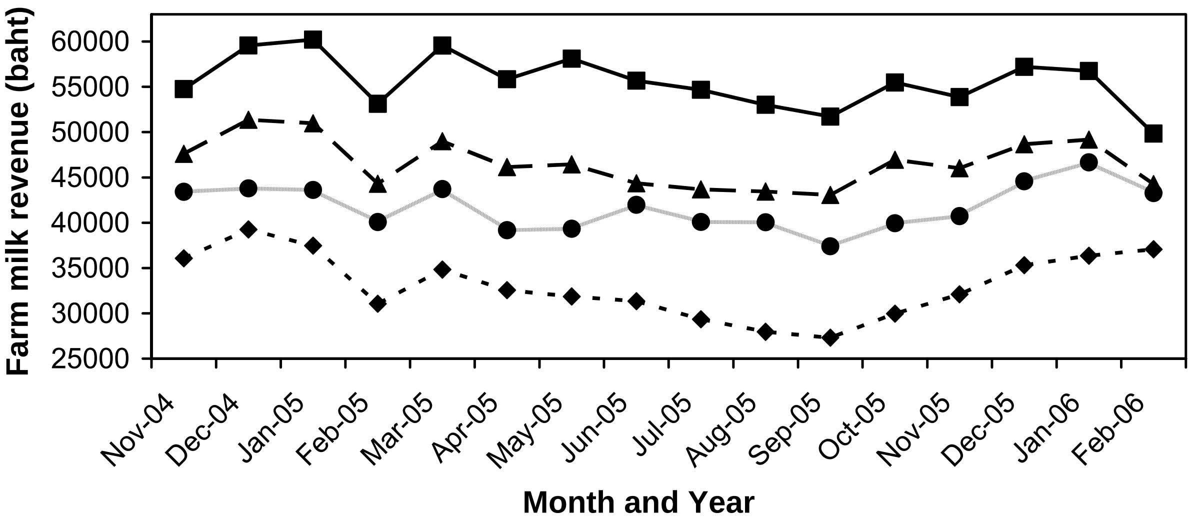

Figure 4-2. Farm milk revenue (Thai baht) of farms in Muaklek (■), Kaeng Khoi (♦), Pak Chong (▲), and Wang Muang (●) by month and year

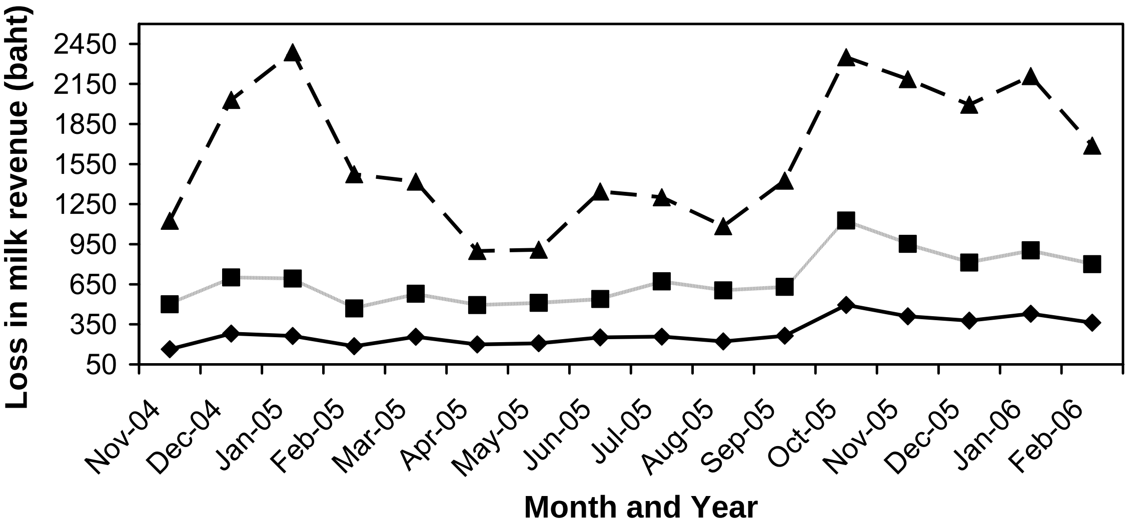

Figure 4-3. Loss in farm milk revenue (Thai baht) due to deductions in milk price by month and year, and small (♦), medium (■), and large (▲) size farms

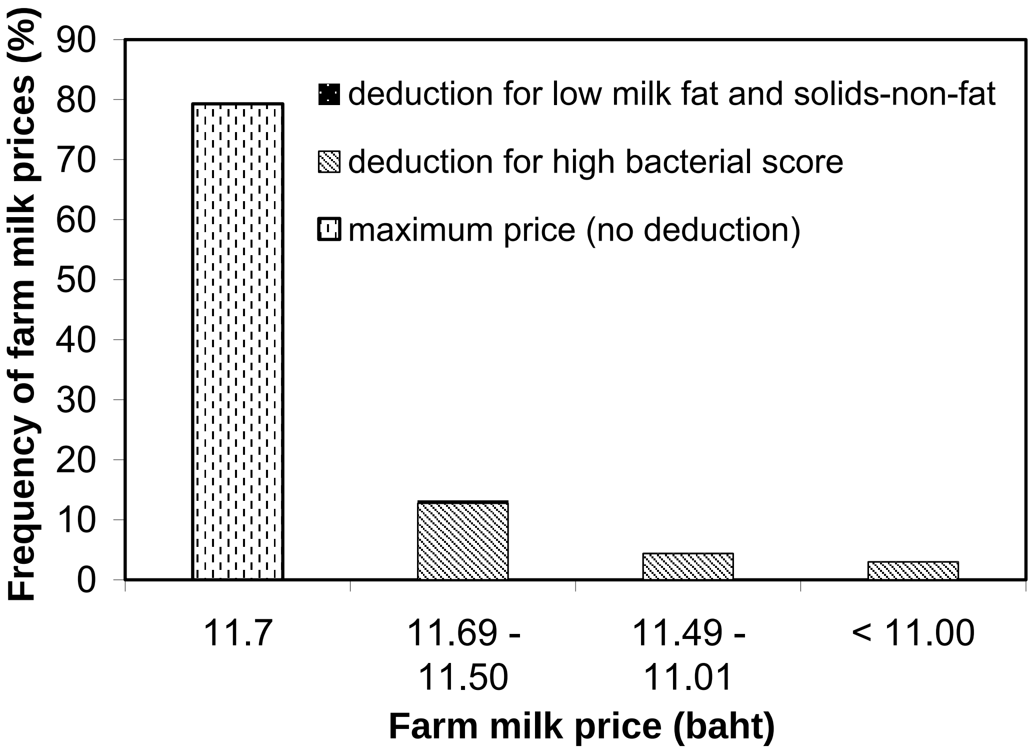

Figure 4-4. Farm milk price percentages in pricing system 1 by milk price and deduction category

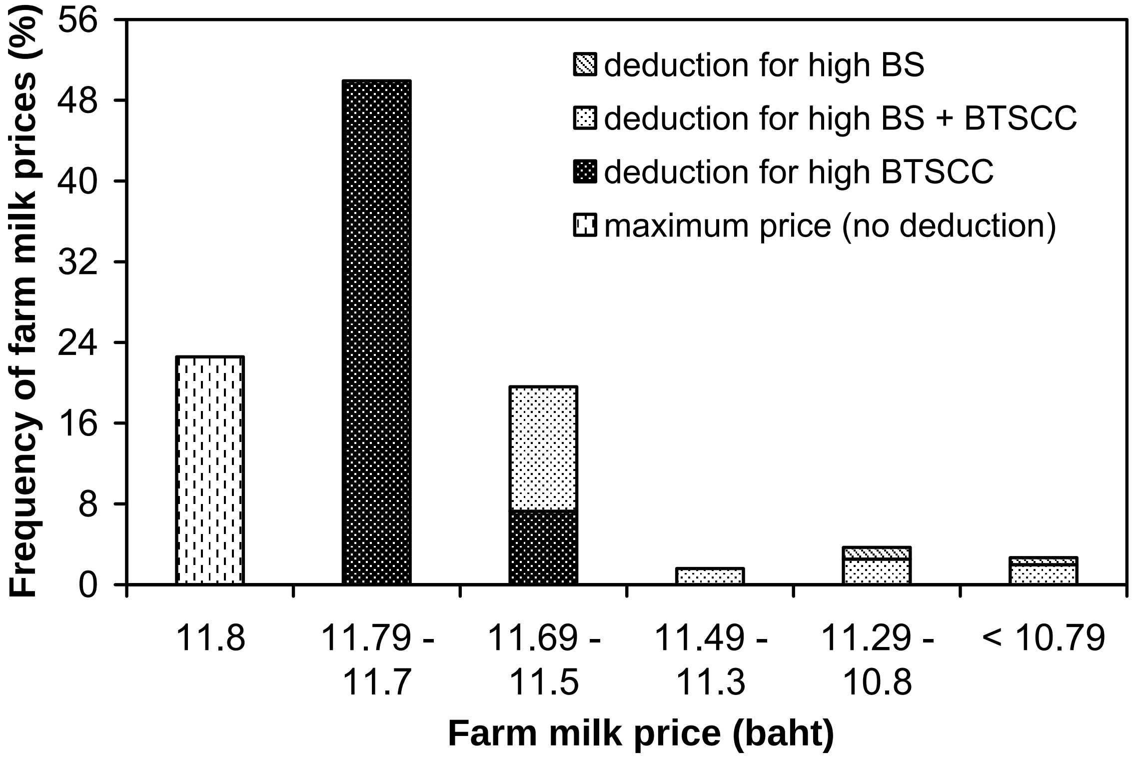

Figure 4-5. Farm milk price percentages in pricing system 2 by milk price and deduction category

CHAPTER 5
SURVEY OF DECISION MAKING PRACTICES, EDUCATIONAL EXPERIENCES, AND ECONOMIC PERFORMANCE OF TWO DAIRY FARM POPULATIONS IN CENTRAL THAILAND

Introduction

Dairy data set analysis at the farm level is often available through dairy cooperatives, private firms, and other government organizations in Thailand. However in many instances these data only contain records of production traits and may be represented as a farm unit with few or no records on individual animals. As a result, detailed farm management, decision making and economic practices are not fully understood at the farm level in many developing dairy organizations. One commonly used method of obtaining this information is through the use of a survey, by administration of a questionnaire, typically done through a personal visit, interview or by mail through the postal service. Since dairy farming technology, methods, and some other decision making and management practices may change over long periods of time, using questionnaires to obtain information from farmers is a good method of staying updated on what is taking place at the farm level. For example, in a previously performed survey in Thailand, Leeuw et al. (1998) reported that most dairy farms were raising high percentage Holstein cattle, with average herd sizes ranging from 20 to 29 animals, and were producing 2,000 kg/milk/cow/yr. Additionally, these farms were feeding 5-6 kg/d of concentrate to lactating cows and allocating 70% of operating costs towards the purchase of feed (Leeuw et al., 1998). In a more recent survey, Garcia et al. (2005) reported that most dairy farms in the Chiang Mai area of Thailand were raising cattle of 75-80% Holstein Friesian and yielding 3,152 to 3,385 kg/milk/cow/yr. Additionally, most of these farms raised their own replacement females, and typically had a second source of off-farm income other than dairy farming (Garcia et al., 2005).

