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TITLE: Characterization of Factors Affecting Milk Yield, Milk Quality and Revenue of Dairy Farms Supported by a Private Organization in Thailand

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THESIS

CHARACTERIZATION OF FACTORS AFFECTING MILK YIELD, MILK QUALITY AND REVENUE OF DAIRY FARMS SUPPORTED BY A PRIVATE ORGANIZATION IN THAILAND

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A Thesis Submitted in Partial Fulfillment of
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Suphawadee Yeamkong 2011: Characterization of Factors Affecting Milk Yield, Milk Quality and Revenue of Dairy Farms Supported by a Private Organization in Thailand. Doctor of Philosophy (Animal Science), Major Field: Animal Science, Department of Animal Science. Thesis Advisor: Assistant Professor Skorn Koonawootrittriron, Ph.D. 152 pages.

The aims of this dissertation were to determine factors affecting milk quantity, quality and revenue of dairy farms supported by a private organization and to compare milk yield and revenue of dairy farms from this private organization with farms supported by a dairy cooperative in Central Thailand. Data consisted of monthly records collected from dairy farms from 2004 to 2009 and information from questionnaires. Traits were monthly milk yield per farm (MYF), milk yield per cow (MYC), milk revenue per farm (MRF), milk revenue per cow (MRC), fat percentage, protein percentage, lactose percentage, solids not fat percentage, total solids percentage and somatic cell count. Data were analyzed using mixed linear models that considered the subclasses of year-season, farm location-farm size, organization-farm size, experience, education, record keeping, labor, and decision making on sire selection as fixed effects, and farm and residual as random effects. Least squares means (LSM) were estimated for each trait, and then pairwise comparisons were made using Bonferroni t-tests. All traits were affected by year-season and farm location-farm size effects, except for protein percentage. Monthly milk yield per cow tended to decrease and somatic cell count tended to increase from 2004 to 2007. Similarly, MYC was found across farm sizes and locations. Large farms had higher somatic cell counts than small and medium farms. Revenues depended primarily on milk yields. Longer experience increased ($P < 0.05$) monthly milk yields and revenues. Farms that hired people produced the highest ($P < 0.05$) monthly milk yields and revenues. Farmers with higher levels of formal education produced more MYC and MRC ($P < 0.05$) than farmers with lower levels of formal education. Farms that kept records had higher MYF and MRF ($P < 0.05$) than those without records. Although differences among farms were non-significant, farms that received help from staff of the supporting organization had higher monthly milk yields and revenues than those that took decisions by themselves or with help from government officials. An interaction effect between organization and farm size was found for monthly milk yields and revenues. Farms supported by a private organization had higher ($P < 0.01$) monthly milk yields and revenues than those farms supported by a dairy cooperative in small and medium size farms, except for MYF and MRF of the large size farms. These findings implied that dairy farmers needed systematic training and continuous support to improve farm milk production and revenues in a sustainable manner. Exchange of experiences and strategies among dairy organizations in Thailand could help accelerate the rate of improvement of milk yield and revenue per farm and per cow at regional and national levels.

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Student’s signature Thesis Advisor’s signature

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Suphawadee Yeamkong

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LIST OF ABBREVIATIONS

°C	=	degree Celsius
FAT	=	fat percentage
kg	=	kilogram
LAC	=	lactose percentage
ML	=	Muak Lek
ml	=	milliliter
mm	=	millimeter
MRC	=	monthly milk revenue per cow
MRF	=	monthly milk revenue per farm
MYC	=	monthly milk yield per cow
MYF	=	monthly milk yield per farm
PC	=	Pak Chong
PRO	=	protein percentage
%	=	percentage
PN	=	Phatthana Nikhom
SCC	=	somatic cell count
SNF	=	solid not fat percentage
TS	=	total solid
WM	=	Wang Muang

CHARACTERIZATION OF FACTORS AFFECTING MILK YIELD, MILK QUALITY AND REVENUE OF DAIRY FARMS SUPPORTED BY A PRIVATE ORGANIZATION IN THAILAND

INTRODUCTION

The main objectives of the dairy promotion program in Thailand are to increase milk quantity, milk revenue and milk quality as well as to increase product safety and satisfaction of consumers. Despite considerable efforts on the part of the government, private organizations and dairy farmers, 305-day milk production in Thailand only averages 3,900 ± 1,100 kg (Dairy Farming Promotion Organization [DPO], 2007). Although milk consumption, number of dairy farms, total quantity of dairy products and land used for dairy production have all increased yearly since the beginning of dairy production in Thailand, progress in terms of milk quality and efficiency of production has been slow (DPO, 2007; Office of Agricultural Economics [OAE], 2008).

Currently every sector in the Thai dairy industry needs to improve their overall competitive strength in terms of productive efficiency and qualitative standards to survive in the business. To become competitive, the Thai dairy industry needs to achieve cost reductions and quality improvements as same as to attract investors for funding expansion and improvements in order to increase quantity and also improve quality of local raw milk. The government, milk collecting centers should provide fair competition and incentives for higher milk quantity, quality and revenue of dairy farms.

Dairy farming has become an increasingly competitive business in Thailand, due particularly to importation of dairy products (e.g., powdered milk and butter) from other countries (i.e., Australia and New Zealand) as a result of international free trade agreements (Department of Trade Negotiations, 2005; OAE, 2008). Survival of dairy farming in Thailand depends on the ability of dairy farmers to increase the profitability and efficiency of their dairy operations, especially when revenues were directly related to amount of milk produced. In addition, milk quality (fat percentage, bacterial contamination and somatic cell count) is also related to the price of raw milk paid to dairy producers (Muaklek Dairy Cooperative Limited [MDCL], 2005). Thus, both quantity and quality of milk have been using to determine the amount of revenue of dairy farmers in Thailand (Seangjun and Koonawootrittriron, 2007; Rhone *et al.,* 2008b, 2008c).

Thailand is a tropical country in Southeast Asia (5° 37′ to 20° 27′ North latitude and 97° 22′ to 105° 37′ East longitude) characterized by high temperature (23.1°C to 29.6°C) and high humidity (66% to 81%; Thai Meteorological Department [TMD], 2009). Central Thailand has the largest number of cows and farms in the country. Milk produced in this region amounted to 1,370 tons/day (66% of the whole country) in 2009. This amount of milk was produced by 139,175 milking cows (68% of the country) raised in 12,240 dairy households (69% of the country; Department of Livestock Development [DLD], 2010) and then sold to a dairy cooperative or a private organization where the farmer was a member. Milk collecting centers are important for milk production particularly in tropical developing countries to decrease expenditure, lower the transportation time of raw milk from dairy farms to milk processing factories, and facilitated the spread of dairy farms far away from milk processing factories (Tantajinna, 2001).

In Thailand, milk collecting centers could be divided into dairy cooperatives (97 centers) and private organizations (81 centers; DLD, 2010). These organizations have responsible to purchase, collect raw milk from dairy farms, and provide services to farm members. Dairy cooperatives belong to farmers, are supported by the government, and are managed by a committee of elected farmers. They were formed by groups of dairy farmers and have a legal status. Cooperatives have a set of bylaws that are approved by their members. Decisions are made by committees that meet at regular times. This may cause delays in making decisions and they receive assistance and support from the government such as loans with government department interest rates (Rhone *et al.,* 2008b). On the other hand, private dairy organizations belong to a business person who also manages the business and makes decisions. They were created with financial support entirely from private individuals or organizations. Administrative organization tends to be hierarchical, thus decisions are made by a few individuals, which in many cases is the owner of the private organization. This could make the decision process substantially faster than in a dairy cooperative that depends on committee decisions, or cooperatives sponsored by government institutions. Although these two types of organizations have similar objectives, they could have dissimilar performance because of different management styles.

Under the current high level of economic competition, farmers need to increase their efficiency of production of high quality milk and lower costs to improve the profitability of their operations. The sustainability of their dairy business was based on the successfulness of controlling and improving the efficiency of milk production and also the revenue of their members. Identification of factors that affect milk production and revenue and their economic importance is necessary to assist dairy farmers to manage their limited resources and economic opportunities would help them improve their productivity and their ability to stay in business. This information would also help dairy cooperatives and private organizations to provide more appropriate and effective support to their members. Studies on factors affecting milk yield, quality and revenue in Central Thailand have been conducted to date only for members of a dairy cooperative (Seangjun and Koonawootrittriron, 2007; Rhone *et al.,* 2008a, 2008b, 2008c, 2008d). Similar studies for members of a dairy private organization do not exist. However, a comparative study between those organizations has not been done. Thus, the objectives of this study were to determine factors affecting milk yield, milk quality, and revenue of dairy farms supported by a private organization and compare the results with those farms supported by a dairy cooperative. The results from this study would provide important data and information which could be used to increase raw milk production and help prevent or reduce problems associated with raw milk production. These results could also help increase of dairy farm efficiency by reducing production costs and increase dairy farm revenues.

OBJECTIVES

The objectives of this study were:

1. To determine factors affecting milk quantity, quality and revenue of dairy farms supported by a private organization in Central Thailand.

2. To assess the effect of experience, education, record keeping, labor, and decision making on monthly milk yield and revenue of dairy farms supported by a private organization in Central Thailand.

3. To compare milk yield and revenue of dairy farms supported by a private organization with those supported by a dairy cooperative in Central Thailand.

LITERATURE REVIEW

1. Dairy production in Thailand

Commercial dairy farming in Thailand was first established in 1961 by the Royal Thai Government with the assistance of the Danish Government. At that time, there were only 114 dairy farms with 3,450 dairy cows (Grittayanawach, 1985). Since then, number of farms and dairy cattle in Thailand has been increasing every year. In 2009, Thailand had 12,240 dairy households with 315,179 dairy cattle (DLD, 2009).

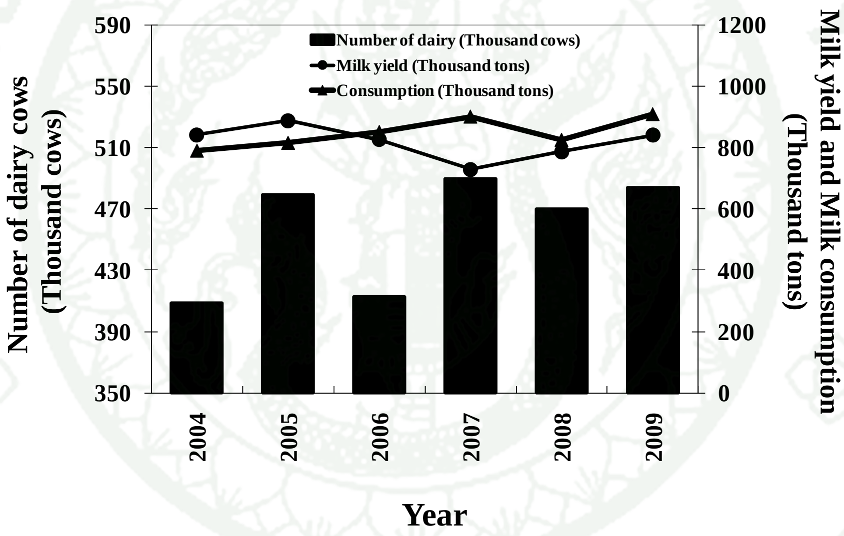


Figure 1 Number of dairy cows, milk yield and milk consumption in Thailand (2004-2009)

Source: Adapted from DLD (2009); OAE (2009)

1.1 Milk production

The number of dairy cattle and milking cows had been increased from 408,350 heads and 164,494 heads in 2004 to 483,899 heads and 204,805 heads in 2009 (4.21% and 8.32% per year; DLD, 2009). However, the number of dairy households was different. It was 23,439 in 2004 and 17,837 in 2009 (decreased 8.67%

per year). The changing of number of dairy cattle affected amount of milk production. Therefore, milk production was reduced from 842,611 tons in 2004 to 840,070 tons in 2009 (reduced 0.27% per year). During this period, milk production had not kept up with demand within the country (OAE, 2009). Figure 1 shows number of dairy cows, milk yield and milk consumption in Thailand from 2004 to 2009.

1.2 Milk consumption

Almost all of the raw milk produced in Thailand is consumed as liquid milk. The consumption of milk increased from 763,526 tons in 2004 to 825,624 tons in 2008 (2.97% per year). Then, milk consumption was increased 825,624 tons in 2008 and 908,180 tons in 2009 (6.52% per year), which pasteurized milk accounted for 77% and powdered milk dissolved in water for 23% of the liquid milk consumed (OAE, 2009).

1.3 Milk price

In 2004 to 2006, the average price of the raw milk delivered to the factory was 12.50 baht/kg. In 2007, the price of the raw milk paid to the factory was 12.50 baht/kg from January to March. In April to September the price had risen to 13.75 baht/kg. Then the price had increased up to 14.50 baht/kg from September until the end of 2007. In 2008 to 2009, the average price of the raw milk delivered to the factory was 16.25 and 17.25 baht/kg (Figure 2; OAE, 2009).

The price paid to the dairy farms was lower than those given to the factory or inventory purchasing. There was 11.38 baht/kg in 2004, 11.48 baht/kg in 2005 and 11.50 baht/kg in 2006. At the beginning of 2006, the average price paid to dairy farms by the dairy cooperatives, private organizations, educational institutions, and the DPO was 11.69 baht/kg. Then it was increased to be 12.91 baht/kg (1st market adjustment) and 13.96 baht/kg (2nd market adjustment). In 2008 to 2009, the price paid to the dairy farm was 14.56 and 15.89 baht/kg, respectively (Figure 2; OAE, 2009).

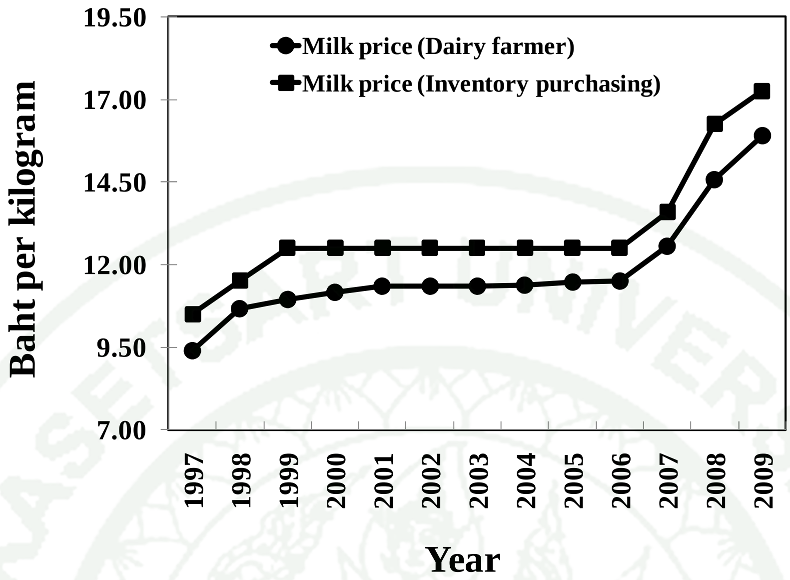


Figure 2 The price of raw milk in Thailand (1997-2009)

Source: OAE (2009)

2. Dairy production in Central Thailand

Central Thailand is the most important dairy area in the country (Figure 3). Saraburi, Lop Buri and Nakhon Ratchasima are the major provinces that have high density of dairy production. In 2003 to 2009, the number of dairy farms increased from 1,682 to 4,100 farms in Saraburi province, from 2,108 to 3,140 farms in Lop Buri province, and from 2,243 to 2,530 farms in Nakhon Ratchasima province. In 2009, there were 89,406 dairy cows raised in 2,538 farms in Saraburi province, which 43% of them were milking cows that could produce 446,640 kg of milk per day (11.65 kg per milking cow per day). The number of dairy cows raised in Lop Buri province was lower than those raised in Saraburi province. There were 54,187 dairy cows raised in 2,122 farms, and 23,111 of them were milking cows that could produce 222,483 kg of milk per day (9.63 kg per milking cow per day). For Nakhon Ratchasima province, there were 66,263 dairy cows raised in 2,381 farms. The number of milking cows was 30,433 and they could produce 323,698 kg per day (10.64 kg per milking cow per day; Table 1; DLD, 2009).

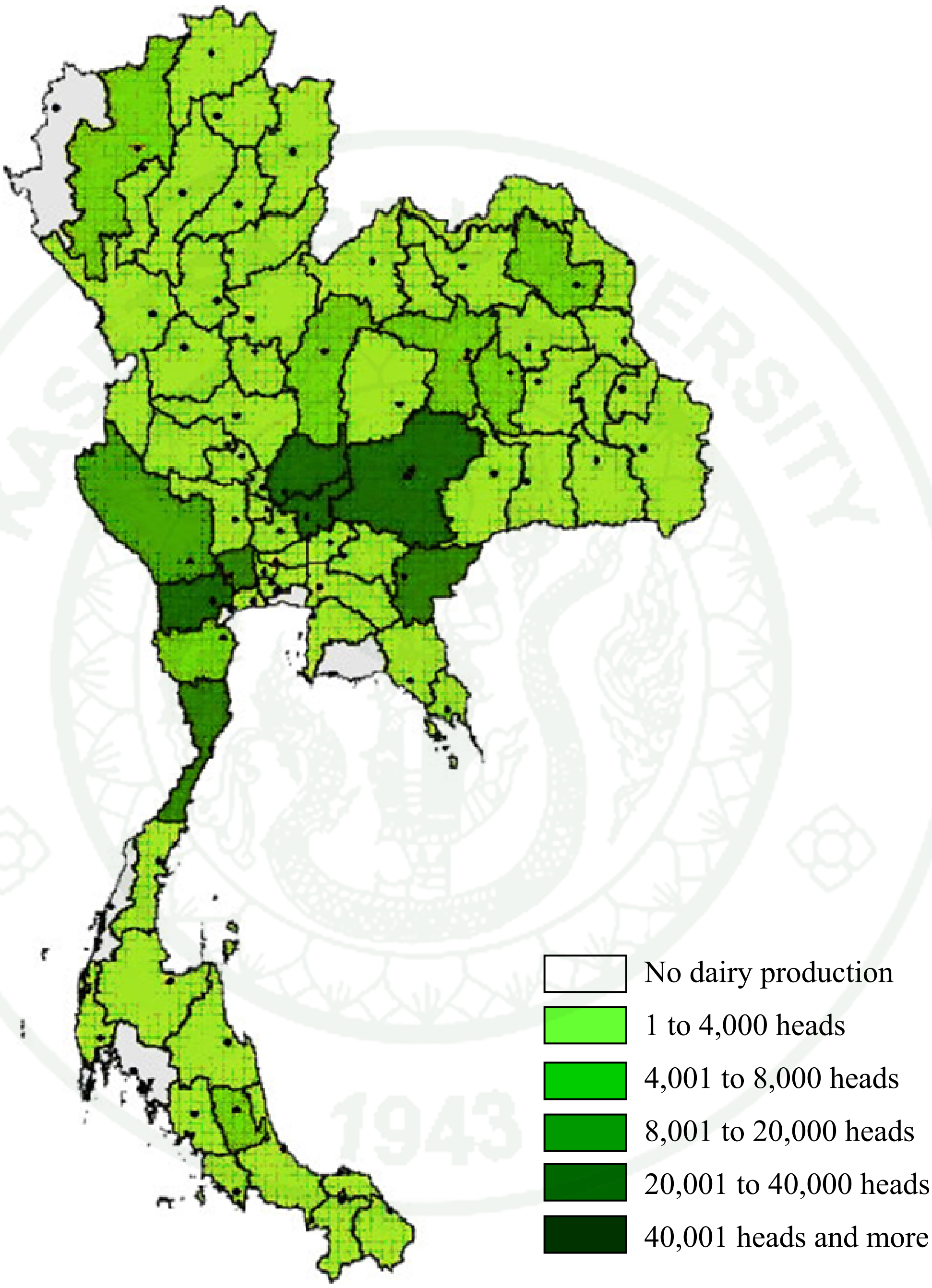


Figure 3 Provincial map of Thailand with location of farms in Lop Buri, Saraburi, and Nakhon Ratchasima

Source: DLD (2009)

Table 1 Number of dairy farms, total dairy cows, milking cows, and milk yield in the Saraburi, Lop Buri and Nakhon Ratchasima provinces

Year	Province		
	Saraburi	Lop Buri	Nakhon Ratchasima
	------Number of dairy farms (farms)------		
2009	2,538	2,122	2,381
2008	2,585	2,108	2,281
2007	4,100	2,235	2,442
2006	1,698	2,464	2,530
2005	3,049	3,140	2,414
2004	3,058	2,378	2,243
	------Total number of dairy cows (heads) ------		
2009	89,406	54,187	66,263
2008	84,158	58,049	65,989
2007	85,813	57,390	65,605
2006	42,928	61,345	58,086
2005	70,544	59,966	58,139
2004	67,462	46,879	53,943
	------Number of milking cows (heads)------		
2009	38,332	23,111	30,433
2008	36,842	22,727	29,314
2006	18,594	23,084	25,821
2004	26,460	19,093	25,660
	------Milk yield (kg/head/day)------		
2009	446,640	222,483	323,698
2008	436,695	224,629	291,123
2006	77,179	247,770	279,918
2004	472,851	187,491	315,499

Source: DLD (2009)

3. Geography, climate and forage crops in Central Thailand

3.1 Geography

The topography of the central region consists of very wide and low river plains. There are 177,900 km^2 (one-third of the total area Thailand separate from the North and Northeast). The west borders Myanmar. The east borders Cambodia. Many important rivers flow throughout the year such as the Chow Phya River, Tachin River, Lop Buri River and Phasak River (Land Development Department [LDD], 2005).