Despite surveys that have been performed throughout Thailand, few if any have focused on obtaining and reporting information from many different areas such as educational experiences, management and decision making practices, and economics of farms. Since farm analysis involve people as well as animals, it is important to look at the cognitive process of farmers and their educational experiences, in addition to animal production information in order to grasp an entire picture of how farmers make decisions and how these decisions affect the performance of their animals.

The objectives of this study were to 1) characterize the dairy production, educational experiences, decision making practices, and income and expenses of dairy farms and to 2) determine if there are any differences of these practices between Muaklek and Non-Muaklek farms located in central Thailand.

Material and Methods

Farms

Thailand is located in the south eastern part of Asia, between 5° 35' to 20° 30' North latitude and 97° 20' to 105° 40' East longitude (Figure 5-1). A total of 85 dairy farms from the central region of Thailand were included in this study. Farms were located in the provinces of Saraburi (n = 63), Nakhon Ratchisima (n = 10), and Lopburi (n = 12). Within these provinces farms were in the districts of Muaklek, Wang Muang, Pak Chong, and Pattana Nikhom. All farms were members of dairy cooperatives and were classified into two groups, farms belonging to the Muaklek dairy cooperative (Muaklek farms) and farms belong to other dairy cooperatives (Non-Muaklek farms).

Questionnaire Data and Methodology

A questionnaire covering the areas of dairy production, reproduction and selection of mates, feeding and nutrition of animals, educational experiences, and income and expenses of farms was written by faculty at Kasetsart University, Bangkok and the University of Florida, Gainesville in February - March of 2006. The questionnaire contained questions from the four categories'

- Dairy production
- Educational experience (formal and informal education, and dairy farming experience)
- Decision making practices
- Income and expenses

The dairy production category included subcategories of number of cattle, dairy production, reproduction and selection of mates, feeding and nutrition, and animal health care of farms. The questionnaire contained four types of questions of 1) multiple choice, 2) fill in the blank, 3) choose all that apply, and 4) Likert scale (Likert, 1932). Only multiple choice, fill in the blank, and choose all apply questions were used in this study.

Questionnaires were originally to be mailed out to all Muaklek dairy cooperative farms (~ 1,000 farms). Following a pilot questionnaire performed on 40 farmers and a review from other dairy experts in Thailand, it was determined that approximately half of Muaklek dairy cooperative farms (~500 farms) may be unable to understand and complete the questionnaire. Additionally due to the uncertainty of farmer addresses, the questionnaire was to be handed out to farmers at dairy production seminars. In April of 2006, the questionnaires were distributed to 250 Muaklek dairy cooperative farmers attending two dairy production seminars given by Kasetsart University faculty and administered by the Muaklek dairy cooperative. Because only 250 Muaklek dairy farmers attended the two seminars, the additional 250 questionnaires were distributed to farms belonging to other dairy cooperatives by the Dairy Farming Promotion Organization. A cover letter and postage-paid self-addressed return envelope were included with each questionnaire. Farms mailed questionnaires to Kasetsart University upon completion. A total of 85 farms completed and returned questionnaires (17% response rate). Questions that were filled out improperly were followed up by phone calls to farmers. Data from the questionnaires were then recorded and edited in an Excel spreadsheet.

Data Analysis

The Proc Means procedure of SAS (SAS, 2004) was used to calculate means, standard deviations, and number of farms for dairy production and income and expenses of farms. Descriptive statistics for income and expenses of farms included average monthly expenses, milk revenue, and profit, on a per lactating cow basis. Expenses and revenues per lactating cow were calculated by dividing the average monthly expenses and milk revenue of farms by their total number of lactating cows. Average monthly expenses included the categories of feed, semen, health and veterinary, milk transportation, and equipment. Profit per lactating cow was calculated by subtracting average total monthly expenses per lactating cow from the farm milk revenue per lactating cow.

The Frequency procedure of SAS (SAS, 2004) was used to calculate frequencies of educational experience and decision making practices of farms. Frequencies for educational experience included level of formal education and training experiences. Descriptive statistics for decision making practice included breed of animal and type of sires used, method of selecting cows and raising replacement heifers, milking method, production system used, mineral supplementation, type of information used to select sires and dams, and organization of influence. Breed of animal was defined on a farm herd basis. Farms with herds containing two-thirds or greater total dairy animals within a breed group were assigned to that breed group (Table 5-3).

For each frequency analysis, a Chi-square test was performed to determine differences of proportions for multiple choices and choose all that apply questions between farm groups (Muaklek and Non-Muaklek). Significant levels for Chi-square tests were at a $P = 0.05$ level.

Results

Dairy Production and Educational Experience

Number of animals, dairy experience and length of dairy cooperative membership by farm group are in Table 5-1. The total number of lactating dairy cows in Muaklek farms (16.58 ± 11.75) was similar to that of Non-Muaklek farms (16.59 ± 11.24). Muaklek dairy farms had more dairy farming experience (14.23 vs. 10.57 yrs) and longer dairy cooperative membership (10.29 vs. 7.98 yrs) than Non-Muaklek farms. The majority of farmers had a primary or high school level of education in both farm groups and received most of their information on dairy production through training from a dairy cooperative (Table 5-2). A higher percentage of Muaklek farms ($P < 0.05$; 80%) said their dairy cooperative had the largest influence on their dairy business, compared to 52% of Non-Muaklek farms (Figure 5-3).

Farms of both groups primarily used a combination stall and pasture production system (Muaklek = 71% and Non-Muaklek = 77%) and milked their cows using a single unit milking machine (Table 5-4). While there was no difference in which climatic season (summer, rainy, winter) cows were in their best body condition ($P = 0.76$), climatic season where cows were in their worst body condition approached a significant difference ($P = 0.06$) between Muaklek and Non-Muaklek farms (Table 5-4).

Decision Making Practices and Income and Expenses

Record keeping practices were similar for both farm groups ($P \geq 0.33$) with 52% and 41% of Non-Muaklek and Muaklek farms recording the amount of milk sent to their respective dairy cooperative following every milking time. In the Non-Muaklek farm group, 52% of farms recorded milk production on individual cows, but were not different ($P = 0.52$) from the Muaklek farm group, where 44% of farms collected records on milk production from individual cows (Table 5-2). Of the farms that collected records on milk production from individual cows, only 24% and 7% of Muaklek and Non-Muaklek farms recorded this information every milking time cows were milked.

Crossbred Holstein, containing at least 75% Holstein blood, was the largest represented breed of both Muaklek (48%) and Non-Muaklek farms (45%). When asked what type of sire farms mated to their cows, 53% of Muaklek and 60% of Non-Muaklek farms said they used Purebred Holstein (Table 5-3). Decision making on selection of cows approached significance ($P = 0.09$), where 13% of Muaklek farms used advice from a Coop or veterinarian in addition with their own decision, compared to 30% of Non-Muaklek farms. Conversely, a greater percentage ($P < 0.05$; 80%) of Non-Muaklek farms used both Genetic (EBV) and phenotypes for selecting sires, compared to 54% of Muaklek farms (Figure 5-2). For selecting dams, 65% of Muaklek and 66% of Non-Muaklek farms used both genetic (EBV) and phenotypic information and were not different ($P = 0.91$) from one another.

Average monthly expenses per lactating cow for Muaklek and Non-Muaklek farms are presented in Figures 4 and 5, respectively. Feed costs were the highest related expense of both farm groups (Muaklek = 83% or 2,397.00 baht and Non-Muaklek = 88% or 2,659.92 baht). Health and veterinarian costs were higher for Muaklek farms (188.36 baht) than Non-Muaklek farms (119.81 baht) and semen cost represented one of the smallest categories of expenses. Overall profit per lactating cow was higher in Muaklek farms (1,641 vs. 1,029 baht) compared to Non-Muaklek farms (Figure 5-6).

Discussion

Dairy Production and Educational Experience

The number of total animals and lactating cows from all farms in this study were higher than Chantalakhana and Skunmun (2001) study that reported average number of lactating cows from farms in Saraburi and Lopburi provinces were 9.2 and 8.5 head, respectively. Additionally, cattle numbers were also higher than those reported in Rhone et al. (2007), which could suggest that, on the average, farms in this study may have been slightly larger than the average sized dairy farm in Thailand. Although there were no differences ($P = 0.26$) between the two farm groups for level of education, the majority of farms of both groups had a primary or high school education, which is important to understand when working with or training farmers. For example, in a previous study performed with fish farmers in Thailand, materials that used pictures to describe management practices were more readily adopted and used by farmers, than those that contained fewer pictures and were more verbose in nature (Turongruang and Demaine, 1997). Educational level of farmers coupled with the fact that most farms identified dairy cooperatives as their main method of obtaining information on dairy production is critical for all organizations in the Thai dairy industry to understand. Thus, results from this study show that when reaching farms through training and extension activities, it should probably be through or in cooperation with their dairy cooperative.

The production system used by farms (confinement vs. combination of pasture and confinement) is likely dependant on the size of farm, availability of forages coupled with what type of labor is available or used by farms. Further information is needed to determine to what extent farmers are using pasture for the diet of their animals and how this is affecting animal performance. Although most farms gave a mineral supplement, it is unclear if the supplement contained trace minerals, and if so, which ones and in what quantity. Proper mineral supplementation is important as it has shown to not only increase milk, fat, and protein levels, but also reproductive rates, and lower post partum interval of dairy cattle (Nocek et al., 2006). The body condition of cows from Non-Muaklek farms being the worst in the rainy season compared to Muaklek farms in the summer season may be due to difference in geographical climate and/or from lack of certain feedstuff during certain parts of the year of these two regions. Further research is needed in order to determine the effect of mineral supplementation and body condition of cows on animal performance in farms.

Decision Making Practices and Income and Expenses

Although approximately 50% of farms from both groups recorded milk production on individual cows, only 17-24% of these farms recorded it at every milking time (Table 5-2). Previous studies have shown farms that keep records on individual animal performance have higher milk yields than those that do not (Losinger and Heinrichs, 1996). Thus, emphasis needs to be placed on encouraging and training farmers to record individual animal performance in order to track progress and improve production and efficiency of their animals. Breed of dairy cattle of both farm groups is consistent with government data that reports the majority of cattle in Thailand to be 75% Holstein or greater (MOAC, 2005). However, there is little information in the literature about the decision making process of dairy farms when selecting sires and cows for breeding. The results of this study showed a greater percentage ($P < 0.05$) of Non-Muaklek farms used a combination of EBV and phenotypes when selecting sires, which could be due to these farmers having a higher level of education and the fact that they use advice from their cooperative or veterinarian as compared to Muaklek farms who placed less emphasis on genetic information (EBV) and used less advice from a dairy cooperative and/or a veterinarian (Table 5-3). Nonetheless, if farms are going to make improvements on milk production and other economically important traits proper use of genetic information (EBV) must be encouraged through extension and training from dairy cooperatives, universities, and government organizations.

Feed expenses of farms from both groups were much higher than those reported by Suzuki (1998), which were approximately 50% of total farm expenses, but similar to values from Garcia et al. (2005) that were around 70% (Figures 5-4 and 5-5). Although profits from all farms were between 1,000 and 1,500 baht/lactating cow and similar to the study by Suzuki (1998), other expenses such as loan payments and hired labor were not included in the expenses of farms. Moreover, income from selling bull calves and cull cows were also not included in farm revenues, and as a result, the overall profit per lactating cow may not be entirely accurate. It is important to remember that because farmers in this study were not randomly selected, rather they were those that attended a dairy seminar, they may be more progressive in nature, and thus they may not entirely represent the entire dairy population in Thailand. In addition, because only 17% of farms completed and returned the questionnaires, possibly the farms in this study were biased towards having greater educational experience and herd management than those that did not reply. Despite this, results from this study provide important background information and decision making practices of farms that are useful in determining areas that need to be addressed by the respective dairy cooperatives. Lastly, knowledge of the educational level and experiences of farmers should help develop future teaching methods and materials for increasing the level of record keeping and their use to improve reproduction, production, genetic, health, and economic practices of Thai dairy farms.

Table 5-1. Number of animals, dairy farming experience and dairy cooperative membership of Muaklek and Non-Muaklek dairy farms in means and standard deviations (SD)

	Muaklek farms			Non–Muaklek farms		
Item	N	Mean	SD	N	Mean	SD
Number of Animals						
Total animals	58	39.43	24.68	27	41.29	23.27
Heifers	58	10.41	3.45	27	8.93	4.50
Dry cows	58	4.46	2.90	27	4.22	2.44
1st lactation cows	58	4.78	5.89	27	3.70	3.26
2nd and later lactation cows	58	11.81	8.39	27	12.88	9.45
Total lactating cows	58	16.58	11.75	27	16.59	11.24
Dairy experience (yrs)	56	14.23	10.81	27	10.57	5.89
Cooperative membership (yrs)	56	10.29	7.30	27	7.98	5.39

Table 5-2. Educational levels, sources of dairy information, and record keeping practices of Muaklek and Non-Muaklek farms

Item	Muaklek farms N	Muaklek farms Freq (%)	Non-Muaklek farms N	Non-Muaklek farms Freq (%)	Chi-square Value	Chi-square P value
Level of formal education					2.65	0.26
Primary school	20	43	8	33		
High school	17	36	7	29		
University degree	9	19	9	37		
Sources of information for dairy production/technology					0.34	0.95
Dairy magazine, newsletter, and book	4	8	2	8		
Seminar	8	16	5	21		
Training from business firm	3	6	1	4		
Training from dairy cooperative	33	68	15	65		
Record amount of milk sent to cooperative					0.76	0.68
Do not record	15	28	5	21		
Sometimes record	16	30	6	26		
Record every time	22	41	12	52		
Record milk production for individual cows					0.40	0.52
No	29	55	11	47		
Yes	23	44	12	52		
If record, how often recorded					2.17	0.33
Every milking time	6	24	1	7		
Once a week	11	44	9	64		
Once a month	8	32	4	28		

Table 5-3. Breed of animals and type of sires used, methods of selecting cows and replacement heifers of Muaklek and Non-Muaklek farms

	Muaklek farms		Non-Muaklek farms		Chi-square	
Item	N	Freq (%)	N	Freq (%)	Value	P value
Breed used by farm					3.50	0.32
Purebred Holstein	9	20	7	35		
Crossbred Holstein (> 75% Holstein)	22	48	9	45		
Crossbred Holstein (50-75% Holstein)	5	11	3	15		
Mixed breeds and Holstein	9	20	1	5		
Type of sire mated to cows					3.35	0.34
Purebred Holstein	22	53	12	60		
Crossbred Holstein	7	17	6	30		
Other dairy breeds	7	17	1	5		
Crossbred Holstein and beef breeds	5	12	1	5		
Selection of cows					2.72	0.09
Own decision	38	86	16	69		
Own decision and advice from Coop or vet	6	13	7	30		
Replacement females					0.90	0.63
Raise on own farm	44	80	21	87		
Buy	2	3	1	4		
Raise own and buy	9	16	2	8		

Table 5-4. Milking method, type of production system (confinement or pasture), mineral supplementation, and body condition of cows of Muaklek and Non-Muaklek farms

Item	Muaklek farms N	Muaklek farms Freq (%)	Non-Muaklek farms N	Non-Muaklek farms Freq (%)	Chi-square Value	Chi-square P value
Milking method					2.94	0.22
Single unit milking machine	47	85	24	96		
Multi-unit milking machine	2	3	1	4		
Single Unit milking machine and by hand	6	10	0	0		
Production system					0.26	0.67
Confinement	14	28	5	22		
Confinement and pasture	35	71	17	77		
Mineral supplementation					0.01	0.88
Only salt	34	72	17	73		
Salt and minerals	13	27	6	26		
Season of best body condition of cows					0.08	0.76
Winter (Nov. - Feb.)	19	55	12	60		
Summer (Mar. - Jun.)	0	0	0	0		
Rainy (Jul. - Oct.)	15	44	8	40		
Season of worst body condition of cows					5.5	0.06
Winter (Nov. - Feb.)	3	8	3	15		
Summer (Mar. - Jun.)	22	62	6	30		
Rainy (Jul. - Oct.)	10	28	11	55		

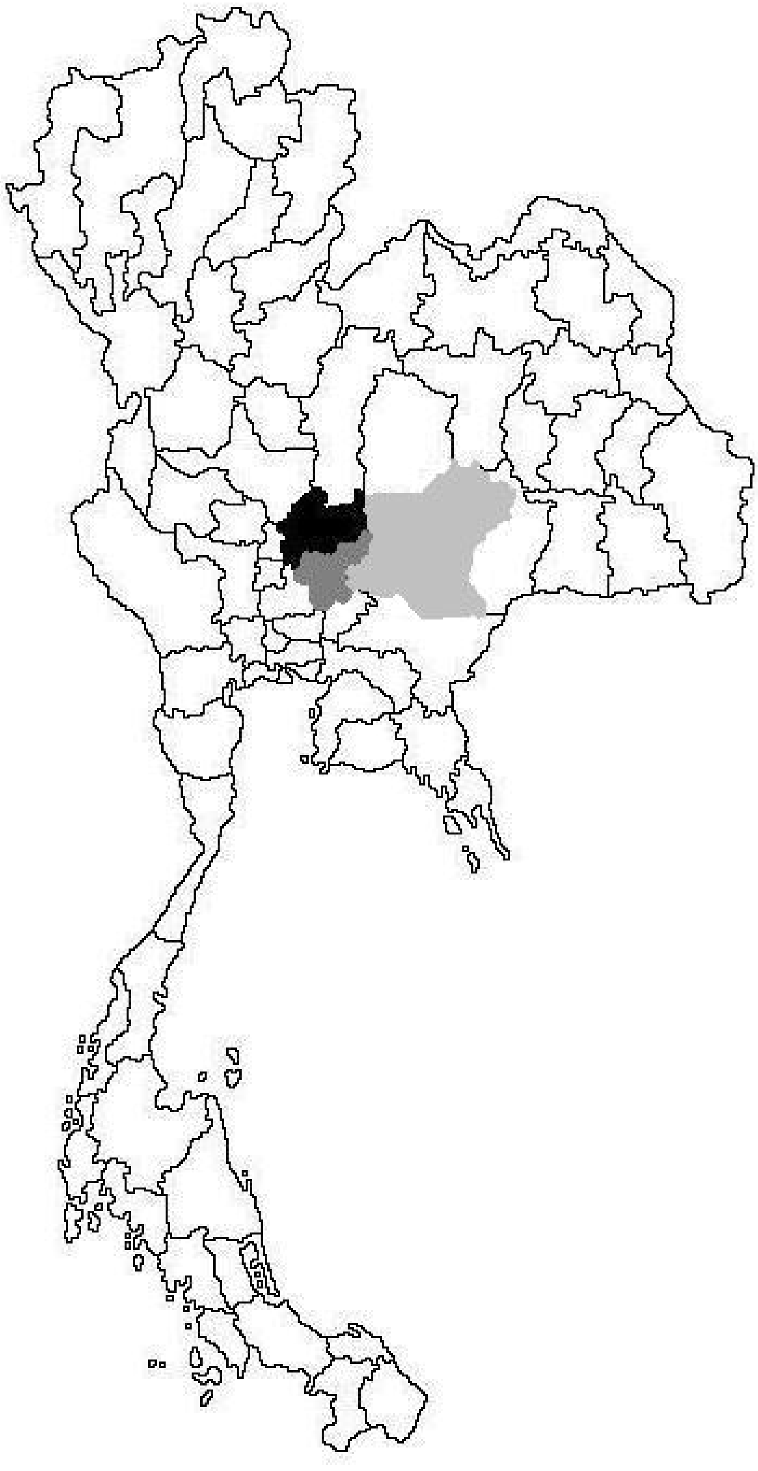

Figure 5-1. Provincial map of Thailand with location of farms in Lopburi (black), Saraburi (dark grey), and Nakhon Ratchisima (light grey)