Saraburi province is a part of the basin in Central region and a part of Dong Phaya Yen mountain range. The area is approximately 3,580 km^2 or about 2,237,000 rai. The general topography has 3 characteristics. Low lying plains with an elevation of about 5 to 100 meters above sea-level. Patch Mountains or short mountains elevated about 200 to 400 meters above sea-level. The majority of the area is a plateau about 500 to 1,000 meters above sea level (LDD, 2005).

Lop Buri province is located along the east edge of the plains and on the west shore of the Lop Buri River. The area spreads through the plateau edge about 6,642 km^2 or about 3,874,846 rai. The majority of the area (about 70 percent) is a plateau alternating with hills and mountains about 40 to 600 meters above sea-level. The low land is about 25 to 60 meters above sea-level and is approximately 30 percent of the total area (LDD, 2005).

Nakhon Ratchasima province is a basin with long rows from the southwest to the northeast located in the center of the widest part of Thailand. The majority is area waving plains. The San Kam Pang – Phanom Dong Rung mountain ranges lie in the west to the south of province. The area is approximately 20,494 km^2 or about 12,808,728 rai and is 150 to 300 meters above sea-level (LDD, 2005).

3.2 Climate

Season in Central Thailand was winter (November to January), summer (February to May), and rainy (May to October), which had average temperature 28.0 $^{\circ}$C, 23.5 $^{\circ}$C and 33.3 $^{\circ}$C, respectively (Table 2). Terrain is mostly plains. Level ramp area downs south to the gulf of Thailand. In this region there are some hills, but mostly not very high mountains (TMD, 2009).

Table 2 Average temperatures in Central Thailand

Seasons	Winter	Summer	Rainy
Average temperature ($^{\circ}$C)	26.1	29.6	26.3
Average minimum temperature ($^{\circ}$C)	21.1	24.6	24.8
Average maximum temperature ($^{\circ}$C)	31.7	35.5	32.8

Source: TMD (2009)

Central Thailand is in two types of storms, southwest and northeast monsoons. The southwest monsoon comes over Thailand between May and October. This monsoon brings moist air mass from Indian Ocean to Thailand (cloudy and rain common). The northeast monsoon comes after all the influence of the southwest monsoon, around October to February. This monsoon originates from the high pressure in the northern hemisphere of Mongolia and China. Cold and dry air mass is blown out to cover Thailand (clear cold and generally dry). In 2009, the range of total rainfall was 800 to 1,200 mm in Saraburi province, 800 to 1,000 mm in Lop Buri province, and 1,000 to 1,200 mm in Nakhon Ratchasima province (Table 3; TMD, 2009).

Table 3 Rainfall in Thailand by region and season

Regions	Rainfall (mm)			Number of day with rain per year
	Winter	Summer	Rainy	
Northern	104.6	166.5	955.2	123
Northeastern	72.8	211.1	1,111.9	117
Central	130.0	192.3	907.4	113
Eastern	201.3	257.8	1,440.2	131
Southern (East coast)	819.9	197.9	661.2	148
Southern (West coast)	429.5	380.0	1,914.7	176

Source: TMD (2009)

3.3 Forage crops

The topography and weather in this area are appropriate for agriculture. The completion of irrigation systems in this area has enhanced its use for agriculture. The west of Central region has fertile low plains. The east of Saraburi and Lop Buri provinces is plains alternating with plateaus and foothills plains. The soil is of low quality so only dryer crops are cultivated. The south and the lower plains are below the Chow Phya River. The important forage crops in the central region are corn maize (19%), sorghum (47%), cassava (31%), sugar cane (37%) and other forage crops (4%). The areas in Central Thailand used for cultivated crops are as follows: corn maize (1,148,051 rai), sorghum (100,062 rai), cassava (258,828 rai) and sugar cane (2,288,864 rai). Production was 677,172 tons for corn, 1,532 tons for sorghum, 21,987,106 tons for cassava, and 8,301,886 tons for sugar cane. Averages per rai were 639 kg for corn, 222 kg for sorghum, 3,804 kg for cassava, and 9,606 kg for sugar cane (OAE, 2009)

4. Factors affecting efficiency of dairy production

Milk yield and milk composition varied greatly in different animals among or within breeds. Important factors determining milk yield and milk composition can be separated into two groups (1) factors related to the animal (i.e., breed, lactation period, parity, and health) and (2) factors not related to the animal (i.e., season, feed and management, etc.)

4.1 Factors related to the animal

4.1.1 Breed

Milk yield and milk quality of dairy cow varies among breed. Breed of animal has a profound effect on milk yield, but somewhat less of an effect on milk composition. Holstein Friesian had the highest mean lactation yield of milk followed by Brown Swiss, Ayrshire, Guernsey, and Jersey (Table 4; Ensminger, 1993; Hurley, 2000). The percentage of milk fat tends to be higher in Jersey and Guernsey and more variable among individual cows, compared with milk fat of Holstein Friesian, Brown Swiss and Ayrshire. The milk composition also differs, however, among individual animals within a breed. Intrabreed variability is greatest for milk fat, followed by solids not fat, protein, and lactose. The effect of breed on milk composition is illustrated in Table 4. Significant differences "within breed" can be found among a number of studies (e.g., Warwick, 1980; Ensminger, 1993). However, there is great variability due to geographic location, time of sampling, and herd management factors (Harding, 1995).

Currently, there are more than ten different breed presented in Thai dairy population (e.g., Holstein (H), Brahman, Brown Swiss, Jersey, Red Dane, Red Sindhi, Sahiwal, Shorthorn, and Thai Native) in both purebred and crossbred forms. Most of them are crossbred animals composed of up to seven breeds. However, Holstein is a major breed that has been used to improve milk production in Thailand, while Jersey became breed of interest to improve milk composition. At present, 90%

of the population is over 75% H with small fractions of other breeds (Koonawootrittriron *et al.,* 2002, 2009). Differences in number of dairy breed and breed fractions of individual cows raised in particular environments may have effect on milk quantity, quality, and revenue of the farms.

Table 4 Milk yield and milk composition by breeds of dairy cows

Breeds	Milk yield (kg)[1]	Fat (%)[2]	Protein (%)[2]	Lactose (%)[2]	Solid Not Fat (%)[2]	Total Solid (%)[2]
Holstein	6,321	3.7	3.1	4.9	8.45	12.4
Brown Swiss	5,465	4.0	3.6	5.6	8.99	13.3
Ayrshire	5,177	4.1	3.6	4.7	8.52	13.1
Guernsey	4,575	5.0	3.8	4.9	9.01	14.4
Jersey	4,049	5.1	3.9	4.9	9.21	14.6

Source: [1] Hurley (2000); [2] Ensminger (1993)

4.1.2 Lactation period

After calving, the beginning of lactation begins, milk yield of the dairy cow normally increase and it reaches the highest yield at approximately 4 to 8 weeks of lactation. Afterwards milk yield decreases until drying off. Association between pattern of lactation and milk production of dairy cows in Thailand had been reported (Koonawootrittriron *et al.*, 2001; Seangjun *et al.*, 2009). The initial yield, peak yield, days to peak and persistency of lactation pattern could be varied by quality of management, environment, age, lactation number, body condition, health status, breed, and also individual cows (e.g., Larson, 1985; Koonawootrittriron *et al.*, 2001; Seangjun *et al.*, 2009).

Milk composition changes over lactation period (Jenness, 1985). During the immediate postpartum period, colostrums contains much more total protein, casein, whey proteins and minerals but less lactose than the normal milk that appears after several days. The total solids content of colostrums may be as high as 25%. The greatest difference in composition between colostrums and milk is the elevate content of antibodies in colostrums (up to 10%), which are transferred to the newborn calf (Harding, 1995). After that, colostrum was dissipated decrease of fat and protein, and increase before the lactation period for 16 weeks. Milk protein then rises gradually and increases for 6 months. Lactose has a slow decrease during the lactation period (Figure 4). Fat and protein content in milk is negatively related to milk yield. Thus, at the peak of lactation, fat and protein percentages are lower than at the end of the lactation period. Lactose decrease at the end of the lactation period depends on epithelial cell decline and mastitis (Whittemore, 1980).

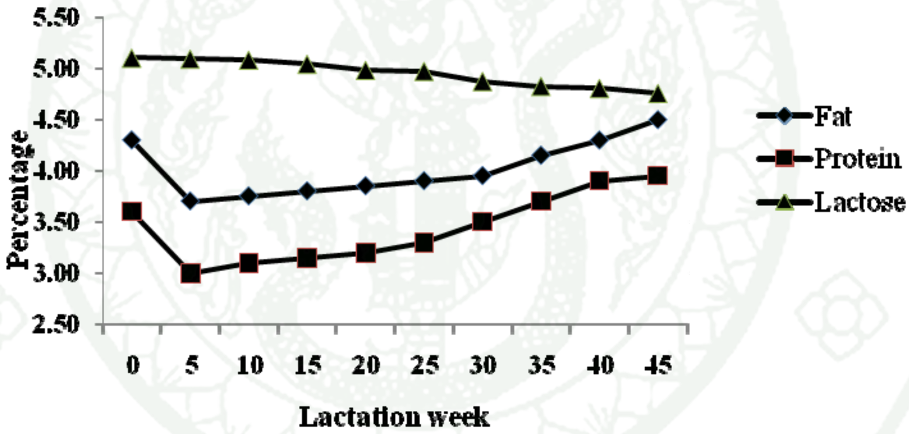


Figure 4 Changes in milk fat, protein, and lactose during lactation

Source: Jenness (1985)

4.1.3 Lactation number

Milk yield normally increased with lactation number. The largest milk yield occurred in the 4th or 5th lactation or when cows were 7 to 8 years of age. This was due to increase in cow size and udder development between the first and the fourth or fifth lactation. This can result in an increase in milk yield of 30% (Anderson, 1985). Percentages of milk yield increase per lactation from lactation 1 to 5 are:

Lactation number 1 to 2	increase in milk yield = 13 %
Lactation number 2 to 3	increase in milk yield = 9 %
Lactation number 3 to 4	increase in milk yield = 5 %
Lactation number 4 to 5	increase in milk yield = 3 %

After the 5^{th} lactation, milk yield decreased because of epithelial cell decline and mastitis. Jenness (1985) reported that during the 5^{th} lactation milk fat decreased 0.2% and solid not fat decreased 0.4%. Decrease of solid not fat had positive associated with casein. Gravert (1987) reported that casein decreased as the lactation number increased. Lactose percent also decreased with age. At age 2 to 4, 4 to 6, and 6 to 8 years, lactose decreased 0.13%, 0.16%, and 0.25%, respectively. However, the amount of milk yield decreases as dairy cows grew older and it depended on the characteristics of the individual animal.

4.1.4 Disease

One of the main diseases that affect milk yield of dairy cows is mastitis. It impairs the ability of secretary tissue to synthesize milk components and destroys the secretary tissues and consequently lowering milk yield. A decrease in production persists after the disappearance of the clinical signs of mastitis due to destruction in the secretary tissues (Shuster, 1991; Harmon, 1994; Mustafa, 2005; El-Tahawy and El-Far, 2010).

Moreover, infection of the udder (mastitis) greatly influences milk composition. Concentrations of fat, solid not fat, lactose, casein, α-lactogolbulin and β-lactalbumin are lowered and concentrations of blood serum albumin, immunoglobulins, sodium, and chloride are increased. In severe mastitis, the casein content may be below the normal limit of 78% of total protein and the chloride content may rise above the normal maximum level of 0.12%. Mastitis is also responsible for differences observed in milk composition from different quarters of the udder. Jenness (1985) and Ajariyakhajorn (2005) reported that the management of farms lacking hygienic conditions and proper milking procedures caused dairy cow's mastitis problem and negative effects on milk yield and composition.

4.2 Factors not related to the animal

4.2.1 Season

Seasonal effects on milk yield and composition are largely attributed to extremes in environmental temperatures. The consumption of roughage is reduced during environmental heat stress, resulting in decreased milk production as well as percentage fat. Similarly, milk protein and lactose percentages are lower during the hot season (Harding, 1995). Differences in milk composition are commonly observed with dairy cattle in temperate regions. In general, milk fat and solid not fat percentages are higher in cold and lower in hot. Milk fat and protein percentages are lower by 0.2 to 0.4% in hot than cold. Cows calving in the fall or cold produced more fat and solid not fat than cows calving in the spring and hot. Considerable variations in milk composition can also be observed in dairy cows which were raised in pasture (Mustafa, 2005).

Harding (1995) reported that percentage of fat, total solids, and solid not fat are greater during the cold months. Most of the seasonal variation in solid not fat is due to variation in the milk protein content. Percentages of fat and protein are lower during the hot season and higher during cooler months, in part, due to seasonal changes in forage quality and availability. The stresses associated with hot and cold environmental temperatures adversely affect dairy cattle metabolism by increasing maintenance requirements. Although water intake decreases, feed consumption increases during cold stress, which prevents the decline in milk production until temperatures fall below -5°C. The increase in nutrient uptake is due to the increase of maintenance requirements, i.e., for metabolic heat production, not increased yield. Alternatively, water intake increases but feed consumption decreases during heat stress, leading to a reduction in milk yield, despite the increase in maintenance requirements. Heat stress decreases animal consumption by directly affect feed intake centre in the brain. Likewise, intake is decreased because of increased gut fill due to reduced rate of passage and increased water consumption, and the increase respiration rate to dissipate body heat (Collier, 1985; Johnson, 2002; West, 2000).

The effect of calving season on 100-d milk yield was found to be significant ($P < 0.01$; Sondhipiroj *et al.*, 1992). The average milk yield in each season of the year was different. Especially in summer season, milk yield tended to decrease. This was due to high temperatures resulting in stress on dairy cow and feed intake decreases (Nickerson, 1995). Similar results were found by Ray *et al*. (1992) and Vajrabukka (1992). However, Tekerli *et al.* (2000) found that the peak yields for cows that calved in spring and summer in Turkey were lower than those that calved during fall and winter. The relationship between calving season and peak yield may result from increasing temperatures and decreasing fodder, especially in summer. Difference result was reported by Koonawootrittriron *et al.* (2001). Holstein Friesian cows that calved in the rainy season in Thailand had peak yields than cows that calved in winter and summer.

4.2.2 Nutrition

Nutrition is an obviously key factor influencing milk yield and composition, since the milk-producing cells of the mammary gland requires a constant and optimum supply of precursors to synthesize milk components. The major substrates absorbed from the blood are glucose, acetate, β-hydroxybutyrate, amino acids, fatty acids, and minerals. The cow's diet can be manipulated to vary the percentages of milk component. For example, fat content can be varied over a range of 3.0 percentage units and protein can be varied by 0.6 percentage units. However, lactose content is not influenced by diet manipulation, except through overfeeding or underfeeding (Nickerson, 1995). Similar investigation to the study was conducted by Grant (2000) who reported that changes in feed and feeding affected milk composition. The affect had different variables of milk composition. Percentage of fat was the most sensitive to change, next is percentage of protein and lactose, respectively.

Pichet (1989) reported that a cow grazing only high quality planted grass pastures in Thailand had 10.5 kg of milk per day while the cow on the ration (15.5% crude protein with a TDN of 70%) produced 17 kg per day. Interaction effect between nutritive value and Holstein fractions (< 75%H, 75%H, 87.5%H, and > 87.5%H) was found by Kaewkamcharn (2003). Cows fed with standard diet based on the NRC's recommendation had milk yield (2.02 kg/cow/day), fat percentage (0.25%), protein percentage (0.16%), and lactose (0.07%) higher than those cows fed with under the standard level.

4.2.3 Experience, education, record keeping, labor, and decision making of the farmers

Factors related to farmers themselves such as experience, education, record keeping, labor, and decision making on sire selection could also have effect on milk yield and revenue. Few studies concerned farmers' experience and education background exist in Thailand (e.g., Boonyanuwat *et al.,* 1995; Borisutsawat, 1996; Rhone *et al.,* 2008d; Sarakul *et al.,* 2009).

Rhone *et al.* (2008a) characterized dairy production, education experiences, decision making practices, and economic performance of dairy farmers in Central Thailand using questionnaire. They found that most of dairy farmers (40%) educated from primary school, following by high school (34%) and university (26%). Farmers in their study had experiences from 10 to 14 years. This report was similar to that of Sarakul *et al.* (2009), which the most of dairy farmers educated from primary school (66%) and had experiences from 9 to 16 years. However, these results were different from the study of Grittayanawach (1985), who surveyed the dairy farms in Central Thailand in 1985 and reported that most (80%) of the farmers had high school and higher than high school levels. Grittayanawach (1985) also reported that the education background of the heads of families did not differ among farm size. The owners of medium and large size farms had somewhat better education than the owners of small farms. Only 17 percent of the small size farm owners graduated from higher degrees but 39% and 44% graduated from primary and high school, respectively.

Tomaszewski (1993) reported that record keeping systems had provided an essential link to significantly increase of milk production. However, Rhone *et al.* (2008c) found that dairy farms in Thailand that kept records did not have significantly higher milk yield than those farms kept no record. However, most dairy farmers in Central, Northern, Northeastern and Southern Thailand kept records (55%) followed by those keeping no record and sometimes keeping record for milk production and pedigree of individual cows (Sarakul *et al.,* 2009).

Hanna *et al.* (2006) reported that cows that had more positive interactions with the stockperson had higher milk yield. This implies that quality of care and management are important for milk production. Thus, behavior of the persons who takes care cows and dairy productions would have some influence on milk quantity, quality and revenue. Unfortunately, there is no study in Thailand that consider effect of these human factors (i.e., experience, education, record keeping, labor and decision making on sire selection) on milk production, and none of them studied their impact on milk revenue.

5. Milk collection centers

Milk collection centers are important for milk production particularly in tropical developing countries. These centers decrease expenditures and lower transportation time of raw milk from dairy farms to milk processing factories. Milk collection centers have several advantages (Tantajinna, 2001) such as they improve the hygienic condition of milk. These centers have the necessary equipment to decrease and maintain raw milk at temperatures between 5 and 10 °C while waiting for transportation to the factory. They serve as a resource of news and information for dairy farmers. Officers at milk collection centers can offer advice and provide updated information on new technologies and equipment, and proper care and handling of dairy products and they provide a cost-effective mean of transportation raw milk. Individual dairy farmers attempting to transport raw milk to the factory are not as efficient and it is ultimately more expensive (Suksawat, 2004).

Suksawat (2004) reported that milk collection centers in Thailand were classified by management and administration (i.e., the dairy cooperative and the milk collection centers). Additionally, the milk collection centers were important for the development of dairy farming far from existing dairy processing factories. These centers have facilitated the spread of dairy farms far away from milk processing factories. Approximately 80% of milk collected at the farm level is done by cooperatives, while 20% is collected by private organizations. In 2010, milk collection centers in Thailand were divided into 2 groups (i.e., dairy cooperatives had 97 centers and private organizations had 81 centers; DLD, 2010).

5.1 Dairy cooperatives

Dairy cooperatives are formed by groups of dairy farmers and have a legal status. Cooperatives have a set of bylaws that are approved by their members. Decisions are made by committees that meet at regular times. This may cause delays in making decisions. Milk collection centers range from small size (less than 1 ton of raw milk collected per day) to large size (more than 100 tons of raw milk collected per day). There were a large number of collection centers and they receive assistance and support from the government such as loans with government department interest rates (Rhone *et al.,* 2008b). These collection centers fall into two categories: 1) cooperatives under the control of the Dairy Farming Promotion Organization (DPO) that received technical support for dairy production, veterinary service, artificial insemination, funds and equipment, and 2) independent cooperatives that depended on their own resources and organization (Suksawat, 2004).

5.2 Private organizations

Private collection centers were created with financial support entirely from private individuals and organizations. Administrative organization tends to be hierarchical, thus decisions are made by few individuals, in many cases the owner of the private center. This makes the decision process substantially faster than in a private cooperative that depends on committee decisions, or cooperatives sponsored by government institutions. Most private collection centers are medium or small size with 40 tons or less of raw milk collected per day (Suksawat, 2004).

6. Economically important traits of dairy farms

6.1 Milk production

In general, milk production is the main source of income for the dairy farms. The Thai farmers milk their cows twice a day, first in the morning and second in the evening. Almost all farmers sent their milk production to the milk collecting center on timely basis (i.e., morning and evening; Rhone *et al.*, 2008a). The amount of milk will be recorded and accumulated for a period of time (e.g., every 10 days, 15 days, or a month) and then they will be multiplied with the determined price considering based on milk quality in that particular period for the revenue (MDCL, 2005; Midland Dairy Limited Partnership [MDLP], 2007). The farm that has high milk production will have higher revenues than that having low milk production. The chance to lose profit from milk production of the farmers is generally related to the quality of milk that they produced (Rhone *et al.*, 2008b).

Rhone *et al.* (2008c, 2008d) analyzed the dataset gathered by a dairy cooperative in Central Thailand. They reported that farm size, farm location, production year, production season, and their combinations had effects on variation of milk production of the farmers. The differences of breed, management, feed and feeding, care, and health status of the cows had been reported that they had effects on milk production in Thailand (e.g., Kangvikkom *et al.*, 1994; Rengsirikul *et al.*, 1999; Koonawootrittriron *et al.*, 2001; Kaewkamcham, 2003; Vijchulata *et al.*, 2003; Seangjun *et al.*, 2008).

6.2 Milk quality

Quality of milk is important for manufacturing (Dalgleish, 1993**;** Piva, 1993; Kincannon *et al.,* 2004) and consuming (Patzig and Hadary, 1945; Klesges *et al.*, 1999; Rich-Edwards, 2007). Price determination for raw milk yield is generally based on milk quality (i.e., DLD, 2003; MDCL, 2005; MDLP; 2007; National Bureau of Agricultural Commodity and Food Standards [ACFS], 2010). The major considerations for quality of milk in Thailand are bulk tank fat percentage, bacterial contamination, and somatic cells. The other minor considerations are protein, lactose, solid not fat and total solid percentage. However, these are not considered for price determination for raw milk (MDCL, 2005; MDLP; 2007; ACFS, 2010).

Table 5 The national standard of milk quality

Milk quality	Standard levels	
	DLD[1]	ACFS[2]
Fat (%)	Not less than 3.20	Not less than 3.35
Protein (%)	Not less than 2.80	Not less than 3.00
Solid not fat (%)	Not less than 8.25	Not less than 8.25
Total solids (%)	Not less than 12.00	-
Somatic cell count (cells/ml)	Not over than 500,000	Not over than 500,000

[1] Department of Livestock Development

[2] National Bureau of Agricultural Commodity and Food Standards

Source: DLD (2003); ACFS (2010)

In order to determine price for one kilogram of milk, a sample of milk production will be taken randomly from bulk tank of a particular farm and then it will be analyzed for the considered quality (i.e., fat percentage, bacterial contamination, somatic cells). This determined price for one kilogram of milk will be given to the farms for the agreement period such as every 10 days or 15 days, which is different among organizations (MDCL, 2005; MDLP; 2007). According to food safety and consumer health, the national standard for milk quality (Table 5) was set by the DLD (2003).

Rhone *et al.* (2008c) studied the effects of season, farm location, and farm size on milk fat of dairy farms in the central region of Thailand. They reported that milk produced in cold season had higher fat percentage ($P < 0.05$) than those produced in hot and rainy seasons. The small size farms produced milk with higher fat percentage ($P < 0.05$) than the medium and large size farms.

Kaewkamcham (2003) investigated factors affecting yield and composition of milk produced from farms located in Central Thailand. They found that feed management, Holstein (H) fraction (i.e., less than 75% H, 75% H, 87.5% H, and greater than 87.5%H), season (hot, rainy, and cold), lactation number (i.e., 1, 2, 3, 4, 5 and more than 5 parity) and body condition scoring (i.e., thin, moderate, and fat) had effect on milk yield and composition. Milk yield increased proportionally with increasing H fraction, whereas milk components gradually decreased. Cows produced milk with lower components in hot season than ($P < 0.01$) in rainy and cold seasons. Furthermore, milk yield increased with increasing parity, and it had highest yield at the 5th lactation (22.27% higher than the 1st lactation).

The number and type of somatic cells present in milk depends largely on whether a cow has mastitis. Somatic cells in milk are composed mostly of white blood cells (Surawong *et al.*, 2004). Dairy cows with mastitis may have from 1 to 11% neutrophils, 66 to 88% macrophages, 10 to 27% lymphocytes, and 0 to 7% epithelial cells. Research studies indicated high association between mastitis and somatic cell count in milk (0.60 to 0.80; e.g., Heringstad *et al.,* 1999; Lund *et al.,* 1999; Rupp *et al.,* 1999; Hansen *et al.,* 2002; Othmane *et al.,* 2002; Buayai, 2004; Caraviello, 2004; Koivula *et al.,* 2005).

Rhone *et al.* (2008c) studied the effects of bulk tank somatic cell count (BTSCC) of dairy farms in Central Thailand. They reported that large farms had highest BTSCC ($P < 0.05$). Ajariyakhajorn *et al.* (2005) also found that farms lacked hygienic conditions and proper milking procedures had low milk quality. Occurring of mastitis had negative correlation with milk yield and milk composition (Rojanasthien *et al.*, 2006).

6.3 Pricing system and purchasing price

Pricing systems for raw milk 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 kg of raw milk sold and is not market driven, but rather determined and set by the national livestock committee of Thailand (Rhone *et al.*, 2008b). The national livestock committee is made up by dairy cooperatives, dairy processing factories and government authorities in Thailand. From 1998 to 2006, the standard price for one kg of raw milk sold was 12.5 baht. However, the base price that farmers' actually receive may be lower than this. The main causes of low base price were due to administration and transportation costs of milk collection centers (Ministry of Agriculture and Cooperatives, 2006; Rhone *et al.*, 2008d).

Table 6 Milk prices for the dairy farmers, cost of milk production, and inventory purchasing price in 1997 through 2009

Year	Milk price for the dairy farmers (baht/kg)	Cost of milk production (baht/kg)	Inventory purchasing price (baht/kg)
1997	9.39	7.74	10.50
1998	10.66	7.72	10.50/12.50
1999	10.94	7.47	12.50
2000	11.17	7.56	12.50
2001	11.33	8.00	12.50
2002	11.34	8.15	12.50
2003	11.35	8.20	12.50
2004	11.38	8.51	12.50
2005	11.48	9.03	12.50
2006	11.50	10.60	12.50
2007	12.55	12.31	12.50/13.75/14.50
2008	14.56	13.48	14.50/18.00
2009	15.89	12.60	18.00/16.50

Source: OAE (2009)

For example, in 2006 the Muaklek Dairy Cooperative Limited base price given to farmers was set at 11 baht/kg of raw milk sold. In addition to the base price, the Muaklek Dairy Cooperative gave their members additions and deductions based on milk fat percentage, SNF, bacterial score (measure of bacteria in raw milk) and bulk tank somatic cells (MDCL, 2005; Rhone *et al.*, 2008b). However, OAE (2009) reported that the price of raw milk had ranged from 11.38 to 15.89 baht/kg from 2004 to 2009.

The change in the purchase price of raw milk from 1997 to 2006 had been adjusted only once in 1998, and this adjustment was an increase of 19% (the original price at the factory was 10.50 baht/kg and the price at the milk collecting center was 8.75 baht/kg). This price adjustment occurred to compensate for increases in price of imported animal medicine and feed, higher interest rates on loans for these purchases, and a drop of 52% in the exchange rate of the baht relative to the dollar. Because the cost or production of milk had increased by 25%, dairy cooperatives and farmers in Thailand asked the government to increase price for raw milk yield in Thailand. Raw milk prices paid to dairy farmers, cost of milk production, inventory purchasing prices from 1997 to 2009 are shown in Table 6 (OAE, 2006).

6.4 Revenue

Revenues of the dairy farms in Thailand came mainly from selling milk production. The others were from selling male calves, heifers, culled cows, and manure for fertilizer (Grittayanawach, 1985; Rhone *et al.*, 2008d). Besides, dairy farmers may also sell some of their dairy cows when they urgently need cash and evaluated farm household income of dairy farmers by size. The dairy farms in this study were grouped into 3 different sizes (small, medium, and large) depended on the number of milking cows. Small size farms were those had less than 10 milking cows. Farms with 10 to 20 milking cows were considered to be medium size. Large farm were those with more than 20 milking cows (Table 7; Grittayanawach, 1985).

Table 7 Farm household incomes of dairy farmers by size of farm in 1983

Items[1]	Farm Size[2]			Average
	Small	Medium	Large	
Milk sales	110,483	232,901	476,658	273,347
	(91.65)[3]	(89.26)	(94.96)	(93.29)
Calf sales	1,940	2,485	8,500	4,308
	(1.61)	(1.07)	(1.69)	(1.47)
Cull Cow Sales	1,881	2,263	4,300	2,815
	(1.56)	(0.97)	(0.85)	(0.46)
Dairy Cow Sales	6,250	23,285	12,500	12,012
	(5.18)	(10.00)	(2.62)	(4.78)
Total	120,554	260,934	501,958	294,482
	(100)	(100)	(100)	(100)

[1] Unit (baht/farm/year)

[2] Farm size: Small, less than 10 milking cows; Medium, between 10 to 20 milking cows; Large, more than 20 milking cows

[3] Values in parentheses were percentage of the farm household income

Source: Grittayanawach (1985)

Table 7 shows farm household income of the dairy farms separated by farm size in 1983. In that particular period, the main source of household income was from selling milk (93% of the total income). The other was from selling dairy cows (5% of the total income), and calves and culled cows (2% of the total income). Annual household income increased with farm size. The annual income earned by large dairy farmers was more than twice (501,958 baht) that of small farmers. Proportionally, the income obtained by medium farms from selling dairy cows was higher than for large farms. The medium farms faced more severe cash flow problems (Grittayanawach, 1985).

Rhone *et al.* (2008d) reported that the main dairy feed in Thailand was concentrate. However, the farmers that used grazing system on the improved planted grasses had been profitable in their operations. This was similar to results of Pichet (1989) who reported that cows 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 300-d lactation, with profits increasing to 20,620 baht per lactation. However when cows were fed to appetite on a concentrate diet with no grazing, although milk yield increased 0, 5, 100 kg per 300 d lactation, profits decreased compared to the other diets to 18,150 baht per lactation.

Wongchotikul (1995) reported that the volume and prices of dairy milk varied accordingly to the farm size. The average cost of dairy milk production was 8.44 baht/kg for small size farms, 7.50 baht/kg for medium size farms, and 6.55 baht/kg for large size farms, respectively. Net return of dairy production was based on actual price received by farmer. The small size farm lost 0.79 baht/kg, the medium and the large size farm gained 0.49 and 1.74 baht/kg. Base on the price 8.50 baht/kg for raw milk production quoted by the government, net return was 0.06 baht/kg for the small size farms, 1.00 baht/kg for the medium size farms, and 2.04 baht/kg for the large size farms.

Seangjun and Koonawootrittriron (2007) surveyed dairy farmers in Central Thailand and reported that the small size farms got purchasing price higher ($P < 0.005$) than those medium and large size farms. The purchasing price had correlation with bacterial contamination ($r = -0.89$; $P < 0.01$) more than somatic cell count ($r = -0.14$; $P < 0.01$) but had no correlation with fat content ($r = 0.01$; $P > 0.05$). Furthermore, Suriyasathaporn *et al.* (2006) evaluated a short-term economic cost of raw milk produced in Chiang Mai province. They reported that the average milk price was only 11 baht/kg, whereas the average cost of raw milk production was 11.77 baht/kg.

6.5 Expense

Feed for dairy cattle in the farms is the major expense (Grittayanawach, 1985; Kaewkamcham, 2003; Rhone *et al.*, 2008d). Farmers are interesting to reduce feed cost and some of them are considering the least cost combination of feed, and mixing ration for the dairy cattle. Rhone *et al.* (2008d) reported that most dairy farms in the Central Thailand used some forms of confinement based operation. Concentrate is 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, building and loan costs also are part of a farms budget.

Table 8 Farm household income, expenditures, and net income of dairy farmers by farm size

Items[1]	Farm size[2]			Average
	Small	Medium	Large	
Household income	120,554	260,934	501,958	294,482
	(100)[3]	(100)	(100)	(100)
Household expenditures	103,609	186,340	379,482	223,143
	(85.9)	(71.4)	(75.6)	(75.8)
- Household consumption	40,811	57,919	92,107	63,612
	(33.8)	(22.2)	(18.4)	(21.6)
- Dairy production	62,798	128,421	287,375	159,531
	(52.1)	(49.2)	(57.2)	(54.2)
Household net income	6,945	74,594	122,476	71,339
	(14.1)	(58.6)	(24.4)	(24.4)

[1] Unit (baht/farm/year)

[2] Farm size: Small, less than 10 milking cows; Medium, between 10 to 20 milking cows; Large, more than 20 milking cows

[3] Values in parentheses were percentage of the farm household income

Source: Grittayanawach (1985)

Grittayanawach (1985) reported that household expenditures of dairy farmers were classified into consumption and production expenses. Household consumption expenditures included outlays for food and non-food. Non-food expenses included education, medicine, clothing, and social and religious activities. Household consumption expenditures averaged 63,612 baht a year, 22 percent of annual household income. Of these expenses, 45,215 baht was spent on food and 18,397 baht on non-food items. Expense for dairy production accounted for 54 percent of total farm income or 159,531 baht a year (Table 8). Household expenditures for consumption and production purposes were varied by farm size. Consumption costs increased with size of farm. Large farms also spent a higher percentage of farm income on production costs. Large dairy farms spent 57 percent of their total income on production; small and medium farmers spent 52 and 49 percent, respectively.

Table 9 Milk production, price, cost and profit of farms by farm size

Items	Farm size			Average
	Small	Medium	Large	
Milk production (kg/day)	12.65	11.54	11.19	11.80
Milk price (baht/day)	11.30	11.23	11.41	11.31
Milk cost (baht/kg)	12.09	11.09	11.50	11.56
- Roughage (%)	27	28	32	30
- Concentrate (%)	45	48	44	45
- Equipment and medicine (%)	3	3	4	4
- Artificial insemination (%)	1	1	3	2
- Fresh milk for calve (%)	7	5	6	6
- Transportation (%)	2	2	2	2
- Veterinary (%)	1	2	1	1
- Water and fire (%)	3	2	1	1
- Labor (%)	9	9	7	8
- Others (%)	2	0	0	0
Milk profit (baht/kg)	0.78	0.14	0.09	0.24

Source: Wangtal (2006)

Wangtal (2006) evaluated cost, expenditure, product per head, and economics of the dairy farms in Thailand (Table 9). The used information was gathered from 27 dairy cooperatives. Two farms of each farm size (6 farms) were randomly selected for each cooperative, and then a totally 162 farms ($27 \times 6 = 162$) were gathered information. The results showed that, in average the dairy farms lost money, but the medium farm size had more capital than other farm sizes.

MATERIALS AND METHODS

This research was targeted to characterize factors affecting monthly milk quantity and milk revenue of dairy farms that were member of a private organization and then compared the results with those of a dairy cooperative. This study was done in Central Thailand, which is the most important dairy production area in the country (Figure 5). This research was set into 3 Trials, which was related to each of objectives of the study.

Trial 1: Milk quantity, quality and revenue in dairy farms supported by a private organization in Central Thailand

Trial 2: Effect of experience, education, record keeping, labor and decision making on monthly milk yield and revenue of dairy farms supported by a private organization in Central Thailand

Trial 3 A comparative study on dairy production and revenue of the dairy farms supported by a private organization with those supported by a dairy cooperative in Central Thailand

Study location

The study location was in Central Thailand. Farms presented in the study located in Muak Lek (Saraburi province), Wang Muang (Saraburi province), Phatthana Nikhom (Lop Buri province) and Pak Chong (Nakhon Ratchasima province; Figure 5). These farms were separated into 2 groups, 1) member of a private organization, and 2) member of a dairy cooperative.

Season in this region (TMD, 2009) were winter (November to February), summer (March to June), and rainy (July to October). Weather in winter season is cool (21°C to 32°C) and dry (70% RH, precipitation 124 mm/year). While in summer season, there is hot (25°C to 36°C) and dry (69% RH, precipitation 187 mm/year). And in rainy season, the weather becomes hot (24°C to 33°C) and humid (79% RH, precipitation 903 mm/year)].

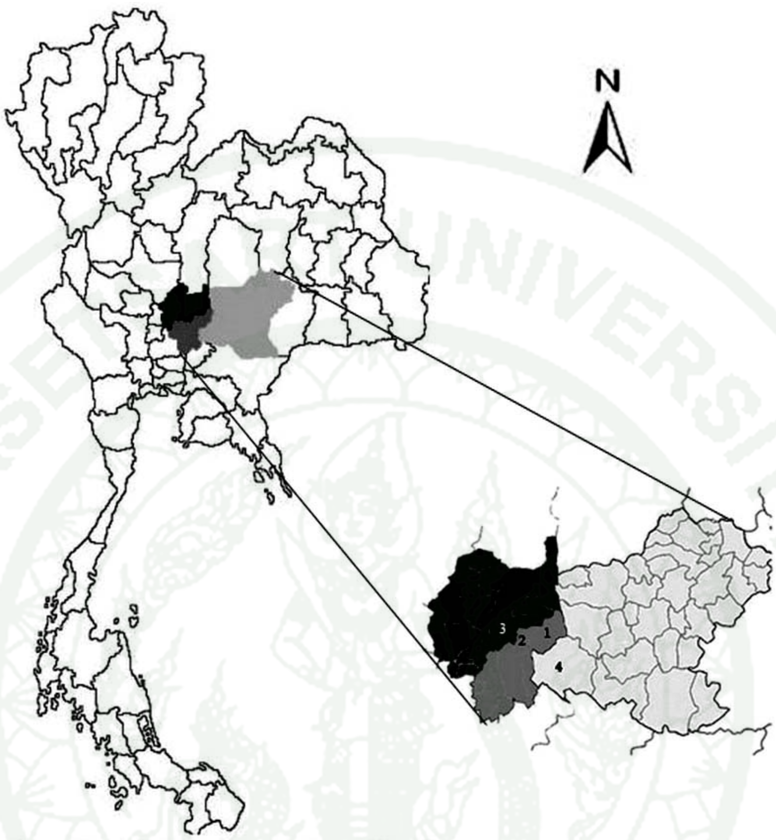


Figure 5 Map of Thailand showing the districts where farms where located: 1 = Muak Lek (Saraburi province), 2 = Wang Muang districts (Saraburi province), 3 = Phatthana Nikhom (Lop Buri province), and 4 = Pak Chong (Nakhon Ratchasima province)

Farms, animals and management

Animals and farms

The majority of dairy cattle in the population were over 75% Holstein (H). The remaining fraction (25% or less) contained genes from one or more of the following breeds: Brown Swiss, Brahman, Jersey, Red Dane, Red Sindhi, Sahiwal and Thai Native. The number of breeds represented in a particular cow ranged from one to more than 8 different breeds.