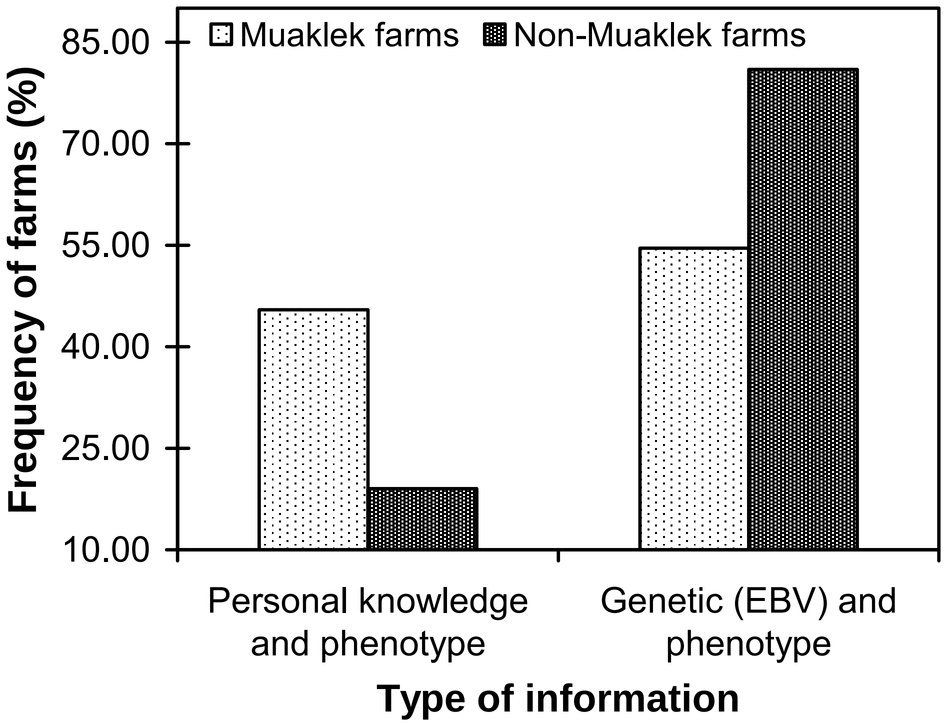

Figure 5-2. Information used by Muaklek and Non-Muaklek farms to select sires

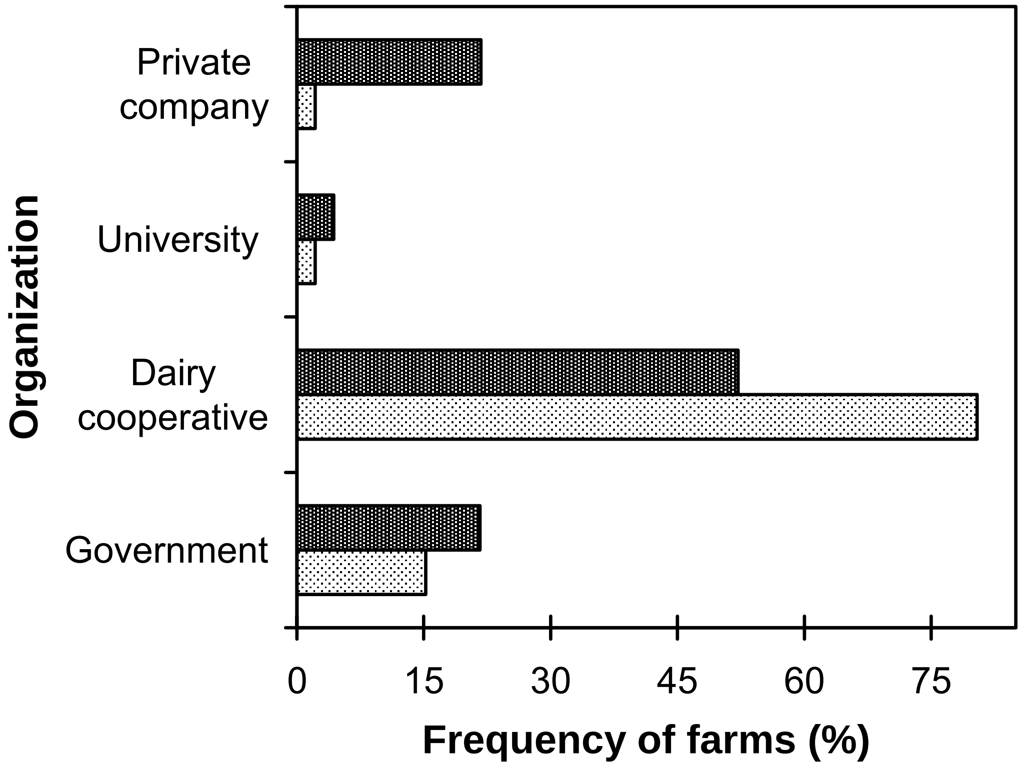

Figure 5-3. Organization with the largest influence on Muaklek (-▒-) and Non-Muaklek (-▓-) farms

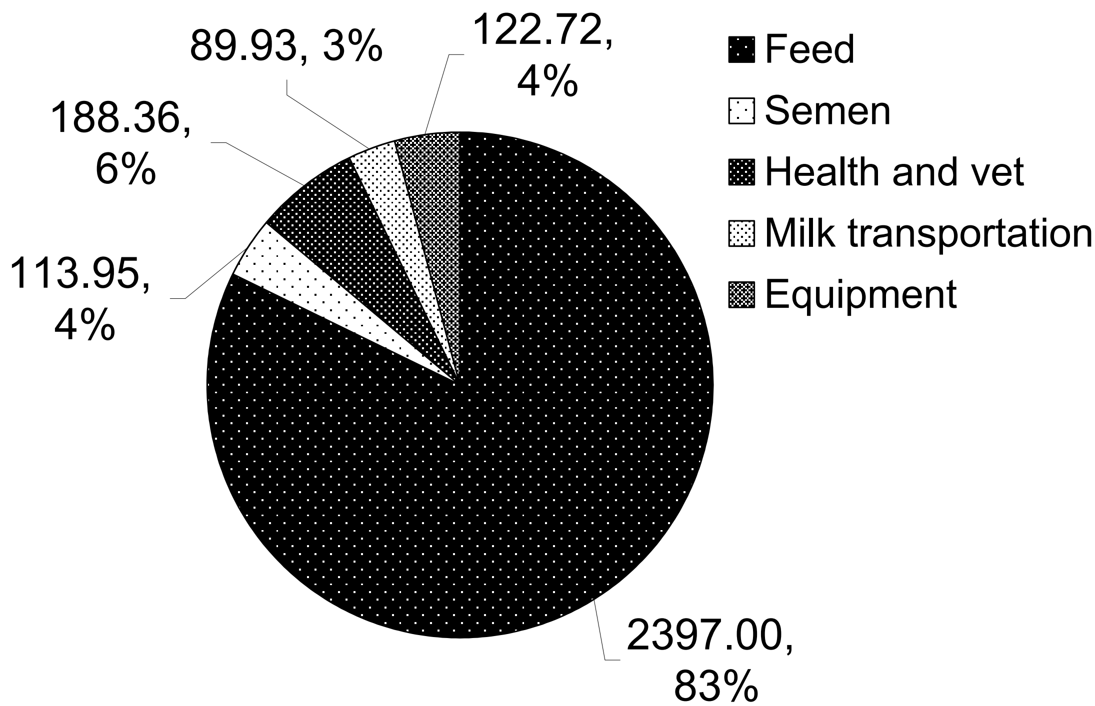

Figure 5-4. Average monthly expenses of Muaklek dairy farms by category and percentages in Thai Baht

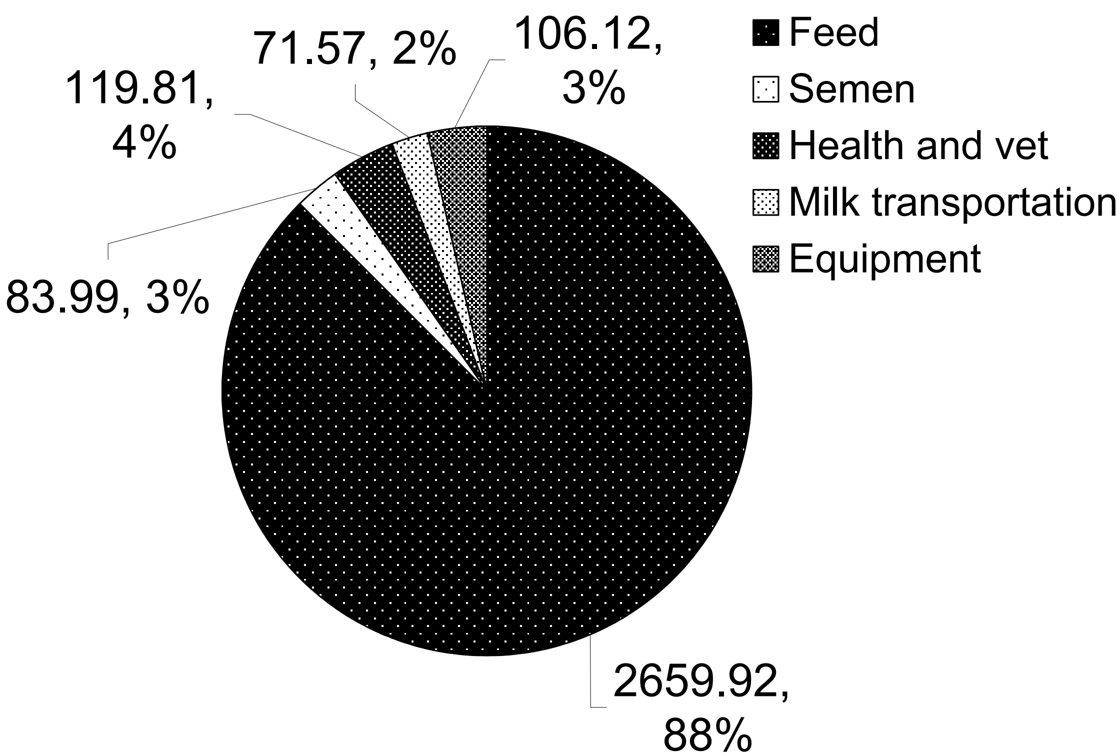

Figure 5-5. Average monthly expenses of Non-Muaklek dairy farms by category and percentages in Thai Baht

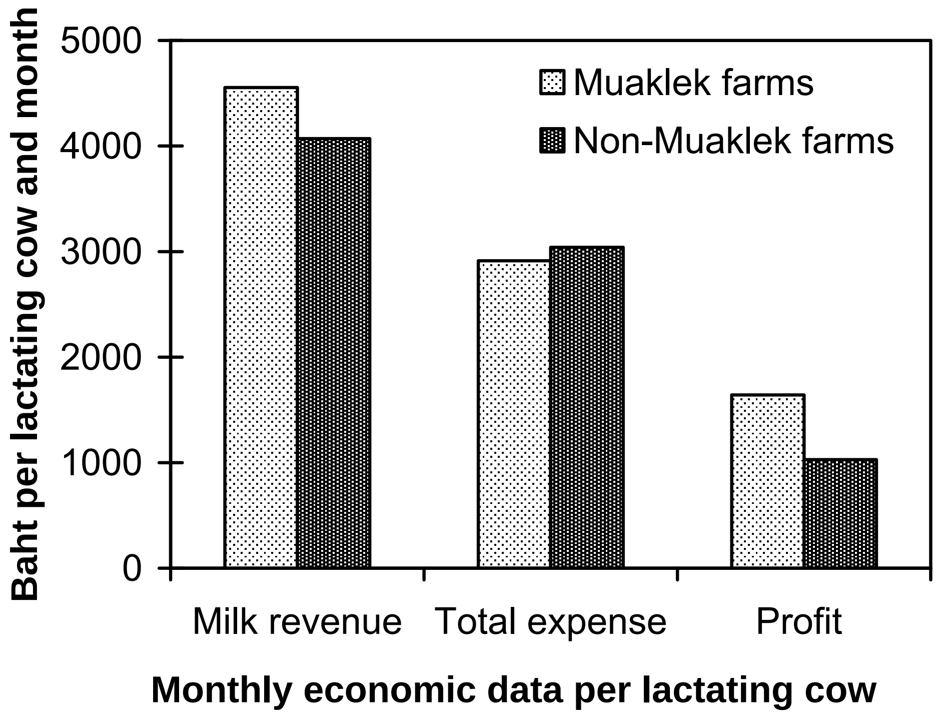

Figure 5-6. Average milk revenue, total expense and profit per lactating cow of Muaklek and Non-Muaklek dairy farms

CHAPTER 6
RECORD KEEPING, GENETIC SELECTION, EDUCATIONAL EXPERIENCE AND FARM MANAGEMENT EFFECTS ON AVERAGE MILK YIELD PER COW, MILK FAT PERCENTAGE, BACTERIAL SCORE AND BULK TANK SOMATIC CELL COUNT OF DAIRY FARMS IN THE CENTRAL REGION OF THAILAND

Introduction

In dairy farms across the globe farmers are striving to increase profits by improving traits of economic importance such as milk, fat, and protein yield, somatic cell count, reproduction and productive life (VanRaden and Multi-State Project S-1008, 2006). All these traits are affected in some measure by genetic and environmental factors. Genetic evaluation and selection of animals as well as the level of nutrition, management, and health conditions will influence individual animal and herd performance as well as profitability of dairy farms. Through genetic progress and the establishment and use of EBV, farmers have been able to select for traits in their animals and make improved progress in the health and production of their herds. However in fairly new and developing dairy industries, such as in Thailand, the use of EBV for genetic selection and other dairy farm management practices such as record keeping are still not utilized by many farmers.

The Dairy Farming Promotion Organization (DPO), in collaboration with Kasetsart University, has been publishing annual sire summaries with genetic evaluations for dairy cattle in Thailand since 1996 (DPO, 2005). Through these efforts and training from dairy cooperatives and other dairy organizations, some segments of the Thai dairy industry have adopted the use of EBV to select sires and are also keeping records on individual animals. This is important because farms that keep records on herd and individual animal performance were shown to have higher rolling herd milk yields than farms that do not (Losinger and Heinrichs, 1996).