Number of milking cows varied across farms. Farm size were grouped as small (less than 10 milking cows), medium (from 10 to 19 milking cows), and large (more than 19 milking cows), which they were considered from the average number of milking cows in particular farms across dataset.

Feed and feeding

Farm feeding and nutritional management varied among seasons. Grasses fed to dairy cattle included *Brachiaria mutica* (para grass), *Brachiaria ruziziensis* (ruzi grass), *Pennisetum purpureum* (napier grass) and *Panicum maximum* (guinea grass), legumes such as *Stylosanthes hamata* cv. Verano (Verano stylo), *Stylosanthes guianensis* (Thapra stylo) and *Leucaena leucocephala* (leucaena). The green roughages were given to cattle both from pastures prepared for grazing and also cut and carry. Approximately, 30 to 40 kg of grasses, which was about 10% of their body weight, was fed to the dairy cows daily. However, the dry seasons (winter and summer), when green roughage was limited (usually due to lack of irrigation), rice straw, hay, and silage were used as supplements. Only some of large farms could make and use their own silage. Small farms fed their cattle with native grasses by cut and carry from public grazing areas.

Farmers also used concentrate composed of cereal, grains, rice bran, mung bean, soybean meal, minerals, vitamins, and byproducts from various milling and industrial plants (e.g., cotton meal, oil palm meal, and coconut meal). Concentrate was purchased from companies such as B.P. Feed Mill Co. Ltd., (Bangkok; feeds contain about 14%, 16% and 21% crude protein), Thai Feed Mills (Saraburi) Co. Ltd., (Saraburi; feeds contain about 16% crude protein), Betagro Public Company Limited (Saraburi; feeds contain about 14%, 16%, and 21% crude protein), and Chokchai Ranch Co. Ltd., (Nakhon Rachasrima; feeds contain about 16% crude protein). The majority of farms purchased ready mixed feeds rather than mixing themselves or a combination. The amount of concentrate fed to cows depended largely on the amount of milk produced by individual cows. Generally, one kilogram of concentrate was fed for each 2 to 3 kg of milk produced.

Management practices

Farmers usually fed milking cows twice a day, once after they were milked in the morning (4:30 to 7:00) and again in the afternoon (14:30 to 16:30). Some farmers fed their cows during milking. Almost all dairy farms used machine rather than hand milking. After each milking, milk was stored in 50 kg bulk tanks that were taken to the milk collection center by either the farmers themselves or by hired people. Prior to milking, farmers cleaned the udders of cows with a chlorine solution. Some farmers applied an iodine-based dipping agent after milking. The extent to preventive management techniques, such as teat dipping and dry cow management, used by farms in this study was largely unknown. The volume of milk received from each farm after each milking (morning and afternoon) was recorded at the milk collecting center. Milk from individual farms was randomly sampled every ten days. Milk samples were sent to the Department of Livestock Development office for milk quality analyses (i.e., FAT, PRO, LAC, SNF, TS and SCC). If a farm had low milk quality (i.e., FAT $<$ 3.2%, PRO $<$ 2.8%, SNF $<$ 8.25%, TS $<$ 12% or SCC $> 500 \times 10^3$ cells/ml), then personnel from the private organization visited that farm and provided suggestions to solve the problems that were identified (e.g., improvements in feeding, housing or milking conditions).

Farms primarily used semen from purebred H rather than crossbred H sires or sires from other dairy breeds or beef breeds to breed their cows by artificial insemination. Generally, farmers used their own experience, sire information (EBV and daughters' production) and suggestions from government and private organization advisors to services, select sires including AI and healthcare for animals. Calves were vaccinated against Hemorrhagic Septicemia between 4 and 8 months of age. All animals were vaccinated against Foot and Mouth Disease twice a year. All farms treated their cows with antihelmintics twice a year. Antibiotics were typically given to treat infections such as mastitis.

Data, traits and variables

The datasets used this research were those monthly records (i.e., number of milking cows, milk yield, milk quality, and milk revenue) collected from individual farms in 2004 through 2009 and questionnaire information distributed to the farmers. All farms in this study located in Central Thailand and also they were member of the considered private organization or dairy cooperative.

Monthly milk yield were classified as two traits; 1) milk yield per farm (MYF; kg) which was the total amount of milk produced by an individual farm in a particular month, and 2) milk yield per cow (MYC; kg) which was calculated as MYF divided by the average number of milking cows per day at an individual farm in a particular month.

Monthly milk revenue were analyzed as two traits; 1) milk revenue per farm (MRF; baht) which was the total revenue from milk sold by a farm to the private organization in a particular month, and 2) milk revenue per cow (MRC; baht) which was computed as MRF divided by the average number of milking cows per day at an individual farm in a particular month.

Monthly milk quality traits were classified as six traits i.e., fat percentage (FAT; %), protein percentage (PRO; %), lactose percentage (LAC; %), solids not fat percentage (SNF; %), total solids percentage (TS; %) and somatic cell count (SCC; $\times 10^3$ cells/ml). The values of FAT, PRO, LAC, SNF, TS and SCC were obtained from milk samples taken randomly once a month from milk containers of individual farms.

Individual farm information of the dairy farms supported by a private organization was also obtained using a set of questionnaires, which contained three types of questions: multiple choices, fill in the blank, and choose all that apply. Questions requested information of farmer background, farm management, and decision making on sire selection. The questionnaire was pre-tested using eight dairy farms chosen randomly in the area of the study. After changes were made to improve its clarity, questionnaires were randomly distributed to the 800 dairy farmers in the original dataset provided by a private organization. Three weeks later, filled questionnaires were collected (627 farms; 78% response rate) and sent back to Kasetsart University for data entry and analyses. Answers to each question were assigned a numeric code that could be used for data analyses.

Experience of the farmer, measured as the number of years a farmer had been dairying, was classified as: 1) no experience (2%), 2) one year of experience (8%), 3) two to five years of experience (20%), 4) six to ten years of experience (28%), 5) eleven to fifteen years of experience (22%), 6) sixteen to twenty years of experience (15%), and 7) more than twenty years of experience (6%). Formal education of the farmer, measured as the farmer's highest educational degree, was classified as: 1) no education or primary school (65%), 2) high school (25%), and 3) bachelor or higher degree (10%). Record keeping for milk production and pedigree information of the farm were defined as: 1) no records (78%), and 2) kept records (22%). Labor, defined in terms of type of workers that participated in dairy operations, was categorized as: 1) family (85%), 2) hired people (5%), and 3) family and hired people (10%). Decision making on sire selection was classified as: 1) decisions made by farmers themselves (82%), 2) decisions made with help from government officials (3%), and 3) decisions made with help from staff of the supporting organization (15%).

Table 10 Datasets used in the study

Trial	Monthly Records	Dairy farms	Traits[1]	Considered factors	Duration time	Source of data
1	34,133	1,101	MYF, MYC, MRF, MRC, FAT, PRO, LAC, SNF, TS and SCC	Year-season and Farm location-farm size subclasses	2004 to 2007	A private organization (Dataset)
2	34,082	497	MYF, MYC, MRF and MRC	Year-season, Farm location-farm size, Experience, Education, Record Keeping, Labor and Decision Making subclasses,	2004 to 2008	A private organization (Dataset and questionnaires data)
3	70,143	1,091	MYF, MYC, MRF and MRC	Year-season, Farm location-farm size and Organization-farm size subclasses	2006 to 2009	A private organization and a dairy cooperative (Dataset)

[1] MYF = monthly milk yield per farm; MYC = monthly milk yield per cow; MRF = monthly milk revenue per farm; MRC = monthly milk revenue per cow; FAT = fat percentage; PRO = protein percentage; LAC = lactose percentage, SNF = solid not fat percentage; TS = total solid percentage; SCC = somatic cell count

Trial 1

Milk quantity, quality and revenue in dairy farms supported by a private organization in Central Thailand

1. Data description

The dataset was composed of 34,133 farm records of milk yields (MYF and MYC), milk quality (FAT, PRO, LAC, SNF, TS and SCC) and milk revenues (MRF and MRC). These records were from 1,101 farms supported by a private dairy organization from January 2004 to December 2007. Unfortunately, no records were taken from individual animals.

The farm identification number created by a private organization was used for the analyses and also to link all related information. The address of individual farms was used to assign farms to 4 locations: Muak Lek, Wang Muang, Phattana Nikhom and Pak Chong. The average number of milking cows for the duration of the study was used to classify farms into 3 sizes: small, medium and large. Seasons were winter, summer and rainy season.

2. Statistical analysis

Single-trait mixed models were used to analyze MYF, MYC, MRF, MRC, FAT, PRO, LAC, SNF, TS and SCC. Computations were carried out using the mixed procedure of the SAS software package (SAS, 2004). The mixed model used for all traits contained the subclasses of year-season and farm location-farm size as fixed effects. Year-season subclasses contained the effects of year, season and year × season interactions. Similarly, farm location-farm size subclasses contained the effects of farm location, farm size and farm location × farm size interactions. Random effects were farm and residual. The model in matrix notation was as follows.

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Z_f u_f} + \mathbf{e}$$

where

y = vector of single trait records (MYF, MYC, MRF, MRC, FAT, PRO, LAC, SNF, TS and SCC),

b = vector of fixed effects (year-season and farm location-farm size),

$\mathbf{u_f}$ = vector of random farm effects,

X = incidence matrix relating records to elements of b,

$\mathbf{Z_f}$ = incidence matrix relating records to elements of u,

e = vector of residual effects.

Random farm effects were assumed to have mean zero, a common variance (σ_f^2) and uncorrelated. Similarly, random residual effects were assumed to have mean zero, common variance (σ_e^2) and uncorrelated. Variances for random effects were estimated using restricted maximum likelihood using option REML in the mixed procedure of SAS. Year-season and farm location-farm size least squares means (LSM) were estimated for all traits, and then compared using Bonferroni t-test.

Trial 2

Effect of experience, education, record keeping, labor and decision making on monthly milk yield and revenue of dairy farms supported by a private organization in Central Thailand

1. Data description

A dataset with 34,082 records collected monthly from January 2004 to December 2008 from 800 dairy farms was provided by a private organization. In addition, individual farm information gathered from all participating dairy farmers using a questionnaire was combined. Monthly milk yield and milk revenue records were linked to the questionnaire dataset through farm identification number and combined into a single dataset. Then, the combined dataset was edited for missing and erroneous information. The resulting dataset contained 24,249 records from 497 farms with complete information on farmer's experience, education, record keeping, labor, and decision making on sire selection.

Farm locations were classified according to districts defined by the Thai government as Muak Lek, Wang Muang, Phatthana Nikhom and Pak Chong. Seasons were classified as winter, summer, and rainy season. Farms were classified according to their average number of milking cows per day into small, medium, and large. Traits in the private organization dataset were: monthly milk yield per farm (MYF; kg), milk yield per cow (MYC; kg), milk revenue per farm (MRF; baht) and milk revenue per cow (MRC; baht)

2. Description of farms information

The average size of each farm presented in this dataset was approximately 4 acres (SD = 6 acres). The majority of dairy farmers in this population (52.4%) depended on their dairy business as the sole source of income. The remaining farmers received additional income from other livestock trade (2.9%), horticulture or agronomy (41.2%), and other sources (3.5%). Each farm employed approximately 2 people (SD = 0.8 people), and in most farms (89.0%) employees were members of the family.

The average number of dairy cattle in each farm was 29 cows (SD = 20) for all types of dairy cattle, and 11 cows (SD = 8) for milking cows. The largest group of milking cows in these farms were crossbreds with Holstein (H) fractions ranging from 51% to 75% (47% of the population), followed by crossbreds with H fractions larger than 75% up to less than 100% (43.5% of the population), crossbreds with H fraction less than 50% (7.8% of the population), and purebred H (1.7% of the population). Most farms (49.3%) preferred to use purebred H rather than crossbred H (32.5%) sires or sires from other dairy breeds (10.0%) or beef breeds (8.2%) to breed their cows by artificial insemination.

Most farmers (86.5%) had areas dedicated to grasses or legumes. Most farmers (57%) cut-and-carried these forages to their cattle and also prepared pastures for grazing. Other farmers either only cut-and-carried grass (39%), or prepared pastures for grazing (4%). Most farmers purchased their concentrate as ready-mixed feeds (90.6% of farmers), whereas 6.3% of farmers mixed their own concentrate, and 3.1% of farmers fed both home-mixed and purchased concentrate.

Almost all dairy farms used machine (95%) rather than hand (5%) milking. Milk was stored in 50 kg bulk tanks that were taken to the private organization by either the farmers themselves (15%) or by hired people (85%). Moreover, most farms were small (55%) and the vast majority of farmers had primary school or no school education (65%), kept no records (78%), used their family members for dairy work (85%), and made decisions on sire selection by themselves (82%) in this trial.

3. Statistical analysis

The dataset was analyzed using a mixed linear model that contained year-season subclasses, farm location-farm size subclasses, experience of the farmer, formal education of the farmer, record keeping of the farm, labor, and decision making on sire selection as fixed effects, and farm and residual as random effects. The model in matrix notation was as follows.

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Z_f u_f} + \mathbf{e}$$

where

y = vector of single-trait records (MYF, MYC, MRF and MRC),

b = vector of fixed effects (year-season, farm location-farm size, experience, education, record keeping, labor, and decision making),

$\mathbf{u_f}$ = vector of random farm effects,

X = incidence matrix relating records to elements of b,

$\mathbf{Z_f}$ = incidence matrix relating records to elements of u,

e = vector of residual effects.

Random farm effects were assumed to have mean zero, a common variance (σ_f^2), and uncorrelated. Random residual effects were assumed to have mean zero, a common variance (σ_e^2), and uncorrelated. Variances for random effects were estimated using a restricted maximum likelihood procedure. Analyses were performed using the MIXED procedure of the Statistical Analysis System (SAS, 2004). Least squares means (LSM) were estimated for each trait and pairwise comparisons made using Bonferroni t-tests. The significance level for comparisons was set to $\alpha = 0.05$.

Trial 3

A comparative study on dairy production and revenue of the dairy farms supported by a private organization with those supported by a dairy cooperative in Central Thailand

1. Data description

The used dataset composed of 70,143 records of monthly milk productions (per farm and per cow) and revenues (per farm and per cow), which were collected from 1,091 dairy farms during January 2006 to December 2009. These dairy farms were member of a private organization (449 farms; 19,975 records) and a dairy cooperative (642 farms; 50,168 records). Their farms were located in Muak Lek (343 farms of a private organization, and 470 farms of a dairy cooperative), Wang Muang (68 farms of a private organization, and 11 farms of a dairy cooperative), and Pak Chong (38 farms of a private organization, and 161 farms of a dairy cooperative).

Years were classified as 2006, 2007, 2008, and 2009. Seasons were winter, summer, and rainy. Farm locations were classified as Muak Lek, Wang Muang, and Pak Chong. Farm sizes which were calculated from average number of milking cows across the study period were grouped as small, medium, and large size farms. Organizations were private organization and dairy cooperative.

Traits in this study (Trial 3) were milk yield per farm (MYF), milk yield per cow (MYC), milk revenue per farm (MRF) and milk revenue per cow (MRC). Table 11 shows descriptive statistics for milk productions (MYF and MYC) and milk revenues (MRF and MRC) of farms supported by a private organization and a dairy cooperative. On average, the dairy farms in this study produced 3,893.37 (SD = 3,167.29) kg for MYF and 304.52 (SD = 102.16) kg for MYC. With these amount of milk, the dairy farms generally got 52,589.22 (SD = 43,312.38) baht for MRF and 4,123.20 (SD = 1,507.35) baht for MRC. Most dairy farms in this study were small size [44% (327 farms) of a private organization, and 39% (255 farms) of a dairy cooperative], followed by medium size farms [40% (293 farms) of a private organization, and 38% (253 farms) of a dairy cooperative], and large size farms [16% (115 farms) of a private organization, and 23% (154 farms) of a dairy cooperative], respectively.

Table 11 Descriptive statistics for milk productions and milk revenues of a private organization and a dairy cooperative datasets

Organizations	Traits[1]	No. of records	Mean	Standard Deviation	Min	Max
Private organization	MYF (kg)	19,883	3,773.46	2,795.13	203	19,731
	MYC (kg)	19,809	320.27	87.52	101	599
	MRF (baht)	19,848	50,772.58	38,902.16	1,011	313,444
	MRC (baht)	19,702	4,275.70	1,247.42	1,018	8,399
Dairy cooperative	MYF (kg)	36,572	3,958.57	3,350.56	201	35,940
	MYC (kg)	25,225	292.15	110.77	101	599
	MRF (baht)	36,625	53,573.70	45,494.44	1,010	379,176
	MRC (baht)	25,939	4,007.37	1,668.83	1,002	8,394

[1] MYF = monthly milk yield per farm; MYC = monthly milk yield per cow; MRF = monthly milk revenue per farm; MRC = monthly milk revenue per cow

2. Statistical analysis

All data was linked to the identification number of the farms supported by the private organization and the dairy cooperative. Milk production per farm and per cow (MYF and MYC) and milk revenue per farm and per cow (MRF and MRC) of a particular farm were considered on monthly basis. Years (2006, 2007, 2008, and 2009), seasons (winter, summer, and rainy season), farm locations (Muak Lek, Wang Muang, and Pak Chong), farm sizes (small, medium, and large), and organizations (a dairy cooperative and a private organization) were classified and combined into a single dataset in this study.

A mixed linear model containing fixed and random effects was created for this study. Years, seasons, farm locations, farm sizes, organizations and their interactions were tested for their effect on MYF, MRF MYC, and MRC using procedures in SAS software (SAS, 2004). Factors that had not significantly effect on the traits were not considered in this study. Finally, the used model contained year-season subclasses, farm location-farm size subclasses and organization-farm size subclasses as fixed effects, and the random effects were farm and residual. The model in matrix notation was as follows.

$$\mathbf{y = Xb + Z_f u_f + e}$$

where

y = vector of single-trait records (MYF, MYC, MRF and MRC),

b = vector of fixed effects (year-season, farm location-farm size and organization-farm size),

$\mathbf{u_f}$ = vector of random farm effects,

X = incidence matrix relating records to elements of b,

$\mathbf{Z_f}$ = incidence matrix relating records to elements of u,

e = vector of residual effects.

Random farm effects were assumed to have mean 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 estimated using a restricted maximum likelihood procedure (REML). All farms were assumed to have no relationship. Least squares means (LSM) of the studied traits were estimated by the considered factors, and then they were compared using Bonferroni t-test. Significant level for the comparison was considered at $\alpha = 0.05$. Regression coefficient of LSM of the study traits was estimated across year-season subclasses and then it was considered as a rate of changing of the study traits per year-season.

RESULTS AND DISCUSSION

Trial 1

Milk quantity, quality and revenue in dairy farms supported by a private organization in Central Thailand

Number of records, mean, and standard deviation of milk yields (MYF and MYC), milk revenues (MRF and MRC), and milk quality (Fat, Protein, Lactose, Solid not fat, Total solid, and Somatic cell count) of dairy farms presented in this study are shown in Table 12. The average values for these traits were similar to those reported for farms supported by a dairy cooperative in Central Thailand (Seangjun and Koonawootrittriron, 2007; Rhone *et al.*, 2008a, 2008b, 2008c)

Table 12 Number of records, mean and standard deviation of milk yields, milk revenues, and milk quality

Traits	Number of records	Mean	Standard deviation
Milk yield per farm (MYF; kg)	23,052	3,232.38	2,553.25
Milk yield per cow (MYC; kg)	23,052	366.90	163.39
Milk revenue per farm (MRF; baht)	23,052	37,521.88	29,849.50
Milk revenue per cow (MRC; baht)	23,052	4,256.12	1,895.08
Fat (FAT; %)	28,612	3.40	0.46
Protein (PRO; %)	28,729	3.01	0.22
Lactose (LAC; %)	28,727	4.57	0.28
Solid not fat (SNF; %)	28,729	8.25	0.36
Total solid (TS; %)	28,700	11.7	0.67
Somatic cell count (SCC; $\times 10^3$ cells/ml)	26,103	657	679

1. Year-season subclasses

Year-season LSM ranged from 4,351.80 ± 89.51 kg (2006-Rainy) to 5,027.46 ± 84.67 kg (2005-Summer) for MYF (Figure 6a) and from 284.30 ± 7.73 kg (2007-Rainy) to 368.57 ± 6.63 kg (2005-Summer) for MYC (Figure 6b). Year-season LSM for MYF tended to increase from 2004 to 2007 (4.57 ± 17.03 kg/year-season; P = 0.7934). In contrast, year-season LSM for MYC decreased over this same period (-6.23 ± 1.42 kg/year-season; P = 0.0011). These trends for MYF and MYC indicated that the increase in milk production per farm that occurred in this dairy cattle population from 2004 to 2007 was not because of an increase in individual MYC, but it was due to an increase in the average number of cows milked per day. The average number of cows milked per day increased from 8.54 ± 6.31 cows in 2004 to 10.7 ± 7.80 cows in 2007.