In previous research in Thailand, clean and hygienic floors of milk spaces, troughs, and drainage systems were factors related to high quality milk of farms (Yhoung-Aree, 1999). Thus, keeping records is of great importance if farmers are to identify and manage mastitis and reproduction of cows in their herds (Ten Hag, 2001). This is relevant since traits such as milk yield, bulk tank somatic cell count, and bacterial score have shown to increase or decrease revenues and overall profits of farms in Thailand (Results in Chapter 2). However, improved management practices will only be adopted by farmers through an effective educational training program. The use of a participatory, farm demonstration and farmer to farmer interaction training has shown to be an effective method of training farmers for improving dairy farm management techniques in Thailand (Wanapat et al., 2000). Once research provides precise solutions to obstacles of dairy farms, dairy cooperatives and organizations should continue to work together in order to properly train dairy farmers in improved techniques and technologies.

The objective of this study was to determine record keeping practices, genetic selection, educational experience, and farm management effects on average milk yield per cow, milk fat percentage, bacterial score, and bulk tank somatic cell count of farms in the central region of Thailand.

Materials and Methods

Farms

A total of 50 farms were included in the study. Farms were located in central Thailand, between 15° 00' North latitude and 100° 00' East longitude, in the provinces of Saraburi and Nakhon Ratchisima. Within these provinces farms were in the districts of Muaklek (n = 42) and Pak Chong (n = 8). All farms were members of the Muaklek dairy cooperative. Farms milked their cows twice a day and used single or multi unit milking machines. Most cattle in Thailand are 75% Holstein or greater cattle, although there are farms that raise purebred Holstein and crossbred Holstein cattle (MOAC, 2005). Breeds such as Sahiwal, Red Danish, Brahman, and Thai native are sometimes used by farmers for crossing with Holstein cattle. The climate of Thailand is tropical and can be categorized into the three climatic seasons of winter (November to February), summer (March to June), and rainy (July to October). During the rainy season farms feed 30-40 kg of planted or native grass roughage, while rice stalk is more frequently fed during the summer (dry) season (Suzuki, 1998). Concentrates are typically fed to milking cows in the amounts of 12 to 15 kg per day.

Data Collection and Records

There were two sources of data for this study: 1) data collected from the Muaklek dairy cooperative and 2) data collected from a survey administered by faculty of Kasetsart University. Records from the Muaklek dairy cooperative were collected from July 1, 2003 through June 30, 2006 and taken from farms that sold milk to the Muaklek dairy cooperative during the time of the study. Survey data was taken from a questionnaire written by faculty at the University of Florida and Kasetsart University and distributed at two dairy seminars held by the Muaklek dairy cooperative in April of 2006. Data from the Muaklek dairy cooperative and the questionnaire were merged by farm identification number to form one data file. This study used a total of 22,180 daily farm milk yield (kg), 1,433 milk fat (%) and bacterial score (score), and 302 BTSCC (cells/cm^3) records.

Records from the data set also included month and year of collection date, breed of cows used by farm, type of production system, fertility of cows in the herd, method of sire selection, type of labor used for dairy production, record keeping, source of dairy information, milking method, method of sending milk to collection center, and the distance in kilometers from farm to the cooperative milk collection center. Breed of cows within a farm were defined as farms having 2/3 or more cows within a breed group, were classified in that breed group. Variables used in this study and their description are shown in Table 6-1.

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). A contemporary group variable was created to account for variation across combinations of farm sizes (small, medium, and large) and districts (Muaklek and Pak Chong). The resulting 4 contemporary groups were: 1) small size farms in Muaklek, 2) medium size farms in Muaklek, 3) medium size farms in Pak Chong, 4) and large size farms in Muaklek.

Milk yield was analyzed as average milk yield per cow (AYC) and was defined as farm milk yield divided by the number of cows milked per day. Bacterial scores were assigned using a methylene blue reduction test. 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 slowest rate and least amount of bacteria and 4 the fastest 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 (MDCL, 2005).

Statistical Analysis

Average milk yield per cow, milk fat, and BTSCC were analyzed using the mixed model procedure of SAS (SAS, 2004). The mixed linear model for AYC included the fixed effects of month nested with year of collection date, contemporary group by production system subclass, breed, fertility, sire selection, record keeping, farm labor, information used for dairy production and the random effects of farm and residual. The model for milk fat percentage contained the same fixed and random effects as the AYC model, but additionally included the sire selection by record keeping subclass.

The BTSCC data were not normally distributed. Thus, data were transformed using natural logarithms after which it was approximately normally distributed. Likewise, 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 mixed linear LBTSCC model included the fixed effects of month nested within year of collection date, contemporary group, breed by production system subclass, milk sending method, farm labor by milking method subclass, source of information for dairy production, record keeping, a covariate accounting for distance from farm to the milk collection center, and the random effects of farm and residual. The log linear model for log of bacterial score (LBS) included the same explanatory variables as the LBTSCC model, but included the record keeping by source of dairy information subclass and no random effects. Additionally, the farm labor and milking method variables were considered as separate fixed effects in the LBS model.

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 square 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.

Results

Average Milk Yield per Cow and Milk Fat Percentage

The contemporary group by production system subclass and month nested within year of collection date were important factors effecting AYC ($P < 0.01$), while all other effects were not

($P \geq 0.14$). Small size farms in Muaklek were higher ($P < 0.05$; 11.92 ± 3.14 kg) for AYC than medium and large size Muaklek farms (11.13 ± 3.16 kg and 10.08 ± 3.14 kg) in confinement production systems (Figure 6-1). Using a combination of confinement and pasture system, small size farms in Muaklek also had higher ($P < 0.05$; 12.60 ± 2.03 kg) AYC than medium size farms in Muaklek (9.10 ± 2.05 kg). There was no difference ($P = 0.70$) for AYC between medium size farms in Muaklek and Pak Chong. Although not significantly different, farms that kept records and used phenotypic and genetic (EBV) information when selecting sires were numerically higher for AYC than those that did not (Table 6-2). Farms that used 1 to 2 AI services per pregnancy, approached being significantly higher ($P = 0.14$) than those farms that used 3 or more services per pregnancy. Farms that raised 50% to 75 % Holstein crossbred cows had the highest AYC of 13.30 ± 3.72 kg, but were not different ($P = 0.67$) from other breed categories.

Except for the effects of breed and labor, all other effects were important sources of variation on milk fat percentage ($P < 0.05$). Farms that kept records and used phenotypic information and EBV when selecting sires had higher milk fat percentage values ($P < 0.01$; 3.96 ± 0.02%) than farms that did not keep records and used phenotypic and genetic information/personal views when selecting sires (Figure 6-2). Small and large size farms in Muaklek were higher for milk fat percentage than medium size farms ($P < 0.05$). There was no difference ($P = 0.38$) for milk fat percentage between medium size farms in Muaklek and Pak Chong. Farms that used training from their cooperative or a business as their source for updating dairy information had higher milk fat percentage values ($P < 0.05$) than those that used a book, magazine, newsletter, or seminar (Table 6-3). Farms that used other (or unknown) breed of cows had the highest milk fat percentage values but were not different from other breed categories.

Bacterial Score and Bulk Tank Somatic Cell Count

All effects in the LBS model were important ($P \leq 0.05$) sources of variation affecting LBS. Small and medium size farms in Muaklek were lower for LBS ($P < 0.01$) than large farm in Muaklek and medium farm in Pak Chong (Table 6-4). Farms that sent milk by themselves had lower LBS values ($P < 0.01$) than those that had someone send it for them. Additionally farms that used either single or multi-unit milking machine when milking cows had lower LBS ($P < 0.01$) than those that used a combination of a single unit and by hand. Farms that used labor of wife or wife and children were lower for LBS ($P < 0.01$) than all other types of labor. Results for record keeping by source of dairy information showed that farms that kept records and used training from a cooperative/business had lower LBS values ($P < 0.01$) than all other farms (Figure 6-3). There was no difference ($P = 0.63$) in farms using purebred Holstein cows for confinement and confinement and pasture systems, while cows of 75% or more Holstein and other (or unknown) breeds where higher for LBS ($P < 0.01$) in confinement systems than a confinement and pasture system (Figure 6-4).

Contemporary group, method of sending milk, labor by milking method subclass, and the covariate accounting for distance from farm to milk collection center were all important ($P < 0.05$) sources of variation affecting LBTSCC, while all other effects were not. Small size farms in Muaklek were lower for LBTSCC (13.14 ± 0.28) than medium ($P = 0.06$; 13.47 ± 0.34) and large size ($P < 0.01$; 13.83 ± 0.38) farms in Muaklek (Table 6-5). There was no difference between medium size farm in Pak Chong and Muaklek for LBTSCC. Farms that sent their milk to milk collection centers themselves had lower ($P < 0.05$) LBTSCC farms that asked someone else or used other method(s) of sending milk to collection centers. Farms that raised Purebred Holstein, 75% Holstein, other or unknown breed of cows in a confinement and pasture production system were lower for LBTSCC ($P \leq 0.08$) than herds that used crossbred cattle with

50% to 75% Holstein (Figure 6-5). There was no difference ($P \geq 0.50$) for breed of cows used in a confinement production system. Results for milking method by labor subclass showed farms using husband or husband and wife labor using a single or multi unit milking machine had lower LBTSCC ($P < 0.01$) than if they used a combination of a single unit machine and milked by hand (Figure 6-6). Additionally, farms using hired labor with a husband or wife using a single unit machine had higher ($P < 0.01$; 13.67 ± 0.35) LBTSCC than farms with a husband or husband of wife type of labor (12.32 ± 0.12).

Discussion

Average Milk Yield Per Cow and Milk Fat Percentage

Small size farms in Muaklek having higher AYC than medium and large size farms in Muaklek is consistent with results found in Chapter one. Unfortunately, it is still uncertain why cows from these smaller farms are having higher average milk yields. Knowing that these farms are mainly family run, coupled with the fact that they probably either grow their own forage or use a cut and carry system, and possibly supplying higher quality forage to their animals could be reasons for the higher milk yields. Additionally, in this study we lack information on percent of diet that came from grazing vs. being stall fed (for confinement-pasture system), and the specific content, amount, and nutrient levels of the forage (or concentrate) that were grazed or fed. This may be why medium size farms in Muaklek had lower AYC than large size farms in Muaklek using a confinement and pasture system. Content and nutritional quality of diet is also a factor that affected differences seen in milk fat percentage between confinement and confinement-pasture system. Since the Muaklek dairy cooperative does not give premiums for milk fat percentage (deduction if < 3.5%) results shown here of the milk fat percentage may not be of great importance to farmers in the Muaklek cooperative.

Although there were no differences between breed groups for AYC here, Kitpipit et al. (2003) reported that cows in Thailand with greater than 75% Holstein had higher yields than those with less than 75%. In a larger study, also in Thailand, Koonawootrittriron et al. (2001) found that ¾ Holstein ¼ Red Sindhi cows had significantly higher 305 d milk yields than both Purebred Holsteins and ½ Holstein ½ Red Sindhi cows. Perhaps the lack of individual animal records coupled with limited information on the feeding and nutrition of animals, prevented breed effects for AYC and milk fat percentage to be appropriately explained here. Additional research is needed in order to obtain more definite and precise evaluation of breed of cow effects on dairy production traits in Thai farms.

One of the major findings in this study is the increased performance in higher milk fat percentage and AYC of those farms that kept records on individual animal performance. Record keeping leading to higher milk fat percentage values and numerically higher milk yields is consistent with Losinger and Heinrichs (1996) that found farms keeping records on individual animals had higher herd milk yield averages than those that did not. The use of EBV when selecting sires was also an important factor leading to higher milk fat percentage ($P < 0.05$) and numerically higher AYC levels. Knowing that milk yield and milk fat percentage are moderately heritable traits, through selection and use of EBV, farmers have the ability to increase level of performance of these traits in their animals (Bourdon, 1997). Interestingly, the results of this study also showed that those farms that used training from their dairy cooperative or a business had higher milk fat percentage values than those that used other methods. Thus, it is critical for dairy cooperatives and other organizations of influence over dairy farms in Thailand to continue to educate and train farmers in the importance and use of record keeping and EBV when selecting sires. Lastly, results of this study show the importance of reproduction on milk yield which are similar to Alejandrino et al. (1999) that found cows which required 3 or more services per conception were much lower in productivity than those with less number of services per conception.

Bacterial Score and Bulk Tank Somatic Cell Count

In a previous study in Thailand, Yhoung-Aree (1999) found that the factors of family farms where children were a main source of farm labor, using more than one method of milking cows (i.e., single unit vs. single unit and by hand), and having a longer time period between finishing milking and milk arriving to the collection center all showed to increase total bacterial counts in raw milk. The results shown by Yhoung-Aree (1999) are very similar to results of this study where farms that used a single method for milking (single unit or multi unit) were lower ($P < 0.05$) for LBS and LBTSCC than farms that used a single unit and milked by hand. Most likely, farms that are milking by hand and using a single unit machine are transferring bacteria from cow to cow or from some other source of contamination to the udder of a cow, thus increasing overall bacterial count. Although most farms in this study sent their raw milk to milk collection centers themselves (Results in Chapter 5), in some situations farmers lack the resources to send the milk themselves. Results here show that farmers that use other methods to send milk have higher ($P < 0.05$) LBS and LBTSCC values than those that send milk themselves. Thus, careful attention should be paid to the length of time from finishing milking to milk arriving at the milk collection center, and the condition the raw milk is in during this time. Dairy cooperatives should work with farmers to reduce bacteria and improve milk quality, in order to bring higher revenues to both sides.

The labor findings in this study suggest that farms should use family labor, in particular if the wife is a major part of dairy labor versus using hired labor. Furthermore, women on dairy's in Asia have shown to be responsible for 40% of the entire dairy management and spend 52% of their time on farm related work, thus dairy cooperatives should provide appropriate training to wives and women working on these dairy farms (Moran, 2005). If dairy organizations are not training woman, organizations are potentially not reaching the primary worker that is responsible for milking animals and controlling hygiene and other factors that affect milk quality in dairies.

There is not a great deal of literature in Thailand on breed effects on LBS and LBTSCC, thus reasons for farms milking 50% to 75% Holstein cows in a combination confinement and pasture system with high LBS and LBTSCC values are somewhat unknown. Since there is no individual animal records and identification in this study, it is difficult to draw precise conclusions if any particular breed type in this study tends to have lower bacterial scores and less mastitis than other breed(s). Further research including individual animal records will be needed in order to come up with definite conclusions.

Lastly, results for record keeping here show its importance for proper management of dairy farms. Farms that kept records produced higher quantity and quality of milk as well as higher milk fat percentages than farms that failed to keep records. Recording information on individual animals allows farmers to identify sick cows and/or cows with mastitis so that spread of bacteria from is limited. Since farms in the Muaklek dairy cooperative receive deductions for high bacterial scores and BTSCC, the need to train farmers in record keeping practices by cooperatives is imperative for improving the quality of milk and increasing profits for farmers and cooperatives. Overall major findings of this study show that farmers that use training from their cooperative or a business to keep updated on dairy information, use genetic information (EBV) when selecting sires, keep records on individual animals, have higher milk fat, AYC values, and lower bacterial scores and BTSCC than farms that do not. The need for continued training efforts of farmers (men and women) in the areas of proper use of EBV, record keeping, use of one milking method and sending milk to milk collection centers will prove to be economically beneficial for not only the farmer, but the cooperative as well.

Table 6-1. Variables, number of variable categories (n), and description of variables used in statistical models

Variable	n	Description
Breed of cows in herd	4	Purebred Holstein
		≥ 75% Holstein
		50 - 75% Holstein
		Other or unknown breed
Production system	2	Confinement
		Confinement and pasture
Fertility (cows in herd)	2	1-2 AI services per conception
		≥3 AI services per conception
Method of selecting sires	2	Phenotype and personal view
		Phenotype and genotype (EBV)
Farm labor	3	Husband or husband and wife
		Wife or wife and children
		Hired labor and husband or wife
Record keeping	2	No records
		Kept records
Source of information used for dairy production	2	Books, magazine, newsletter, or seminar
		Training from cooperative/business
Milking method	3	Single unit milking machine
		Multi-unit milking machine
		Single unit and by hand
Method of sending milk to cooperative	3	Send yourself
		Ask someone to send
		Other method
Distance to cooperative	∞	Distance from farm to milk collection center (km)

Table 6-2. Average milk yield per cow (kg) by fertility, method of selecting sires (sire selection), record keeping, breed, and source of information on dairy production of dairy farms in least square means (LSM), standard errors (SE), and P-values

Effect	LSM	SE	P-Value
Fertility			
1 to 2 AI services per conception	12.99	2.42	< 0.01
2 or more AI services per conception	9.52	2.18	< 0.01
Sire selection			
Phenotype and personal view	10.50	2.57	< 0.01
Phenotype and genotype (EBV)	12.00	2.30	< 0.01
Record keeping			
No records	9.77	2.37	< 0.01
Kept records	12.73	2.29	< 0.01
Breed			
Purebred Holstein	10.15	3.94	0.01
75% or greater Holstein	12.56	2.50	< 0.01
50-75% Holstein	13.55	3.58	0.01
Other or unknown breeds	8.75	3.99	0.04
Source of information on dairy production			
Book, magazine, newsletter, or seminar	13.19	3.12	< 0.01
Training from dairy cooperative/business	9.31	1.82	< 0.01

Table 6-3. Farm milk fat percentages by production system - farm size – farm district, breed, mineral supplementation, labor, and source of information on dairy production of farms in least square means, standard errors and P-values (all effects had a *P* value of $P < 0.01$)

Effect	LSM	SE
Confinement system		
Small size farm: Muaklek district	3.98	0.06
Medium size farm: Muaklek district	3.83	0.03
Large size farm: Muaklek district	3.90	0.04
Confinement and pasture system		
Small size farm: Muaklek district	3.88	0.03
Medium size farm: Muaklek district	3.80	0.04
Medium size farm: Pak Chong district	3.73	0.08
Large size farm: Muaklek district	3.89	0.03
Breed		
Purebred Holstein	3.84	0.04
75% or greater Holstein	3.82	0.03
50-75% Holstein	3.89	0.06
Other or unknown breeds	3.88	0.03
Labor		
Husband and/or wife	3.84	0.02
Wife or wife and children	3.80	0.03
Hired labor and husband or wife	3.94	0.07
Source of information on dairy production		
Book, magazine, newsletter, or seminar	3.82	0.04
Training from dairy cooperative/ business	3.90	0.02

Table 6-4. Bacterial score (log) by contemporary group, method of sending milk, milking method, and type of labor used of dairy farms in least square means and standard errors (SE) (all effects had *P* values of $P < 0.01$)

Effect	LSM	SE
Contemporary group (farm size - district)		
Small: Muaklek	0.423	0.09
Medium: Muaklek	0.387	0.08
Medium: Pak Chong	0.967	0.17
Large: Muaklek	0.580	0.09
Method of sending milk to Cooperative		
Send yourself	0.647	0.04
Ask someone	0.528	0.04
Other	0.593	0.10
Milking method		
Single unit machine	0.458	0.05
Multi unit machine	0.603	0.08
Single unit and by hand	0.706	0.07
Labor		
Husband or Husband and wife	0.6508	0.06
Wife or wife and children	0.428	0.07
Hired labor and Husband or wife	0.689	0.08

Table 6-5. Bulk tank somatic cell count (BTSCC) by contemporary group, method of sending milk, source of information on dairy production, and record keeping practices of dairy farms in least square means and standard errors (SE) (all effects had *P* values of $P < 0.01$)

Effect	LSM	SE
Contemporary group		
Small size farm: Muaklek	13.14	0.28
Medium size farm: Muaklek	13.47	0.34
Large size farm: Muaklek	13.83	0.38
Medium size farm: Pak Chong	12.67	0.44
Method of sending milk to Cooperative		
Send yourself	12.61	0.15
Ask someone	13.40	0.16
Other	13.82	0.58
Source of information used to update dairy production		
Book, magazine, newsletter, or seminar	13.40	0.25
Training from Cooperative/business	13.15	0.16
Record keeping practices		
No records	13.37	0.30
Kept records	13.19	0.16

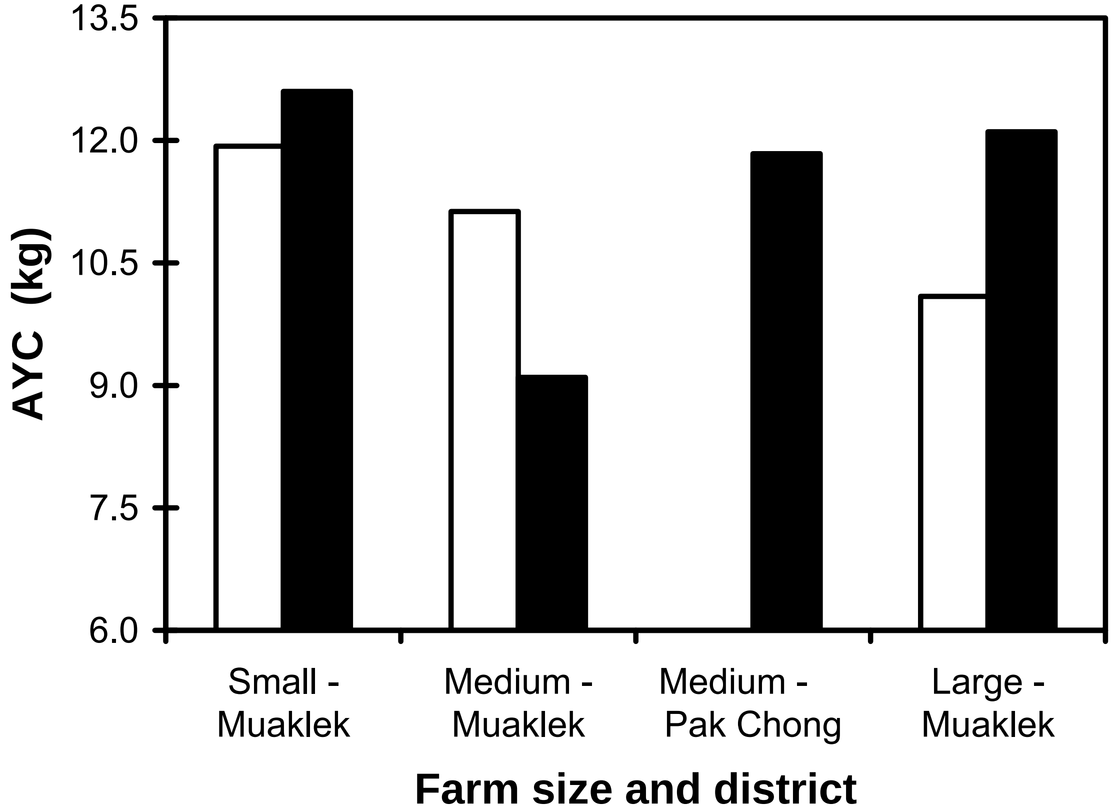

Figure 6-1. Average milk yield per cow (AYC; kg) by type of production system (white column = confinement; black column = confinement and pasture) – farm size – farm district of dairy farms in least square means