Year-season LSM for farm revenues ranged from 50,322.00 ± 1,043.76 baht (2006-Rainy) to 65,441.00 ± 1,155.19 baht (2008-Winter) for MRF (Figure 6c), and 3,429.92 ± 86.56 baht (2006-Rainy) to 4,435.47 ± 104.05 baht (2008-Winter) for MRC (Figure 6d). There was a positive trend of 623 ± 249 baht/year-season (P = 0.0296) for MRF from 2004 to 2007. On the other hand, MRC tended to decrease (-15 ± 23 baht/year-season; P = 0.5321) between 2004 and 2007. The direction of the MRF and MRC trends were the same as those for MYF and MYC. This occurred because the milk revenue system in Thailand depends primarily on milk quantity, thus revenues are proportional to amounts of milk purchased by milk collection centers.

The decreasing trend in MYC found in this dairy population between 2004 and 2007 may have been a consequence of the deterioration of the economic situation of dairy farmers during that period. The price for raw milk yield remained at 12.5 baht/kg from January 2004 to December 2007 (DLD, 2007; OAE, 2008). However, dairy production costs (e.g., feed, fuel, labor, equipment and services) and living expenses (e.g., food, clothes and health care) increased dramatically from 2004 to 2007 (Prateepavanid, 2006; Suriyasathaporn *et al.,* 2006; Ndambi *et al.,* 2008). In order to maintain their revenue the farmers were forced to increase their farm size which could have also led to their inability to supply the required inputs for production. Increased costs may have forced farmers to decrease the quantity and quality of feed supplied to cows, and perhaps to lower the level of management and health care. Decreased levels of nutrition, management, and health care may, in turn, have increased stress on dairy cows resulting in lower MYC.

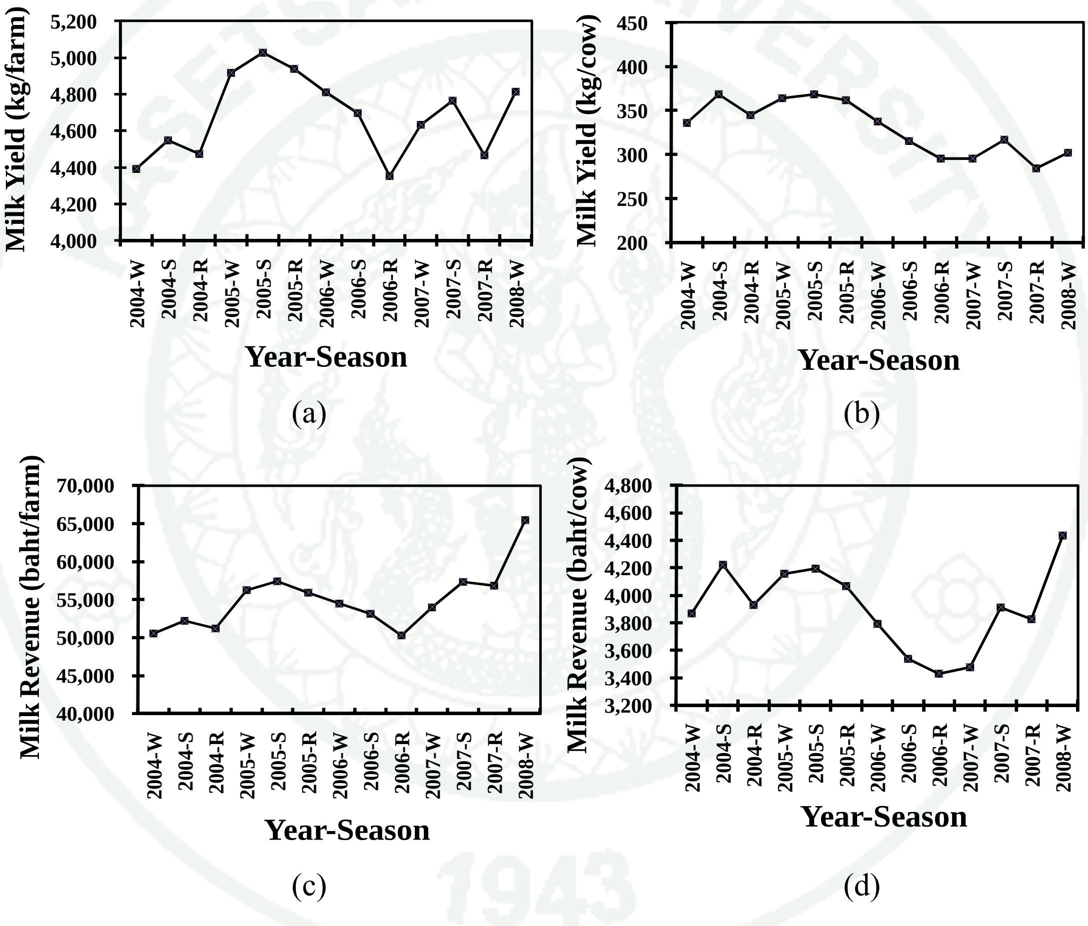


Figure 6 Trends for year-season subclasses least squares means for monthly milk yield per farm (a), milk yield per cow (b), milk revenue per farm (c) and milk revenue per cow (d)

Price of milk was increased to 14.5 baht during the last quarter of 2007 (DLD, 2007; OAE, 2008). Information collected from dairy farms in this study in 2008 and later years will help determine whether this price increase for milk resulted in a corresponding increase in MYC. Additional training on improving the efficiency of milk production, cost-effective feeding, management and health care practices of dairy farmers in this private organization may also help increase the productivity and profitability of their dairy farms.

Table 13 shows LSM and standard errors for the 6 milk quality traits (FAT, PRO, LAC, SNF, TS and SCC) by year-season subclasses. Year-season LSM tended to increase for FAT (0.015 ± 0.006%/year-season; P = 0.0339), LAC (0.024 ± 0.013%/year-season; P = 0.0901), SNF (0.021 ± 0.016%/year-season; P = 0.2103), TS (0.033 ± 0.021%/year-season; P = 0.1337) and SCC (11.31 ± 3.07 $\times 10^3$ cells/ml/year-season; P = 0.0036), and to remain unchanged for PRO (0.003 ± 0.006%/year-season; P = 0.5809). Similar trends across year-seasons for milk quality traits were also found by Azad *et al.* (2007), Seangjun and Koonawootrittriron (2007) and Rhone *et al.* (2008a).

Trends for milk quality traits in this dairy population were low but favorable, except for SCC. Year-season LSM for SCC were all above the recommended maximum of 500,000 cells/ml (DLD, 2003; ACFS, 2010). Thus, improving management and health care of dairy cows to reduce and maintain SCC below the recommended maximum should be a priority for farmers in this private organization. This will likely result not only in lower SCC, but it may also increase milk production.

All milk quality traits were likely influenced by quantity and quality of roughage, management, health care (particularly for SCC) and changing climatic conditions across years and seasons. Thus, variability in environmental conditions across year-seasons should be accounted for when devising management strategies to improve milk quality in Central Thailand.

Table 13 Least squares means and standard errors for fat (FAT), protein (PROT), lactose (LAC), solids not fat (SNF), total solids (TS) and somatic cell count (SCC) by year-season subclasses

Year-Season subclasses	Milk quality					
	FAT (%)	PRO (%)	LAC (%)	SNF (%)	TS (%)	SCC ($\times 10^3$ cells/ml)
2004-Winter	3.48 ± 0.017	3.13 ± 0.008	4.61 ± 0.008	8.44 ± 0.012	11.93 ± 0.023	673.95 ± 26.53
2004-Summer	3.50 ± 0.016	3.09 ± 0.007	4.61 ± 0.007	8.40 ± 0.011	11.90 ± 0.022	770.19 ± 24.28
2004-Rainy	3.31 ± 0.016	2.90 ± 0.008	4.01 ± 0.007	7.61 ± 0.011	11.92 ± 0.022	755.39 ± 24.99
2005-Winter	3.36 ± 0.016	2.93 ± 0.007	4.33 ± 0.007	8.11 ± 0.011	11.73 ± 0.022	672.38 ± 24.59
2005-Summer	3.39 ± 0.019	2.99 ± 0.009	4.62 ± 0.008	8.19 ± 0.013	11.82 ± 0.025	799.38 ± 30.88
2005-Rainy	3.45 ± 0.017	3.08 ± 0.008	4.64 ± 0.008	8.30 ± 0.012	11.97 ± 0.023	736.23 ± 26.17
2006-Winter	3.46 ± 0.016	2.95 ± 0.008	4.61 ± 0.007	8.23 ± 0.011	11.76 ± 0.022	764.25 ± 25.04
2006-Summer	3.41 ± 0.016	3.02 ± 0.008	4.66 ± 0.007	8.27 ± 0.011	11.79 ± 0.022	775.00 ± 24.76
2006-Rainy	3.52 ± 0.018	3.10 ± 0.008	4.65 ± 0.008	8.36 ± 0.012	11.98 ± 0.025	795.36 ± 27.63
2007-Winter	3.52 ± 0.017	3.02 ± 0.008	4.68 ± 0.008	8.35 ± 0.012	11.92 ± 0.023	740.01 ± 26.09
2007-Summer	3.42 ± 0.016	3.02 ± 0.008	4.71 ± 0.007	8.36 ± 0.011	11.85 ± 0.022	843.09 ± 24.87
2007-Rainy	3.68 ± 0.016	3.12 ± 0.008	4.68 ± 0.007	8.47 ± 0.011	12.18 ± 0.022	867.96 ± 24.52
2008-Winter	3.59 ± 0.018	3.05 ± 0.009	4.63 ± 0.008	8.35 ± 0.012	11.97 ± 0.024	838.12 ± 28.04

2. Farm location-farm size subclasses

Farm location-farm size subclasses were important for all traits (MYF, P < 0.0001; MYC, P = 0.0083; MRF, P < 0.0001; MRC, P = 0.0076; Figure 7a). Farm location-farm size LSM for MYF ranged from 6,157.10 ± 625.08 kg in Phattana Nikhom to 8,674.82 ± 228.20 kg in Muaklek for large farms, from 4,111.79 ± 286.43 kg in Phattana Nikhom to 4,759.10 ± 193.72 kg in Pak Chong for medium farms and from 1,566.29 ± 187.54 kg in Phattana Nikhom to 1,822.65 ± 135.32 kg in Pak Chong for small farms.

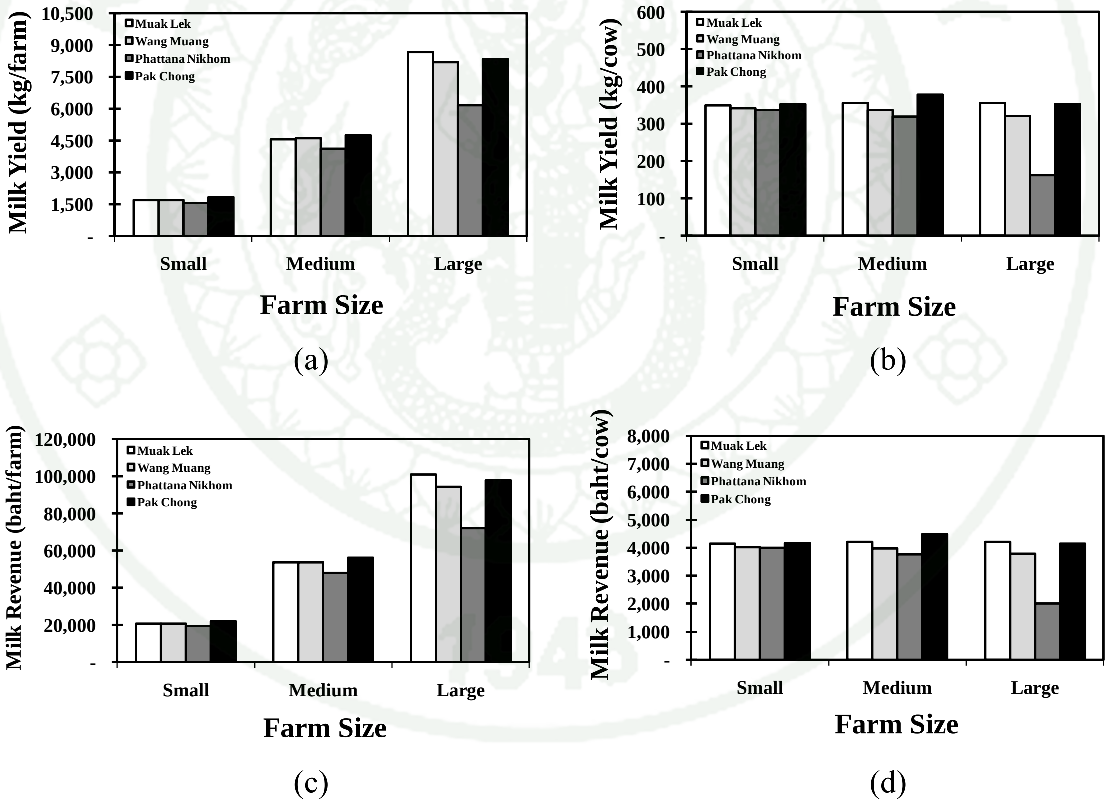


Figure 7 Least squares means for monthly milk yield per farm (a), milk yield per cow (b), milk revenue per farm (c) and milk revenue per cow (d) by farm location-farm size subclasses

Farm location-farm size subclasses LSM for MYC ranged from 162.29 ± 47.40 kg in Phattana Nikhom to 356.04 ± 17.28 kg in Muak Lek for large farms, from 318.83 ± 22.11 kg in Phattana Nikhom to 378.26 ± 14.52 kg in Pak Chong for medium farms and from 336.56 ± 14.71 kg in Phattana Nikhom to 352.53 ± 10.22 kg in Pak Chong for small farms. Except for large farms in Phattana Nikhom, ranges for MYC were similar in all farm location by farm size (Figure 7b).

The low LSM values for MYF and MYC in large farms in Phattana Nikhom was likely due to the low quality and quantity of feed provided to dairy cows. Large farms in Phattana Nikhom made extensive use of rice straw particularly during the dry season because of limited availability and high cost of good quality forage. Most farms in Phattana Nikhom (82%) did not grow grass or legume for their cows, and approximately 84% of the land in Phattana Nikhom was used for crop production (cassava, sugarcane, corn and sunflower).

The pattern of farm location-farm size LSM for MRF across locations was similar to that for MYF (Figure 7c). Farm location-farm size LSM for MRF ranged from 72,015.00 ± 7,273.05 baht in Phattana Nikhom to 100,929.00 ± 2,655.16 baht in Muak Lek for large farms, from 47,987.00 ± 3,334.45 baht in Phattana Nikhom to 56,338.00 ± 2,253.49 baht in Pak Chong for medium farms and from 19,449.00 ± 2,184.06 baht in Phattana Nikhom to 21,960.00 ± 1,574.34 baht in Pak Chong for small farms.

A similar pattern of farm location-farm size LSM across locations existed for MRC (Figure 7d) and MYC (Figure 7b). In particular, large farms in Phattana Nikhom had lower MRC as expected from the low LSM for MYC and the milk pricing system in Thailand. Farm location-farm size LSM for MRC ranged from 2,015.27 ± 549.33 baht/cow in Phattana Nikhom to 4,208.09 ± 200.23 baht/cow in Muak Lek for large farms, from 3,757.63 ± 256.30 baht/cow in Phattanas Nikhom to 4,483.70 ± 168.27 baht in Pak Chong for medium farms and from 3,996.36 ± 170.57 baht/cow in Phattana Nikhom to 4,179.28 ± 118.40 baht/cow in Pak Chong for small farms.

The MRF and MRC patterns across farm location-farm size subclasses were related to MYF and MYC. Low milk revenues (MRF and MRC) were due to low milk production (MYF and MYC) rather than low milk quality (FAT, PRO, LAC, SNF, TS and SCC). Thus, factors that affected milk production (e.g., feed and management) had a direct impact on milk revenues. As with MYF and MYC, low LSM values for MRF and MRC in large farms in Phattana Nikhom were likely due to low quality and quantity of feed given to cows. Thus, feed and management strategies, especially during the dry season, must be improved to increase milk production and revenues in this region.

Table 14 shows LSM for FAT, PRO, LAC, SNF, TS and SCC by farm location-farm size subclasses. Farm location-farm size subclasses LSM for FAT, PRO, SNF, TS and SCC tended to be similar in small and medium farms ($P > 0.05$) and smaller than in large farms ($P < 0.05$) in almost all locations. In contrast, LSM for LAC tended to decrease as farm size increased in all locations, except for Pak Chong.

Values of LSM for FAT across farm location-farm size subclasses ranged from 3.41 ± 0.07% in Pak Chong to 3.60 ± 0.10% in Phattana Nikhom for large farms, from 3.36 ± 0.04% in Pak Chong to 3.57 ± 0.05% in Phattana Nikhom for medium farms and from 3.37 ± 0.03% in Pak Chong to 3.53 ± 0.02% in Wang Muang for small farms. Large farms in Muak Lek, Pak Chong and Wang Muang tended to have similar and higher FAT than small and medium farms. All farm sizes in Muak Lek had LSM for FAT similar to those in Pak Chong and both of them were lower than FAT values of farms in Phattana Nikhom and Wang Muang (Figure 7a). Variability of FAT across farm location-farm size subclasses could be associated with weather patterns, availability of roughage, agricultural activities, irrigation of pastures and the ability of farmers to manage and utilize local feed resources (Allore *et al.,* 1997; Kaewkamcham *et al.,* 2001).