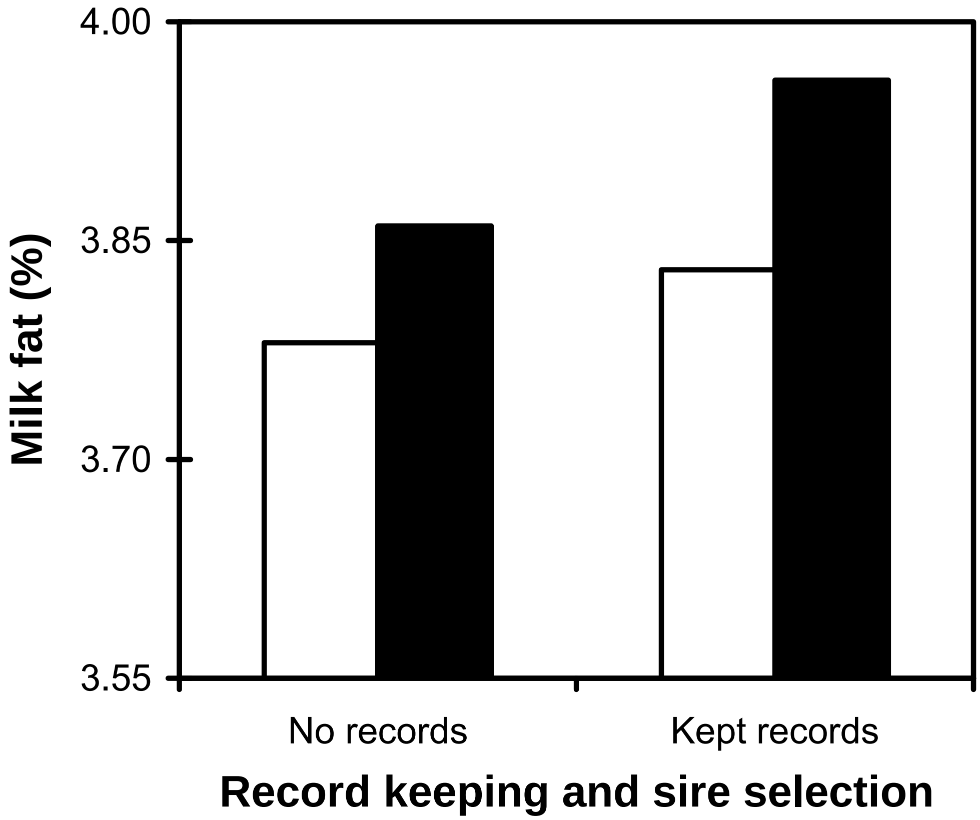

Figure 6-2. Milk fat percentage of dairy farms by individual animal record keeping practices and type of information used to select sires (white column = phenotype and personal view; black column = phenotype and genetic (EBV))

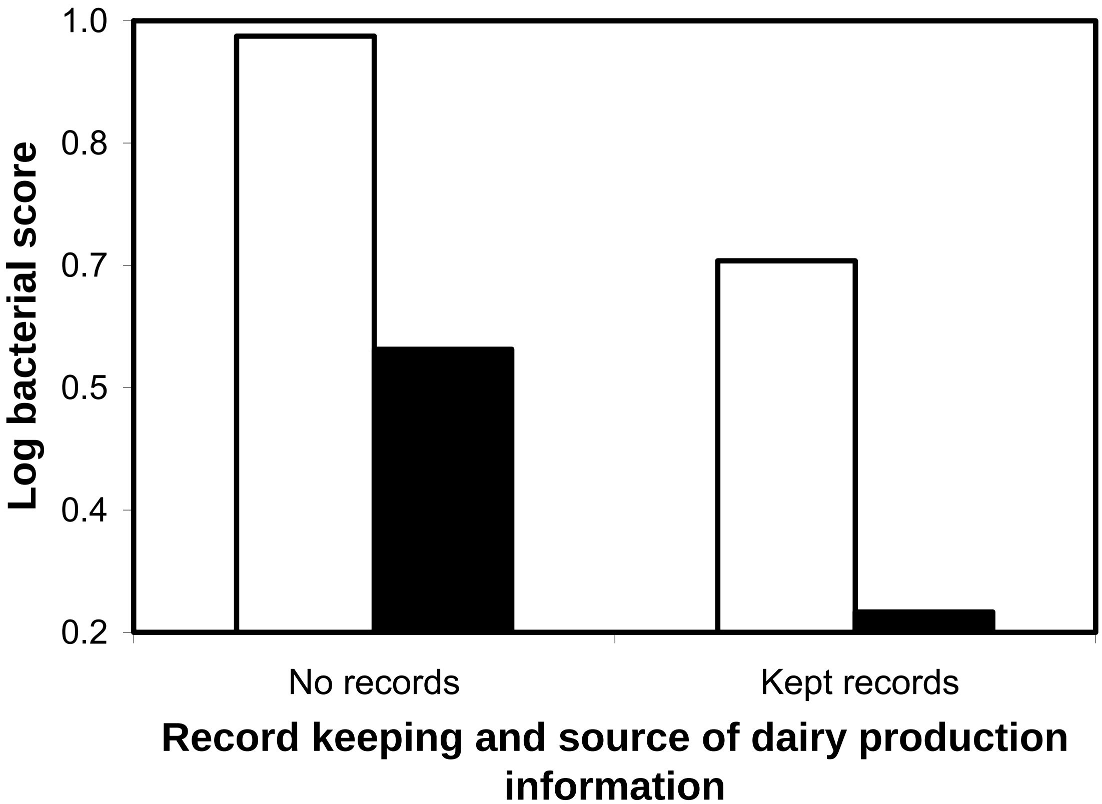

Figure 6-3. Log of bacterial score by record keeping practices and source of information used for updating knowledge on dairy production (white column = book, magazine, newsletter, or seminar; black column = training from dairy cooperative/company) in least square means

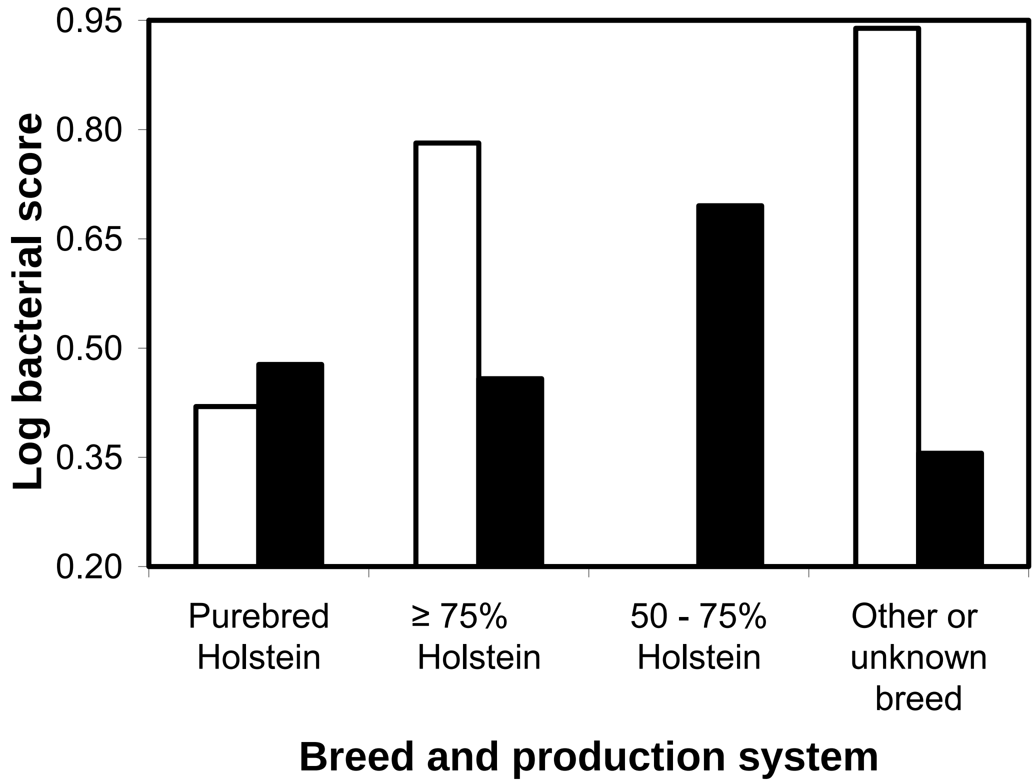

Figure 6-4. Log of bacterial score by breed and production system (white column = confinement; black column = confinement and pasture) of dairy farms in least square means

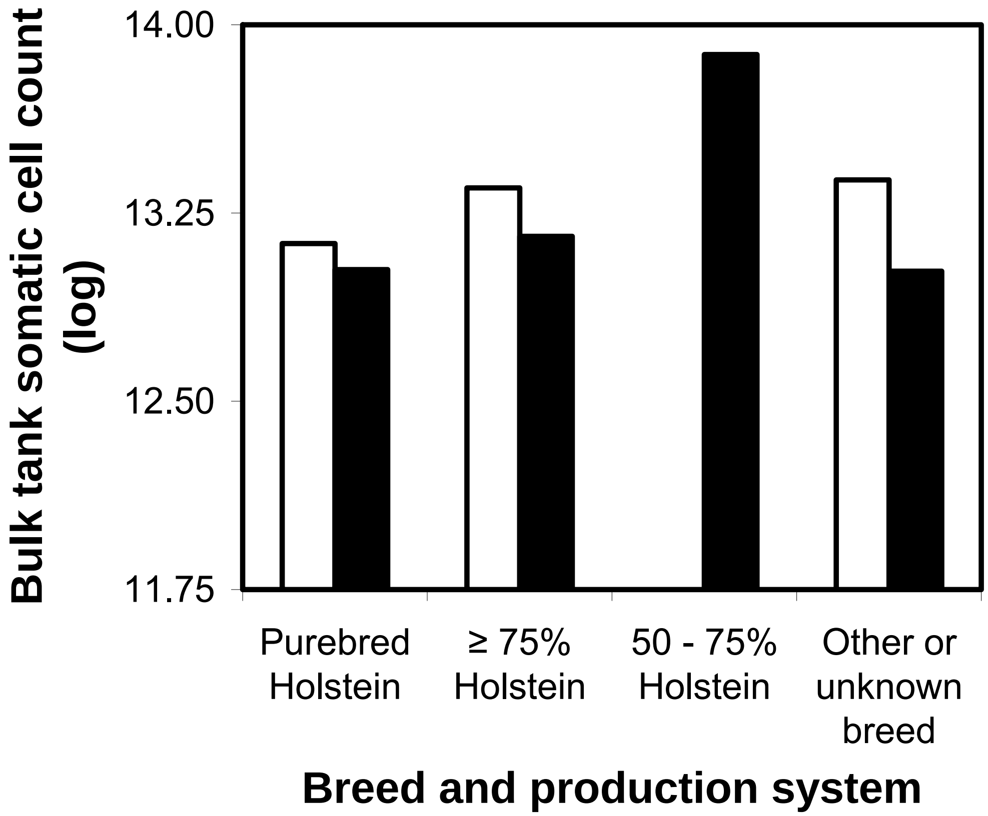

Figure 6-5. Log of bulk tank somatic cell count by breed and production system (white column = confinement; black column = confinement and pasture) of dairy farms in least square means