Table 14 Least squares means and standard errors for fat (FAT), protein (PROT), lactose (LAC), solids not fat (SNF), total solids (TS) and somatic cell count (SCC) by farm location-farm size subclasses

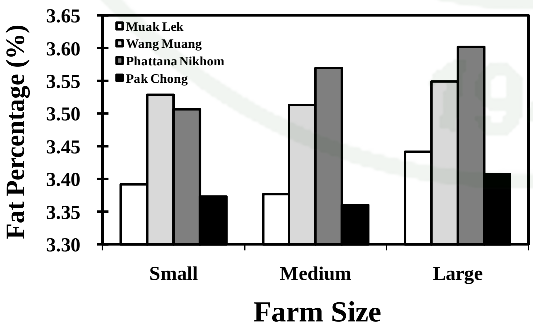
Farm location[1]	Farm size[2]	Milk quality					
		FAT (%)	PRO (%)	LAC (%)	SNF (%)	TS (%)	SCC ($\times 10^3$ cells/ml)
ML	Small	3.39 ± 0.011	3.02 ± 0.005	4.58 ± 0.005	8.26 ± 0.008	11.74 ± 0.016	601.77 ± 17.61
	Medium	3.38 ± 0.016	3.01 ± 0.008	4.59 ± 0.007	8.26 ± 0.012	11.73 ± 0.022	610.60 ± 25.06
	Large	3.44 ± 0.042	3.03 ± 0.021	4.55 ± 0.020	8.24 ± 0.031	11.77 ± 0.059	744.13 ± 65.24
WM	Small	3.53 ± 0.023	3.04 ± 0.012	4.59 ± 0.011	8.29 ± 0.017	11.92 ± 0.032	659.47 ± 36.46
	Medium	3.51 ± 0.040	3.02 ± 0.020	4.58 ± 0.019	8.26 ± 0.029	11.86 ± 0.056	809.30 ± 62.27
	Large	3.55 ± 0.067	3.07 ± 0.033	4.55 ± 0.031	8.28 ± 0.049	11.93 ± 0.093	1,055.53 ± 103.41
PN	Small	3.51 ± 0.031	3.02 ± 0.016	4.61 ± 0.014	8.30 ± 0.023	11.90 ± 0.043	536.45 ± 48.50
	Medium	3.57 ± 0.048	3.03 ± 0.024	4.59 ± 0.022	8.28 ± 0.035	11.95 ± 0.066	639.36 ± 74.35
	Large	3.60 ± 0.098	3.09 ± 0.049	4.58 ± 0.046	8.33 ± 0.072	12.01 ± 0.137	999.75 ± 153.97
PC	Small	3.37 ± 0.025	3.02 ± 0.013	4.53 ± 0.012	8.21 ± 0.018	11.67 ± 0.036	748.71 ± 40.11
	Medium	3.36 ± 0.036	2.99 ± 0.018	4.54 ± 0.017	8.19 ± 0.027	11.64 ± 0.050	791.81 ± 56.39
	Large	3.41 ± 0.073	3.05 ± 0.037	4.56 ± 0.034	8.27 ± 0.054	11.77 ± 0.102	1,062.78 ± 114.03

[1] ML = Muak Lek; WM = Wang Muang; PN = Phattana Nikhom; PC = Pak Chong

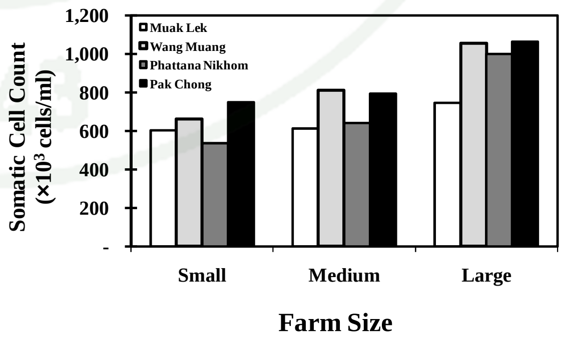
[2] Small = less than 10 milking cows per day; Medium = from 10 to 19 milking cows per day; Large = 20 or more milking cows per day

Farm location-farm size LSM for SCC ranged from 744.13 ± 65.24 × 10^3 cells/ml in Muak Lek to 1,062.78 ± 114.03 × 10^3 cells/ml in Pak Chong for large farms, from 610.60 ± 25.06 × 10^3 cells/ml in Muak Lek to 809.30 ± 62.27 × 10^3 cells/ml in Wang Muang for medium farms and from 536.45 ± 48.50 × 10^3 cells/ml in Phattana Nikhom to 748.71 ± 40.11 × 10^3 cells/ml in Pak Chong for small farms. These results were similar to those reported by Rhone *et al.* (2008a) and Seangjun and Koonawootrittriron (2007). Several researchers (Hansen *et al.*, 2002; Othmane *et al.*, 2002; Koivula *et al.*, 2005) have indicated positive associations between SCC, mastitis and low quality of management. Thus, the high SCC found here is likely be related to low hygienic level in farms (Surawong *et al.*, 2004; Ajariyakhajorn *et al.*, 2005; Kivaria *et al.*, 2006).

Large farms in all locations tended to have higher SCC than smaller size farms (Table 14; Figure 8b). This may be related to lack of training of employees on large farms. Owners of small and medium farms may be more directly involved in their dairies, thus providing a higher quality of management than personnel on large farms. Thus, in order to reduce SCC to acceptable levels (DLD, 2003; ACFS, 2010), large farms would need to increase the level of training of dairy personnel and to improve the management and sanitary conditions of dairy cows.



(a)



(b)

Figure 8 Least squares means for fat percentage (a) and somatic cell count (b) by farm location-farm size subclasses

3. Individual farm effects

Variation among individual farms and ratios of farm variances to total variances are shown in Table 15. These ratios indicated that variation associated with differences among individual farms explained from 25% to 52% of the total variation for these traits. Variability among farms could be due to differences in educational background, experience, training, social networks and economic resources of farmers as indicated by Rojanasthien *et al.* (2006) and Rhone *et al.* (2008b). Thus, to improve monthly milk yield and revenue per farm, increasing the level of training, dairying ability and commercial opportunities for farmers should be considered together with improvements in feeding, management, health care and genetics of dairy cattle.

Table 15 Farm variances and ratio of farm variances to total variances for monthly milk yields, milk revenues, and milk quality (with model not included farmers' information)

Traits	Farm variances	Ratio of farm variances to total variances
Milk yield per farm (kg^2)	1,497,076 ± 70,996[1]	0.52
Milk yield per cow (kg^2)	8,058 ± 421	0.30
Milk revenue per farm ($baht^2$)	202,410,000 ± 9,592,411	0.52
Milk revenue per cow ($baht^2$)	1,082,181 ± 56,551	0.30
Fat ($\%^2$)	0.0497 ± 0.00250	0.25
Protein ($\%^2$)	0.0128 ± 0.00063	0.25
Lactose ($\%^2$)	0.0109 ± 0.00054	0.25
Solids not fat ($\%^2$)	0.0281 ± 0.00134	0.29
Total solids ($\%^2$)	0.0976 ± 0.00484	0.26
Somatic cell count ($\times 10^6$ $cells^2/ml^2$)	120,054 ± 6,048	0.26

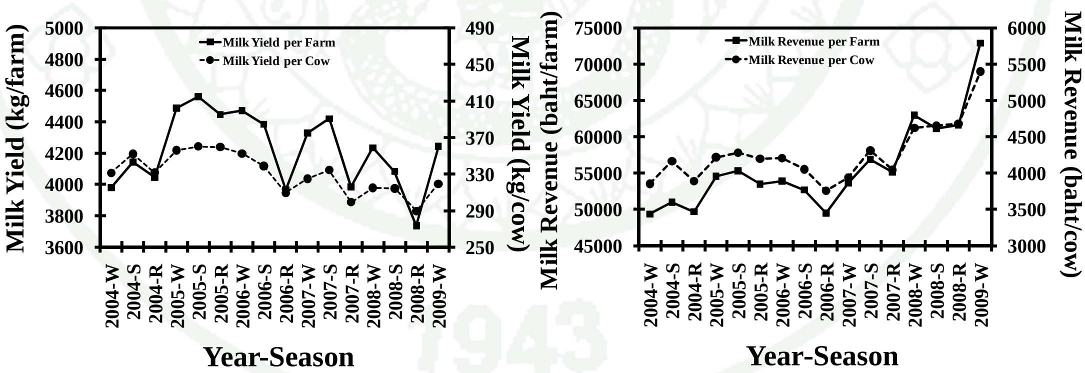
[1] Standard error

Trial 2

Effect of experience, education, record keeping, labor and decision making on monthly milk yield and revenue of dairy farms supported by a private organization in Central Thailand

1. Year-season subclasses

Monthly milk production per farm and per cow (Figure 9a) and revenue per farm and per cow (Figure 9b) varied across year-season subclasses. Year-season LSM ranged from 3,737.67 ± 191.39 kg (2008-Rainy) to 4,561.86 ± 190.90 kg (2005-Summer) for MYF, 289.56 ± 9.59 kg (2008-Rainy) to 360.34 ± 9.55 kg (2005-Summer) for MYC, 49,374.00 ± 2,480.48 baht (2004-Winter) to 72,930.00 ± 2,436.00 baht (2008-Winter) for MRF, and 3,759.90 ± 135.97 baht (2006-Rainy) to 5,399.72 ± 141.98 baht (2008-Winter) for MRC.



(a) (b)

Figure 9 Trends for year-season least squares means for monthly milk yield per farm and milk yield per cow (a) and milk revenue per farm and milk revenue per cow (b) from 2004 to 2008

Monthly milk productions tended to decrease per farm (MYF = -12.09 ± 12.95 kg/year-season; P = 0.3664) and per cow (MYC = -3.27 ± 0.86 kg/year-season; P = 0.0020) from 2004 to 2008. Contrarily, monthly milk revenues tended to increase by farm (MRF = 1,037.89 ± 209.80 baht/year-season; P = 0.0002) and by cow (MRC = 58.46 ± 16.94 baht/year-season; P = 0.0039) during this period.

Decreasing trends for monthly milk productions (MYF and MYC) and increasing trends for monthly milk revenues (MRF and MRC) may have been associated with the current economic situation in Thailand (Yeamkong *et al.*, 2010b). Farm milk revenues decreased during the period of the study. Dairy production costs increased by 58.4% (from 8.51 baht/kg in 2004 to 13.48 baht/kg in 2008), but the price of raw milk increased by only 44.0% (from 12.50 in 2004 to 18.00 baht/kg in 2008; OAE, 2009). Price of raw milk remained steady at 12.50 baht/kg from January 2004 to March 2007 (39 months). It subsequently increased to 13.75 baht/kg for 4 months (April through August 2007), and to 14.50 baht/kg for 10 months (September 2007 to June 2008), and finally rose to 18.00 baht/kg in July 2008. It remained at this price until the end of the study (6 months). Differences in rates of increase of milk production costs and price of raw milk may have forced farmers to reduce the quality and quantity of nutrition, management, and health care of their cows, which in turn may have negatively affected their productive ability resulting in lower MYF and MYC.

2. Farm location-farm size subclasses

Monthly milk production per farm (MYF) and per cow (MYC) and revenue per farm (MRF) and per cow (MRC) varied across farm location-farm size subclasses (P < 0.0001). The LSM for MYF ranged from 2,582.32 ± 294.32 kg (Phatthana Nikhom) to 3,094.68 ± 193.91 kg (Muak Lek) for small farms, from 3,882.84 ± 296.50 kg (Phatthana Nikhom) to 4,254.41 ± 309.69 kg (Pak Chong) for medium farms, and from 5,005.63 ± 198.46 kg (Muak Lek) to 7,060.29 ± 324.46 kg (Pak Chong) for large farms (Table 16). The LSM for MYC ranged from 373.69 ± 14.27 kg (Phatthana Nikhom) to 391.447 ± 14.84 kg (Pak Chong) for small farms, 319.99 ± 14.48 kg (Phatthana Nikhom) to 335.41 ± 15.09 kg (Pak Chong) for medium farms, and 259.88 ± 10.02 kg (Muak Lek) to 308.94 ± 16.77 kg (Pak Chong) for large farms

Table 16 Least squares means and standard errors for milk yield per farm, milk yield per cow, milk revenue per farm, and milk revenue per cow by farm location-farm size subclasses

Farm location[1]	Farm size[2]	Milk yield per farm (kg)	Milk yield per cow (kg)	Milk revenue per farm (baht)	Milk revenue per cow (baht)
ML	Small	3,094.68 ± 193.91	390.10 ± 9.47	40,235.00 ± 2,426.31	5,177.79 ± 135.18
	Medium	3,978.63 ± 194.29	322.60 ± 9.51	51,874.00 ± 2,431.60	4,128.97 ± 135.86
	Large	5,005.63 ± 198.46	259.88 ± 10.02	67,757.00 ± 2,489.85	3,127.19 ± 143.27
WM	Small	2,889.76 ± 272.72	384.95 ± 13.28	38,008.00 ± 3,411.11	5,075.63 ± 189.38
	Medium	3,896.47 ± 273.65	322.49 ± 13.36	49,939.00 ± 3,424.03	4,122.28 ± 190.73
	Large	5,515.59 ± 296.32	285.56 ± 16.02	73,418.00 ± 3,739.38	3,384.77 ± 228.81
PN	Small	2,582.32 ± 294.32	373.69 ± 14.27	34,147.00 ± 3,678.81	5,079.04 ± 202.58
	Medium	3,882.84 ± 296.50	319.99 ± 14.48	50,592.00 ± 3,709.34	4,151.88 ± 206.31
	Large	5,772.56 ± 313.48	271.30 ± 16.46	78,142.00 ± 3,946.62	3,629.07 ± 236.12
PC	Small	2,706.63 ± 307.59	391.47 ± 14.84	35,641.00 ± 3,845.30	5,011.64 ± 211.78
	Medium	4,254.41 ± 309.69	335.41 ± 15.09	55,817.00 ± 3,874.99	4,283.52 ± 215.63
	PLarge	7,060.29 ± 324.46	308.94 ± 16.77	94,913.00 ± 4,080.89	4,040.71 ± 240.97

[1] ML = Muak Lek; WM = Wang Muang; PN = Phatthana Nikhom; PC = Pak Chong

[2] Small = less than 10 milking cows per day; Medium = from 10 to 19 milking cows per day; Large = 20 or more milking cows per day

The pattern of farm location-farm size LSM for MRF across locations was similar to MRC, except for small farms. The LSM for MRF ranged from 34,147.00 ± 3,678.81 baht (Phatthana Nikhom) to 40,235.00 ± 2,426.31 baht (Muak Lek) for small farms, from 49,939.00 ± 3,424.03 baht (Wang Muang) to 55,817.00 ± 3,874.99 baht (Pak Chong) for medium farms, and from 67,757.00 ± 2,489.85 baht (Muak Lek) to 94,913.00 ± 4,080.89 baht (Pak Chong) for large farms (Table 16). The LSM for MRC ranged from 5,011.64 ± 211.78 baht (Pak Chong) to 5,177.79 ± 135.18 baht (Muak Lek) for small farms, from 4,122.28 ± 190.73 baht (Wang Muang) to 4,283.52 ± 215.63 baht (Pak Chong) for medium farms, and from 3,127.19 ± 143.27 baht (Muak Lek) to 4,040.71 ± 240.97 baht (Pak Chong) for large farms (Table 16).

Large farms had higher MYF and MRF, but lower MYC and MRC than medium and small farms in all locations. These trends for MYF an MRF were related to number of milking cows. Large farms had larger number of milking cows that produced more milk and received higher revenues than smaller farms. In contrast, trends for MYC an MRC were associated with ability to produce milk of individual cows as well as quality of management, nutrition, and health care in a particular farm. Owners of large farms may not have been able to provide the same level of care and supervision per individual cow as owners of smaller farms (Kivaria *et al.*, 2006; Seangjun and Koonawootrittriron, 2007; Rhone *et al.*, 2008b). Owners of large farms had to hire employees who may have had insufficient knowledge and ability to perform dairy tasks, resulting in lower levels of milk production per cow. Thus, it appears that large size farms may need to improve their management practices and the training and quality control of their labor force.

3. Experience subclasses

Experience of farmers was important for all traits ($P < 0.0001$). MYF, MRF, MYC, and MRC increased with level of experience from category 1 (0 yr) to category 7 (> 20 yr). LSM increased from 2,670.66 ± 245.08 kg to 5,107.89 ± 208.77 kg ($P < 0.0001$; Figure 10a) for MYF, from 269.08 ± 15.40 kg to 365.79 ± 11.20 kg ($P < 0.0001$; Figure 10b) for MYC, from 37,575.00 ± 3,134.21 baht to 68,503.00 ± 2,637.19 baht for MRF ($P < 0.0001$; Figure 10c) and from 3,405.34 ± 220.82 baht to 4,724.15 ± 160.75 baht for MRC ($P < 0.0001$; Figure 10d).

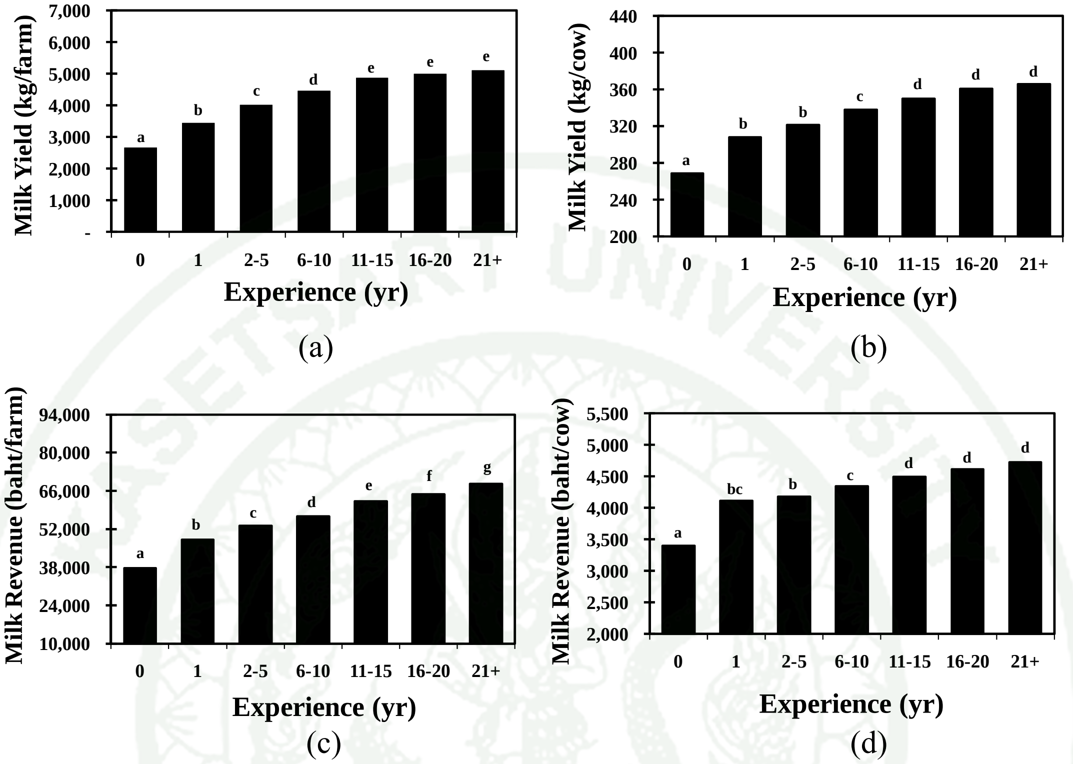


Figure 10 Least squares means for monthly milk yield per farm (a), milk yield per cow (b), milk revenue per farm (c), and milk revenue per cow (d) by level of experience of farmers. Different letters above bars indicate significant differences ($P < 0.0001$ to $P < 0.0402$)

These results suggested that farmers with more years of experience likely had a better understanding and know how to appropriately manage their dairy herds under tough climatic and economic conditions than less experienced farmers. More experienced farmers fed and managed their herds better, produced more milk, and received higher revenues than less experienced farmers. More experienced farmers were able to provide cows with better management (e.g., cleaner stables, better water access, and more comfortable milking practices), better nutrition (e.g., cheaper food alternatives of high nutritional value in difficult economic times such as corn silage, grass silage, brewer grain, dry leucaena leaf, and cassava leaves), and better health care because of their higher knowledge of how to treat common diseases (e.g., tick fever, mastitis, acidosis, laminitis) without calling veterinarians, thus keeping costs low. These results were in agreement with studies that reported a positive association between farmers' experience and accumulated 305-d milk production (Jindatajak *et al.*, 2004) and yearly milk production (Boonyanuwat *et al.*, 1995) of individual animals raised under Thai tropical conditions.

4. Education subclasses

Monthly milk production and revenue per farm and per cow increased with the level of formal education of the farmer. However, LSM differences were significant only for milk production and revenue per cow, but not for monthly milk production and revenue per farm. Farmers with no education or primary school had significantly lower LSM values than those from farmers that had bachelor or higher degrees for MYC (314.00 ± 9.43 kg vs. 347.21 ± 13.65 kg; P = 0.0102; Figure 11b) and MRC (4,028.65 ± 134.69 baht to 4,531.78 ± 193.97 baht; P = 0.008; Figure 11d), whereas non-significant differences existed for MYF (4,031.21 ± 192.47 kg vs. 4,508.74 ± 285.48 kg; P = 0.1939; Figure 11a) and MRF (53,738.00 ± 2,408.94 baht vs. 59,175.00 ± 3,565.30 baht; P = 0.2554; Figure 11c). Farmers that had bachelor or higher degree had higher MYF (11.9%), MYC (10.6%), MRF (10.1%), and MRC (12.5%) than farmers with no education or primary school. Similarly, farmers that had high school education had higher MYF (2.2%), MYC (5.2%), MRF (1.8%), and MRC (5.3%) than farmers with no education or primary school.

Formal educational level of farmers may be an indicator of their ability to adopt appropriate technologies and management practices (Borisutsawat, 1996; Kanchanasinith, 1999; Cicek *et al.*, 2007). Farmers that had a higher formal educational level may have had superior ability to access and understand information and technology, and may have been able to apply them more appropriately to their conditions than farmers with lower formal education. It appears that better educated farmers may have been able to more accurately identify and keep larger number of high production cows, thus their farms produced more milk and they earned higher revenues than lesser educated farmers.

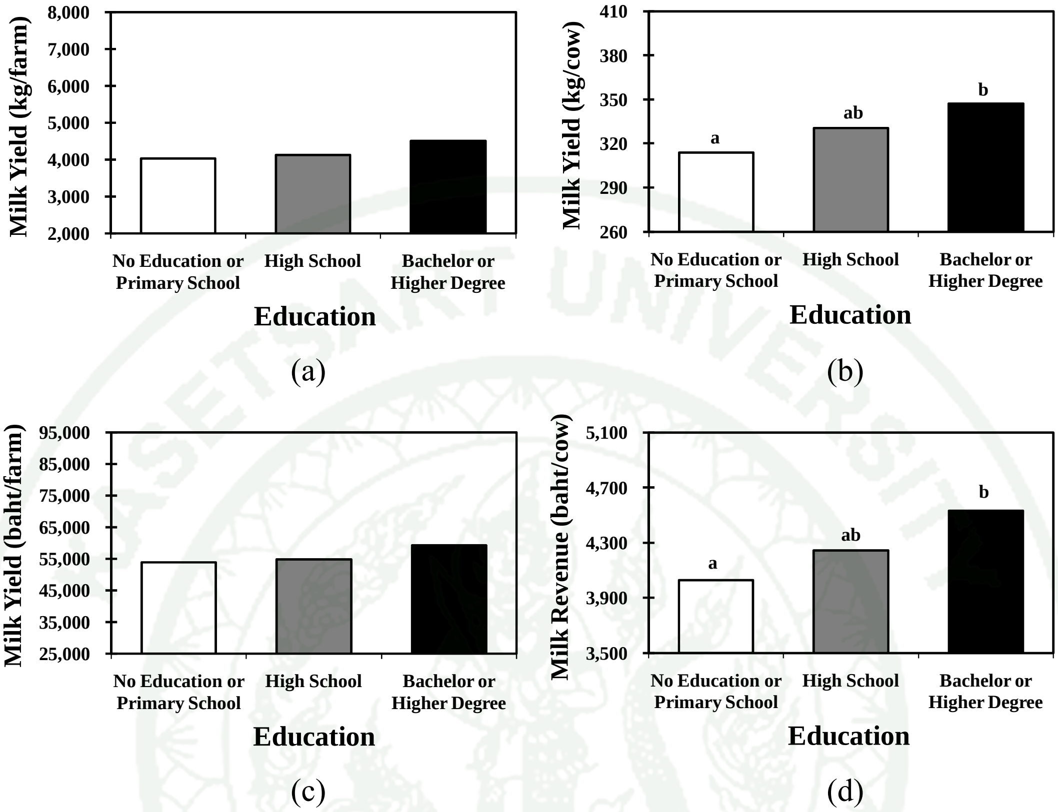


Figure 11 Least squares means for monthly milk yield per farm (a), milk yield per cow (b), milk revenue per farm (c), and milk revenue per cow (d) by level of formal education of farmers. Different letters above bars indicate significant differences ($P < 0.0126$ to $P < 0.0219$)

Most dairy farmers in this study (65%) had no education or primary school, 25% had high school level, and 10% had bachelor or higher degree level. The large number of Thai dairy farmers that had no education or primary school found here was close to the fraction reported in the literature (Uthaiwan, 1992; Borisutsawat, 1996; Thijae, 1999; Rhone *et al.*, 2008a). The large number of farmers in this group may present a challenge when promoting new technologies or disseminating knowledge for improving dairy production and profitability (Borisutsawat, 1996; Thijae, 1999). To overcome these limitations, farmers would need to receive systematic training and continuous support from dairy cooperatives, government organizations, and private organizations involved in dairy production in Thailand.

5. Record keeping subclasses

Record keeping had a significant effect on milk production per farm (P = 0.0457) and revenue per farm (P = 0.0337), but not on milk production per cow (P = 0.0607) and revenue per cow (P = 0.0601). Farms that kept records had LSM of 4,408.70 ± 230.95 kg for MYF (Figure 12a), 338.80 ± 11.15 kg for MYC (Figure 12b), 58,375.00 ± 2,886.98 baht for MRF (Figure 12c), and 4,385.60 ± 158.88 baht for MRC (Figure 12d). Farms that had no records had LSM of 4,031.26 ± 188.28 kg for MYF, 322.26 ± 9.20 kg for MYC, 53,373.00 ± 2,356.01 baht for MRF, and 4,149.82 ± 131.40 baht for MRC. Farms that kept records had higher LSM for MYF (377.44 kg or 9%: P < 0.05), MYC (16.54 baht or 5%; P > 0.05), MRF (5,002.00 baht or 9%; P < 0.05), and MRC (235.78 baht or 6%; P > 0.05) than those that did not keep records.

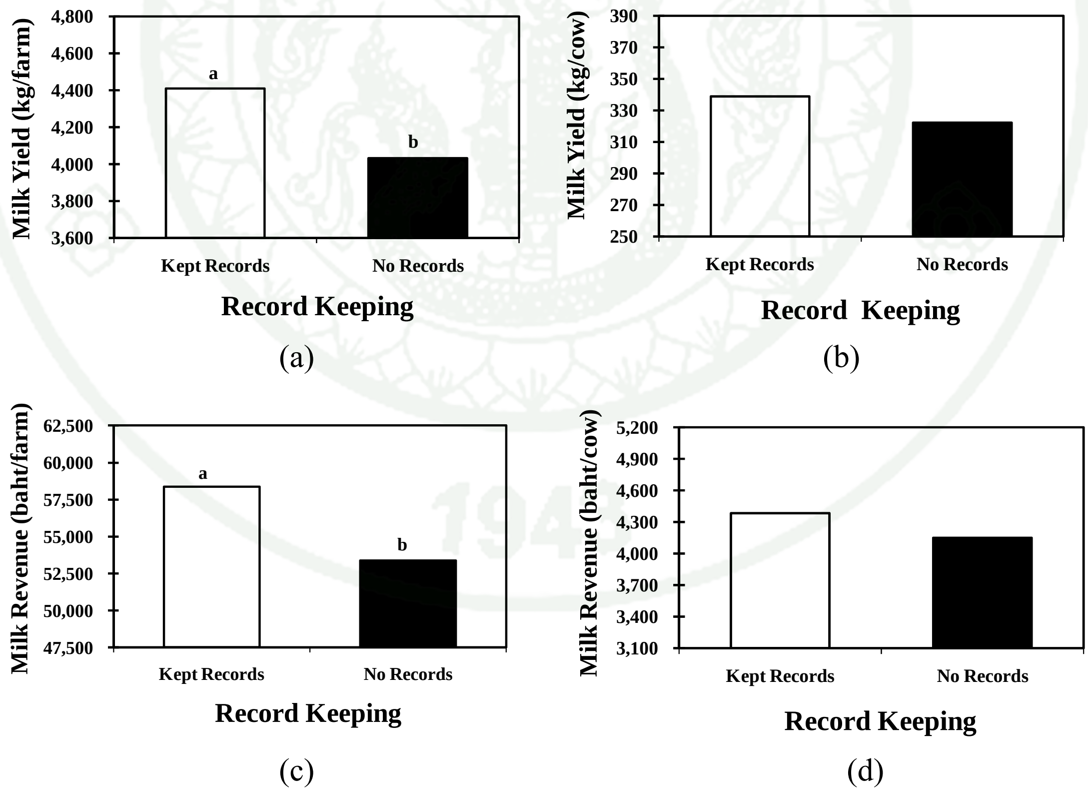


Figure 12 Least squares means for monthly milk yield per farm (a), milk yield per cow (b), milk revenue per farm (c), and milk revenue per cow (d) by record keeping category. Different letters above bars indicate significant differences (P < 0.0337 to P < 0.0457)

Higher LSM for milk production per farm and per cow found here were in agreement with results reported in the literature for dairy production in Thailand (Borisutsuwat, 1996; Suphalux, 2001; Rhone *et al.*, 2008c) and in other countries (Tomaszewski, 1993; Losinger and Heinrichs, 1996). Farms that kept records likely used them for monitoring, planning, culling and selection decisions, and improving management efficiency. Seventy eight percent of all farms did not keep records in this population. This finding was similar to previous reports (Kanchanasinith, 1999; Wittayagone, 1999; Rhone *et al.*, 2008a). However, results here suggest that record keeping needs to be promoted as a way to improve the accuracy of decisions made by dairy farmers because it could lead to increases in both milk production and revenue (Tomaszewski, 1993; Losinger and Heinrichs, 1996). Encouraging record keeping should be an integral part of a systematic training and continuous support dairy program in Thailand. Active involvement of dairy related organizations (Department of Livestock Development, Dairy Farming Promotion Organization, Dairy Cooperatives, and private milk collecting companies) to explain the benefits and encourage Thai farmers to keep records would likely greatly enhance its rate of adoption.

6. Labor subclasses

Type of labor was important for all traits (MYF, $P < 0.0001$; MYC, $P = 0.0001$; MRF, $P < 0.0001$; MRC, $P = 0.0001$). Farms that employed their own family had LSM of 4,147.44 ± 184.91 kg for MYF (Figure 13a), 329.67 ± 8.82 kg for MYC (Figure 13b), 54,460.00 ± 2,309.35 baht for MRF (Figure 13c), and 4,231.87 ± 125.60 baht for MRC (Figure 13d). Farms that hired people had LSM of 4,608.14 ± 215.14 kg for MYF, 344.43 ± 12.09 kg for MYC, 62,028.00 ± 2,726.20 baht for MRF, and 4,499.37 ± 174.26 baht for MRC. Farms that employed their own family and also hired people had LSM of 3,904.37 ± 187.45 kg for MYF, 317.48 ± 9.14 kg for MYC, 51,132.00 ± 2,344.67 baht for MRF, and 4,071.88 ± 130.19 baht for MRC.

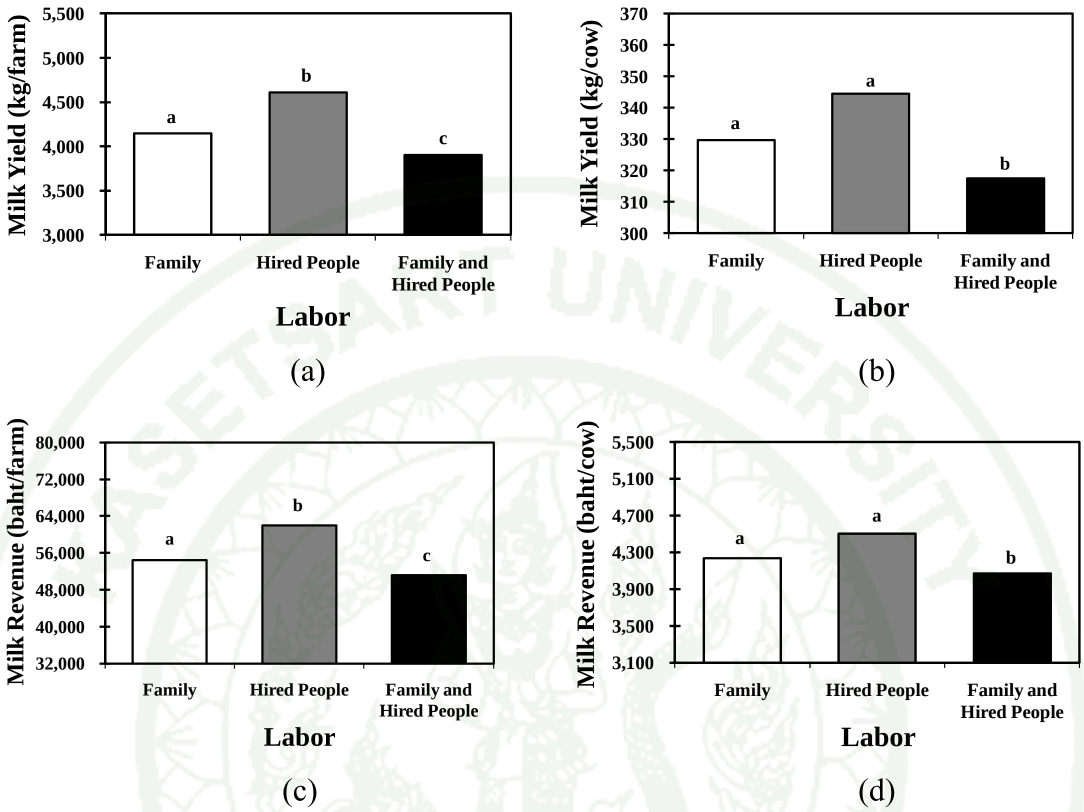


Figure 13 Least squares means for monthly milk yield per farm (a), milk yield per cow (b), milk revenue per farm (c), and milk revenue per cow (d) by type of labor. Different letters above bars indicate significant differences ($P < 0.001$ to $P < 0.006$)

Although farms that hired people had higher LSM than farms that used their own family for all traits, differences were significant only for MYF and MRF ($P < 0.0001$). On the other hand, farms that hired people had significantly higher LSM than farms that used both family members and hired labor for all traits ($P < 0.0001$). Similarly, farms that used only family labor had higher LSM than farms that used family members and hired labor for all traits ($P < 0.0001$). Differences in LSM among these three types of farms may be related to work efficiency, which may have been associated with differences in skill and level of specialization, type of facilities, ability and experience of individual workers, use of standardized work routines, and management ability (Bewley *et al.*, 2001; Ngongoni *et al.*, 2006). It is also possible that owners of farms that used hired workers had more available time to control the quality of work, and also devoted more time to find new information and technology, good-quality feed, and semen from good sires than owners of farms in the other two labor categories. Lastly, a better integrated and more efficient working environment with fewer problems may have helped farms that employed only family members to produce more milk than those that used both family members and hired workers.

Most farms in this population used family members only (85%), followed by farms that used both family and hired people (10%), and farms that used hired people only (5%). This distribution was similar to that reported by Borisutsuwat (1996), Garcia *et al.* (2005), and Rhone *et al.* (2008a, 2008c). Farms that used only family members as employees may not be able to increase their number of milking cows. Thus, to increase milk production and profitability, these farms may have to adopt new technologies that increase their efficiency and level of milk production. To achieve this goal, these farmers would need systematic training and access to supporting technologies (equipment, machinery, tools, and software) on dairy technology, nutrition, management, selection and mating practices, and data recording.

7. Decision making on sire selection subclasses

Decision making on sire selection was not important for any trait (MYF, P = 0.8632; MYC, P = 0.7145; MRF, P = 0.8727; MRC, P = 0.7941). Thus, the pattern of differences among farmers who selected sires by themselves, with help from government officials, and with help from staff of the supporting organization was similar for all traits. Farmers that selected sires by themselves had LSM of 4,274.80 ± 145.51 kg for MYF (Figure 14a), 330.23 ± 7.33 kg for MYC (Figure 14b), 56,053.00 ± 1,824.64 baht for MRF (Figure 14c), and 4,295.41 ± 104.59 baht for MRC (Figure 14d). Farmers that selected sires with help from government officials had LSM of 4,069.02 ± 415.99 kg for MYF, 323.63 ± 19.56 kg for MYC, 54,420.00 ± 5,190.93 baht for MRF, and 4,152.95 ± 278.72 baht for MRC. Farmers that selected sires with help from staff of the supporting organization had LSM of 4,316.14 ±

237.94 kg for MYF, 337.73 ± 11.45 kg for MYC, 57,148.00 ± 2,973.79 baht for MRF, and 4,354.76 ± 163.24 baht for MRC. The highest LSM for all traits was that of farmers that selected sires with help from staff of the supporting organization, followed by farmers that made decisions by themselves and lastly farmers that made decisions with help from government officials.

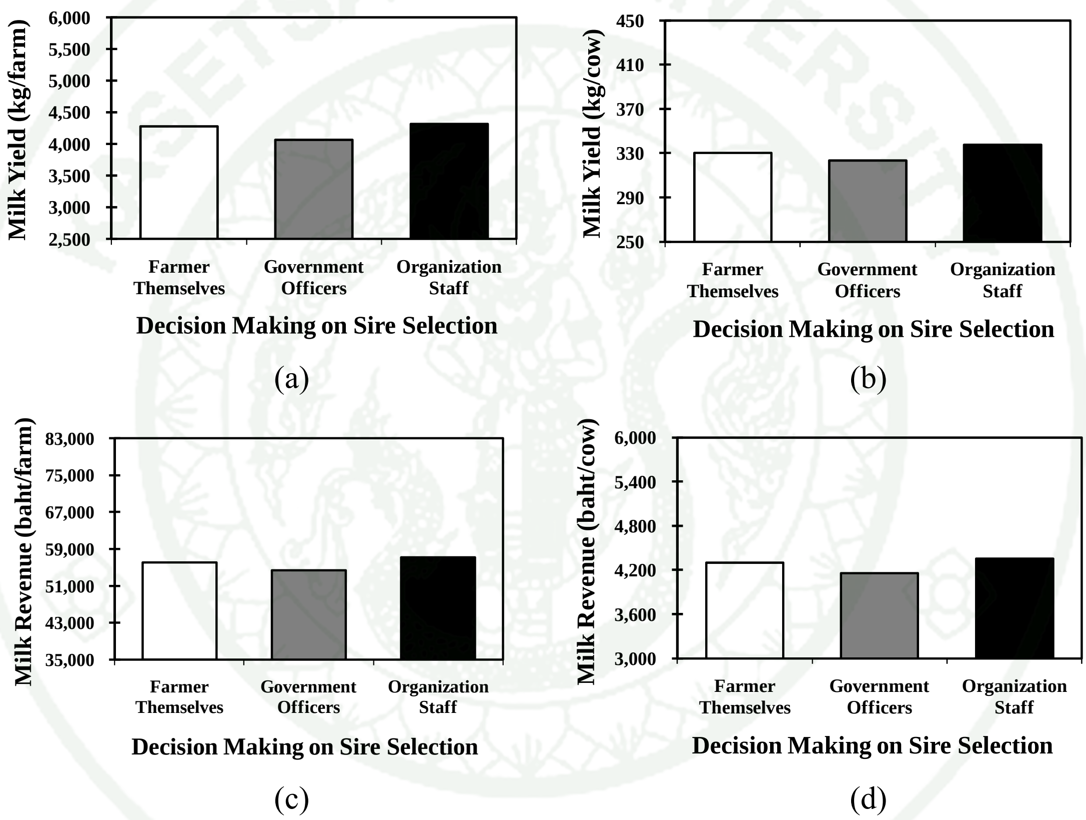


Figure 14 Least squares means for monthly milk yield per farm (a), milk yield per cow (b), milk revenue per farm (c), and milk revenue per cow (d) by category of decision making on sire selection. No significant differences existed among decision making categories (P > 0.05)

Although differences among categories of decision making for sire selection were non-significant, it may be worthwhile to suggest a possible explanation for differences among LSM. Differences in LSM among the three decision making categories could be due to accuracy of decisions. The private organization hired people to provide services (artificial insemination, health care, and farm monitoring) and support their members. Support personnel had frequent visits to each individual farm and also gathered information. Thus, sire selection decisions made by farmers supported by staff of the supporting organization appeared to have been more accurate than decisions made by farmers in the other two categories. In contrast, government officials provided various services (disease control, extension, and artificial insemination services) to all dairy farmers in a region, regardless of their membership in any organization. Thus, government officials may not have enough specific information from individual farmers (pedigree, production traits, and reproduction traits of the individual animals) or, as indicated by Srinoy *et al.* (1999), they may not have provided a particular service. Consequently, government officials may frequently not be able to give accurate suggestions to solve specific problems in individual farms.