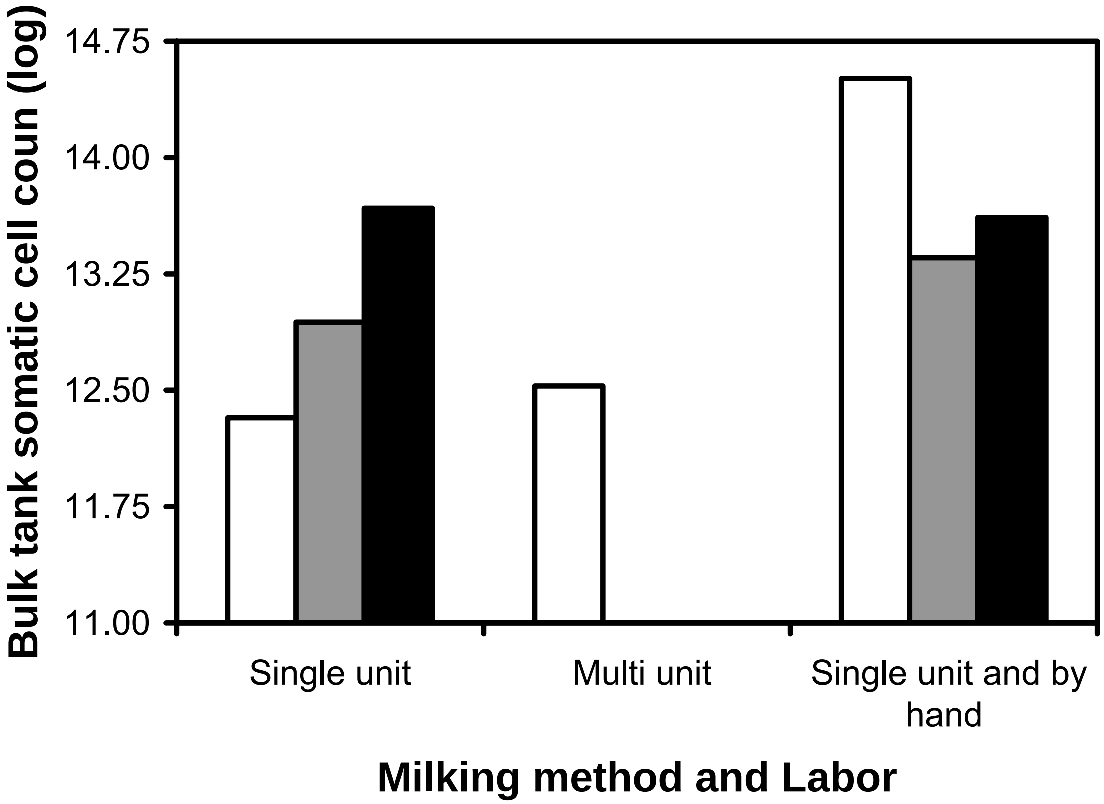

Figure 6-6. Log of bulk tank somatic cell count by milking method and type of labor (white column = husband or husband and wife; grey column = wife or wife and children; black column = hired labor and wife or husband) of dairy farms in least square means

CHAPTER 7
CONCLUSION

Summary

The findings from descriptive data received through the questionnaire of this study showed that most farms from the Muaklek dairy cooperative and farms that came from other dairy cooperatives (Non-Muaklek farms), had a primary or high school education, used a combination of confinement and pasture based production system, milked cows that were ≥75% Holstein, used AI with semen from purebred Holstein bulls, and identified their dairy cooperative as the organization with the largest influence on their dairy business. There was no difference ($P = 0.52$) among Muaklek and Non-Muaklek farms for keeping records on individual animals, where both farm groups were around 50%. A greater percentage of Non-Muaklek farms ($P < 0.05$; 80%) used genetic information (EBV) along with phenotype when selecting sire, compared to 54% of Muaklek farms. Both Muaklek and Non-Muaklek farms said that their dairy cooperative was the main source where they received updated information and technology for their dairy business.

The research findings from the regression analysis across all districts in the Muaklek dairy cooperative showed that small size farms had higher ($P < 0.05$) average milk yield per cow, milk fat percentage and lower ($P < 0.05$) bacterial scores and bulk tank somatic cell counts compared to medium and large size farms. In addition farm milk yield across all farms were lower ($P < 0.05$) in the rainy season compared to all other seasons. When analyzing farm milk price, small size farms in the Muaklek district were higher for farm milk price than medium or large size farms. The majority of losses in farm milk revenue of farms came from deductions due to having high bacterial scores and bulk tank somatic cell counts. The losses in milk revenue due to these factors were greater across larger size farms. Lastly when combining the information received from the questionnaire and the data collected through the Muaklek dairy cooperative used in this study, results showed that the majority of small size farms using a confinement or confinement and pasture system production system had higher ($P < 0.05$) average milk yield per cow values than medium and large size farms within that particular production system. Results also showed that there was no difference for breed group for AYC. However, farms that kept records on individual animals and used genetic information (EBV) to select sires had significantly higher milk fat percentages and, although not significant, higher numeric values for AYC. Additionally, farms that kept records and used training from a cooperative/business had lower LBS and higher milk fat values ($P < 0.01$) than all other farms. When looking at milk quality, farms that sent milk to the cooperative themselves, instead of asking someone else, and used a single method of milking cows (single unit milking machine vs. single unit machine and by hand), had lower bacterial score and bulk tank somatic cell counts than farms that did not.

Implications

The findings of this study show that small size farms, in particular in the Muaklek district (which make up 60% of all farms), are outperforming larger size farms in the areas of milk and fat yield, milk quality, higher milk prices, and lower losses in milk revenue. This implies that the management and decisions that these farms are making are likely different than the average medium and large size farm. However, this does not imply that all medium or large size farms are performing poorly, rather that on average the smaller farms that milk fewer cows are achieving better results. Due to the fact that we have limited information on nutrition and feeding, health, and other important dairy farm management practices on all farms in the Muaklek dairy cooperative, it is difficult to identify important factors that are leading to these differences. The fact that farm milk yields were lower and bacterial scores of farms were higher during the rainy season in this study implies that there may be a heat stress problem with high percentage Holstein cattle during this very hot and humid part of the year. However, because there were no individual animal records in this study, coupled with no information on breed of animal and lactation number and/or stage of lactation of cows, this implication can not be justified. As a result, future research at the farm level in the Muaklek dairy cooperative that includes individual animal records needs to be performed to further clarify findings in this study.

Nonetheless, the data received from the questionnaire, although not entirely representative of all farms in the Muaklek cooperative, gives an insight into what factors may be affecting the performance of dairy cattle and farms. Farms in the Muaklek district that participated in the questionnaire clearly show that key management practices, such as keeping records on individual animal performance and receiving training and information on dairy production from their dairy cooperative, led to these farms having higher average milk and fat yields, and milk quality, than farms that did not use these practices. In addition, another area of concern for the Muaklek dairy cooperative is the fact that only ~55% of farms in the Muaklek district (compared to 80% of Non-Muaklek farms) are using EBV when selecting sires to mate to their cows. Thus this clearly shows an area that needs improvement and an area in which farmers need to continue to be trained.

On the management practices related to milk quality, farmers need to be trained to use only one milking method (Machine or hand), and work with the dairy cooperative to limit the amount from when the milk is collected from cows and when it arrives at the milk collection center. Clearly the farmers that send milk themselves can shorten this time, and thus reduce the growth of bacteria in milk. However there are many farmers that simply do not have their own source of transportation to send the milk and rely on others or the dairy cooperative to take milk to the cooperative. Farmers and the dairy cooperative should work together to shorten this time and reduce overall growth of bacteria in raw milk sent to cooperative milk collection centers.

Lastly, because it is likely that most of these farmers in the Muaklek district have a primary or high school education and have received their education and have received most of their knowledge in dairy production from on farm working experience, it is very important to use information and teaching methods that will achieve the highest rate of adoption. Using materials with complex scientific terminology or power point presentations may not be a successful way of achieving adoption, as seen in studies cited in Chapter five and six in this document. Thus, to increase the likelihood of adoption, training of farmers in Muaklek should emphasize participatory learning and hands on training.

In conclusion, more research is warranted that includes individual animal records of Muaklek dairy cooperative farms in order to determine factors affecting milk and fat yield, and bacterial scores of different farm sizes and during the rainy season. Once there has been over a years worth of bulk tank somatic cell count data collected from the Muaklek dairy cooperative, this data should also be reanalyzed. In addition, farmers should be trained to keep records on individual animals, use EBV when selecting sires, use a single milking method, and limiting the amount of time when milk is collected at the farm and sent to the milk collection center. This training should be done in cooperation with the dairy cooperative and should be performed at a level that would achieve the highest adoption rate from farmers.

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BIOGRAPHICAL SKETCH

Jeffrey (Jeff) Andrew Rhone was born in Wichita Falls, Texas and grew up with an interest in agriculture from a young age. In high school, Jeff raised and showed heifers and steers at state and national junior livestock shows while also being involved in leadership positions and activities in the Future Farmers of America. In May of 1995, Jeff graduated high school from S.H. Rider High School in Wichita Falls, Texas. In August of 1995 Jeff enrolled at Texas Tech University, majoring in Animal Science. While at Texas Tech University, Lubbock, Jeff participated on the 1996 Texas Tech wool judging team, the 1997 meat judging team, and the 1998 livestock judging team. While on the 1997 meat judging team, Jeff and his teammates won first place in four major intercollegiate contests, including winning the national championship. Also while living in Lubbock, Jeff worked three years for Durham Shorthorns, a registered and commercial cow-calf beef cattle operation. During his time working at Durham Shorthorns, and with owners Bob and Gin Durham, Jeff became lifelong friends and family with the entire Durham family.

In 1998, Jeff participated in a study/teach abroad program where he went to China for three months and studied mandarin Chinese and taught English at a middle school. While in China, Jeff really felt that he was called to live, work and serve the people of that part of the world. Upon returning and graduating from Texas Tech University with his Bachelor of Science in animal science in December, 1999, Jeff left to work and study in China for 2 years. While in China Jeff studied mandarin Chinese for about one and a half years and worked at Global Partners, an organization that performed educational, medical, and rural development projects in northeast China. While Jeff was in China, God gave Jeff a passion for serving the Chinese people. Also Jeff was able to connect with two other companies, involved in agriculture work in southwest China. After 2 years in China Jeff returned to the US to pursue graduate school, but up to this day has been involved with work in China and every year returns to China to work.

In August of 2003 Jeff began a Master of Science degree in animal breeding at Texas A&M University. During his 2 years at Texas A&M University Jeff participated in a internship with Winrock International, in Bali Indonesia. Jeff spent three months in Bali and thoroughly enjoyed every minute of his time there. While in Bali, Jeff trained farmers in growing melons and in post harvest handling techniques. After graduating from Texas A&M University Jeff chose to pursue a PhD degree in animal sciences at the University of Florida. Jeff chose the University of Florida, because of a research project his advisor, Dr. Elzo, was working on in the field of dairy production in Thailand. While working on his doctorate research Jeff traveled and spent time in Thailand. It was while Jeff was in Thailand that he met his wife, Miss Kirathirat (Kira) Wetthayawaikoon. In December of 2007, Jeff and Kira married. Jeff will finish his PhD program and graduate in May of 2008. Jeff and Kira plan on returning and working in China/Asia region for many years.

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