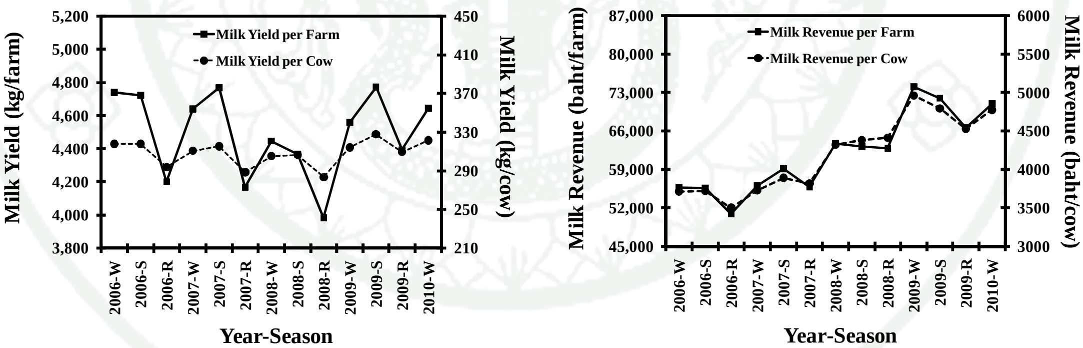
Farmers that made decisions on sire selection by themselves constituted 82% of all farmers in this population. They had higher LSM for all traits than farmers that made decisions with help from government officials, but lower LSM than farmers that made decisions with help from staff of the supporting organization. A program of training and support on how to choose the most suitable bulls for their farms that targets farmers that make decisions by themselves seems advisable to improve accuracy of sire selection in the largest group of farmers in Thailand. This program would need to provide these farmers with accurate genetic predictions for individual bulls (estimated breeding values, and assisted markers) for appropriate sire selection (Rhone *et al.*, 2008a; 2008c; Koonawootrittriron *et al.*, 2009).

Trial 3

A comparative study on dairy production and revenue of the dairy farms supported by a private organization with those supported by a dairy cooperative in Central Thailand

1. Year-season subclasses

Year-season subclasses were important for milk yields (MYF and MYC; P < 0.0001) and revenues (MRF and MRC; P < 0.0001). Year-season LSM ranged from 3,983.35 ± 94.64 kg (2008-Rainy) to 4,772.36 ± 94.94 kg (2009-Summer) for MYF (Figure 15a), 283.46 ± 3.65 kg (2008-Rainy) to 327.81 ± 3.68 kg (2009-Summer) for MYC (Figure 16a), 50,891.00 ± 1,295.34 baht (2006-Rainy) to 74,058.00 ± 1,293.73 baht (2009-Winter) for MRF (Figure 16b), 3,500.78 ± 52.36 baht (2006-Rainy) to 4,958.20 ± 52.39 baht (2009-Winter) for MRC (Figure 15b).



(a) (b)

Figure 15 Trends for year-season least squares means for milk yield per farm and milk yield per cow (a) and milk revenue per farm and milk revenue per cow (b) from 2004 to 2009

The regression coefficient estimate was -8.47 ± 19.76 kg/year-season for MYF (P = 0.6763), 0.45 ± 1.00 kg/year-season for MYC (P = 0.6641), 1,646.74 ± 268.03 baht/year-season for MRF (P < 0.0001), and 114.53 ± 15.58 baht/year-season for MRC (P < 0.0001). Trends for MYF and MYC had not significant with high standard errors. The difference between LSM in 2006-winter and 2010-winter was -96.2 kg for MYF and 3.72 kg for MYC. Considering variation of MYF and MYC across year-season subclasses (Figure 1), MYF and MYC had similar pattern (r = 0.95). They had the lowest values in rainy season and the highest values in winter or summer season of each year. These patterns of milk production were consistent to the study of Koonawootrittriron *et al.* (2001), Kaewkamchan (2003), and Rhone *et al.* (2008b). They could be related to the proportion of milking cows and lactation period in the herd, which was high in winter or summer but low in rainy season, in this dairy population.

Considering the variation of MRF and MRC across year-season subclasses, the tendency of milk revenues increased. From 2006 to 2009, the price for raw milk increased dramatically from 12.50 baht/kg to 18.00 baht/kg (OAE, 2009). Thus, increase of MRF and MRC could be related with the changing of price for raw milk rather than the amount of milk ($r_{MRF.MYF} = 0.19$; $r_{MRC.MYC} = 0.30$).

2. Farm location-farm size subclasses

Farm location-farm size subclasses were important ($P < 0.01$) for milk yields (MYF, $P < 0.0001$ and MYC, $P = 0.0080$) and milk revenues (MRF, $P < 0.0001$ and MRC, $P = 0.0016$). The LSM for MYF ranged from 2,103.17 ± 188.62 kg (Pak Chong) to 2,721.17 ± 89.35 kg (Muak Lek) for small size farms, from 3,896.36 ± 241.44 kg (Wang Muang) to 4,280.29 ± 193.93 kg (Pak Chong) for medium size farms, and from 6,513.76 ± 110.17 kg (Muak Lek) to 7,653.12 ± 285.96 kg (Pak Chong) for large size farms (Figure 16a). The LSM for MYC ranged from 322.26 ± 3.40 kg (Muak Lek) to 330.48 ± 9.11 kg (Wang Muang) for small size farms, from 290.04 ± 9.30 kg (Wang Muang) to 323.91 ± 7.67 kg (Pak Chong) for medium size farms, and from 283.67 ± 11.36 kg (Wang Muang) to 303.71 ± 11.32 kg (Pak Chong) in large size farms (Figure 16b).

The LSM for MRF ranged from 27,730.00 ± 2,578.05 baht (Pak Chong) to 37,568.00 ± 1,220 baht (Muak Lek) for small size farms, from 53,280.00 ± 3,296.29 baht (Wang Muang) to 58,061.00 ± 2,654.99 baht (Pak Chong) for medium size farms, and from 88,021.00 ± 1,512.36 baht (Muak Lek) to 111,713.00 ± 3,915.41 baht (Pak Chong) in large size farms (Figure 16c). The LSM for MRC ranged from 4,403.74 ± 48.61 baht (Muak Lek) to 4,514.64 ± 129.97 baht (Wang Muang) for small size farms, from 3,908.52 ± 132.85 baht (Wang Muang) to 4,475.88 ± 109.75 baht (Pak Chong) for medium size farms, and from 3,896.16 ± 162.98 baht (Wang Muang) to 4,094.38 ± 163.55 baht (Pak Chong) in large size farms (Figure 16d).

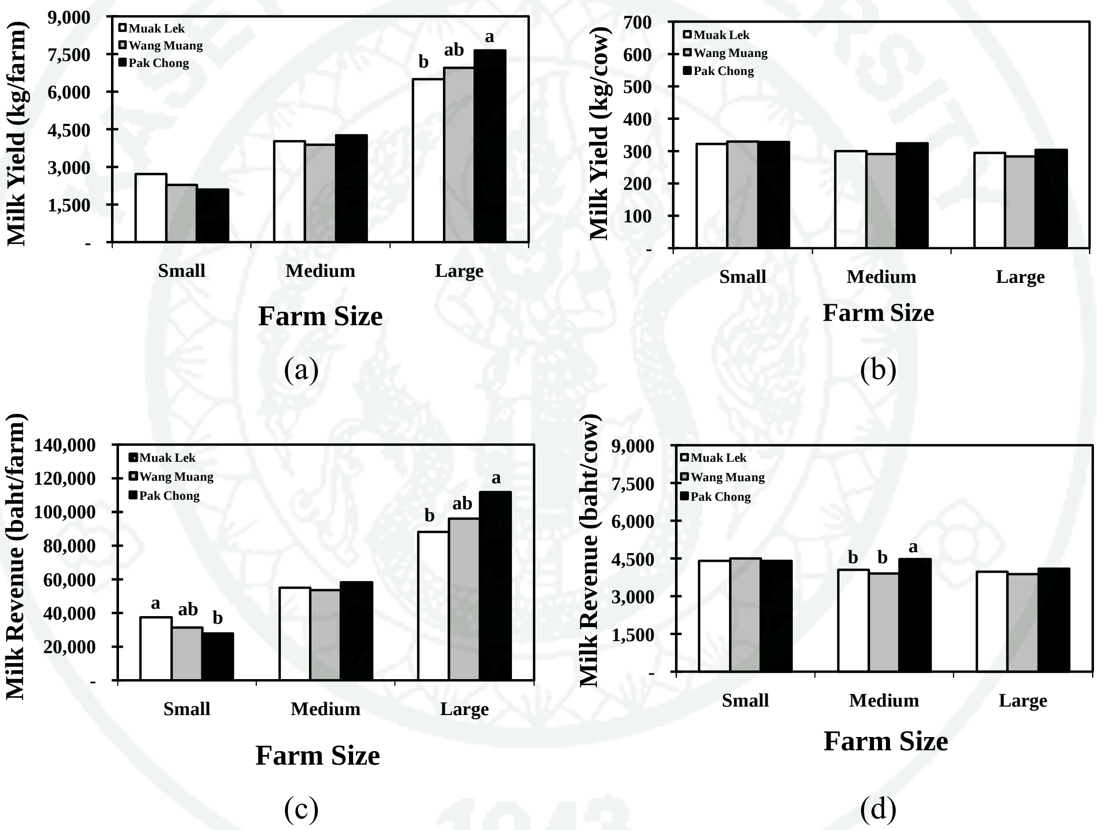


Figure 16 Least squares means for milk yield per farm (a), milk yield per cow (b), milk revenue per farm (c), and milk revenue per cow (d) by level of farm location-farm size subclasses. Different letters above bars indicate significant differences (P < 0.0001 to P < 0.9260)

Large size farms had higher MYF and MRF than smaller size farms due to the numbers of cows in each farm size. Considering farm locations of each farm size subclasses, it appears to have no specific pattern for both MYF and MRF. Considering MYC and MRC, there were no different among farm locations in each farm size except for medium size farms (Figure 16b, 16d). However, across farm location-farm size subclasses had MYC ranged from 283.67 ± 11.36 kg to 330.43 ± 9.11 kg, and MRC ranged from 3,896.16 ± 162.98 baht to 4,514.64 ± 129.97 baht.

Although large size farms had higher MYF due to number of milking cows, but there were no different MYC compared to medium size and small size farms (Figure 16a, 16b). This was not relevant to opportunity and elaboration in production process (e.g., feeding, food, and heath care). Large farms may have low opportunities in caring or manage each cow in production process due to large numbers of cows in comparison to smaller size farms. Furthermore, large farms usually take time to increase milk production during the process (Allore *et al.*, 1997; Seangjun and Koonawootrittriron, 2007; Rhone *et al.,* 2008b; Yeamkong *et al.,* 2010a, 2010b). The pattern of MRF was similar to MYF. The larger farms got more MRF than the smaller farms. This was associated with the difference in the amount of MYF produced by cows on those different farm sizes. However, a similar pattern was also found between MRC and MYC. These results revealed the ability to produce milk of the individual cows on average.

3. Organization-farm size subclasses

Organization-farm size subclasses in this study were important ($P < 0.0001$) for all traits (MYF, MRF, MYC and MRC). The LSM of farms supported by a private organization had higher MYF than those supported by a dairy cooperative for medium size (4,269.29 ± 123.07 kg *vs.* 3,863.53 ± 149.05 kg; $P = 0.2167$) and small size farms (2,748.61 ± 120.51 kg *vs.* 1,995.46 ± 147.70 kg; $P < 0.0001$). In contrast, large size farms supported by a dairy cooperative had higher ($P < 0.0001$) MYF (8,046.86 ± 186.86 kg) than those supported by a private organization (6,030.38 ± 157.43 kg; Figure 17a). However, farms supported by a private organization had MYC higher than those supported by a dairy cooperative for small (333.15 ± 4.63 kg *vs.* 320.40 ± 5.59 kg; $P = 0.6364$), medium (324.99 ± 4.79 kg *vs.* 284.65 ± 5.64 kg; $P < 0.0001$), and large size farms (304.82 ± 6.39 kg *vs.* 283.50 ± 7.18 kg; $P = 0.1349$), respectively (Figure 17b).

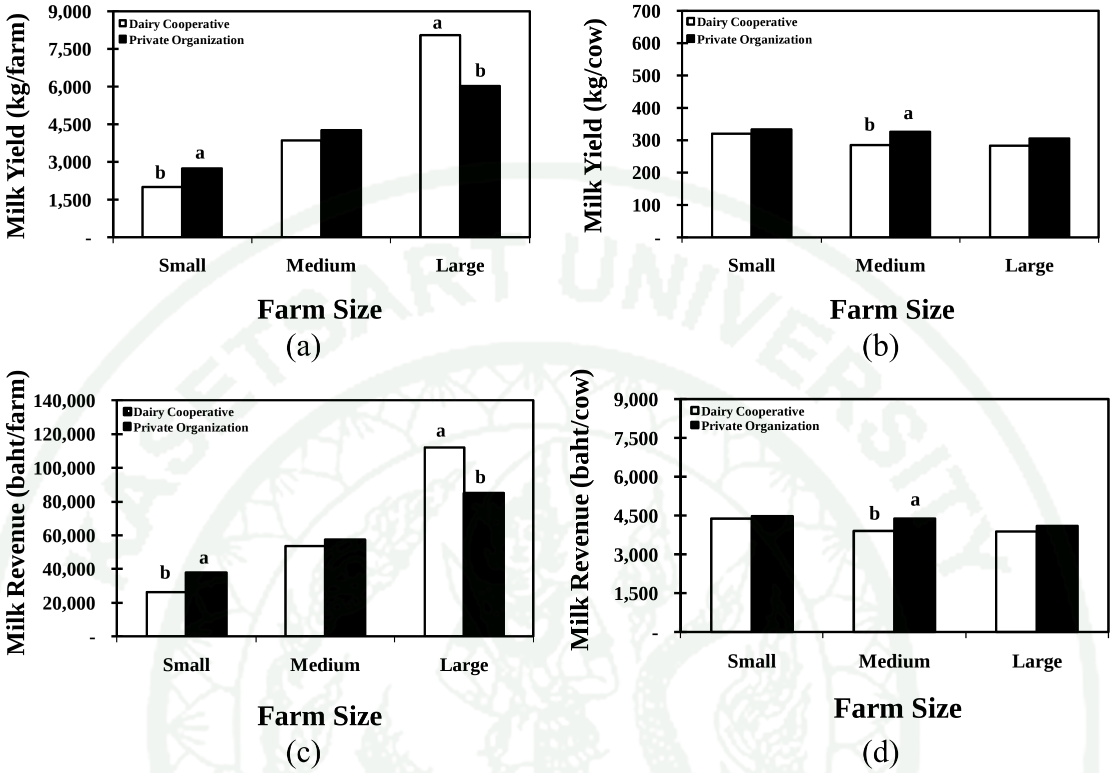


Figure 17 Least squares means for milk yield per farm (a), milk yield per cow (b), milk revenue per farm (c), and milk revenue per cow (d) by level of farm location-organization subclasses. Different letters above bars indicate significant differences (P < 0.0001 to P < 0.9841)

Pattern of milk revenues (MRF and MRC) was similar to milk yields (MYF and MYC). Farms supported by a private organization had higher MRF for small (37,888.00 ± 1,646.03 baht *vs.* 26,419.00 ± 2,013.15 baht; P < 0.0001) and medium size farms (57,353.00 ± 1,682.52 baht *vs.* 53,510.00 ± 2,031.82 baht; P = 1.0000), but lower MRF for large size farms (84,813.00 ± 2,164.63 baht *vs.* 112,239.00 ± 2,551.87 baht; P < 0.0001) than those supported by a dairy cooperative (Figure 17c). Farms supported by a private organization had a higher MRC for small (4,492.09 ± 66.15 baht *vs.* 4,396.88 ± 79.68 baht; P = 1.0000), medium (4,398.79 ± 68.50 baht *vs.* 3,901.06 ± 80.41 baht; P < 0.0001), and large size farms (4,097.25 ± 492.43 baht *vs.* 3,884.75 ± 102.47 baht; P = 1.0000) than those supported by a dairy cooperative (Figure 17d).

Farms supported by a private organization had higher MYF and MRF than those supported by a dairy cooperative for small ($P < 0.0001$) and medium ($P > 0.05$) size farms. Large size farms supported by a dairy cooperative had higher ($P < 0.0001$) MYF and MRF than those supported by a private organization. This could be due to the difference in the number of milking cows in each farm of each organization. Farms supported by a private organization in medium and small size farms had a higher number of milking cows than those supported by a dairy cooperative, except for large size farms (20 to 45 cows *vs.* 20 to 70 cows). Moreover, the proportion of farms supported by a private organization and a dairy cooperative was 44% and 39% for small size farms, 40% and 38% for medium size farms, and 16% and 32% for large size farms, respectively. Larger size and higher number of milking cows lead the farms had high milk production.

Farms supported by both organizations had similar LSM for MYC and MRC in all farm size, except for the medium size farm. This was consistent to the study of Pichet (1998) and Rhone *et al.* (2008b) who reported that farms from small size farms had higher milk production than large size farms. These results could be due to quantity and quality of farm management and nutrition. Large farms may have inadequate areas of growing food for cattle or they may have limit time in allocate crops and dairy cow food in high quality for larger number of milking cows (Chinwala and Umrod, 1988; Garcia *et al.,* 2005).

4. Individual farm effects

The variance ratio between farms and study traits was 0.60 for MYF, 0.48 for MYC, 0.59 for MRF, and 0.47 for MRC (Table 17). These estimates indicated the relationship between the variation of farms and the variation of the trait. Range of variance ratio was from 47% (MRC) to 60% (MYF) indicated that the difference among individual farms was highly related to the difference of the traits (i.e., MYF, MYC, MRF, and MRC). The difference among farms could be from the difference of the farmers themselves (e.g., experience, education background, training, decision making, and social relationship) and their resources (Rojanasthien *et al.,* 2006; Rhone *et al.,* 2008a). The difference among farms could be a cause of the difference of the organizations. Farmers who had high activity and preferred quick services and supports would be members of the private organization rather than the dairy cooperative. However, this should be confirmed with further investigation. In order to improve milk production and revenue per farm and per cow of the dairy farms, increasing knowledge, ability and opportunity of the farmers need to be considered together with finding the way to improve dairy management, feed and feeding, and genetic of the dairy cattle at farm level.

Table 17 Farm variances and ratio of farm variances to total variances for monthly milk yields and milk revenues (with model included farmers' information)

Traits	Farm variances	Ratio of farm variances to total variances
Milk yield per farm (kg^2)	3,722,571 ± 167,437[1]	0.60
Milk yield per cow (kg^2)	5,158 ± 231	0.48
Milk revenue per farm ($baht^2$)	689,820,000 ± 31,510,038	0.59
Milk revenue per cow ($baht^2$)	1,044,912 ± 46,869	0.47

[1] Standard error

CONCLUSIONS

Determination factors affecting milk quantity, quality and revenue in dairy farms supported by a private organization in this study found that year-season and farm location-farm size effects had significantly ($P < 0.01$) influenced on monthly milk yields, milk revenues and milk quality, except for protein percentage. Monthly farm values for milk yield per cow traits tended to decrease but somatic cell count tended to increase across year-seasons subclasses from 2004 to 2007. Milk yield and revenue per cow was similar across farm location-farm size subclasses. Large farms had higher somatic cell count than small and medium farms. Variation among individual farms accounted for 25% (FAT, PRO and LAC) to 52% (MYF and MRF) of the total variability for each trait. Ratios of individual farm variance to total variance for milk yields and milk revenues (30% to 52%) suggested that factors related to farmers themselves could have an effect on milk yields and milk revenues.

Assessment the effect of experience, education, record keeping, labor, and decision making on monthly milk yield and revenue of dairy farms supported by a private organization in Central Thailand showed that increasing experience would increase milk yields and revenues ($P < 0.0001$). Farm that hired people produced the highest milk yields and revenues, follow by those farms used family and then those farms used both family and hired people ($P < 0.001$). The higher educated farms produced more milk yield and revenue per cow than the lower educated farms ($P < 0.05$). Farms that kept records had higher milk yield and per farm than those farms did not ($P < 0.05$). Farms that made decisions with help from staff of the supporting organization had higher milk yields and revenues than those farms that made decisions by themselves and with help from government officials. However, most farms were small (55%) and the vast majority of farmers had primary school or no school education (65%), kept no records (78%), used their family members for dairy work (85%), and made decisions on sire selection by themselves (82%). These results implied that dairy farmers in Central Thailand need a program that includes systematic training and continuous support to improve farm milk production and revenue in a sustainable manner. Furthermore, if the structure in Central Thailand were similar to the rest of the country, then a national program of this kind would seem advisable.

Moreover, a comparative milk yield and revenue of dairy farms supported by a private organization with those supported by a dairy cooperative in Central Thailand found that milk yields and revenues varied across organization-farm size subclasses ($P < 0.01$). Farms supported by a private organization had higher milk yield and revenue per farm than those supported by a dairy cooperative for medium and small size farms, except for large size farms supported by a dairy cooperative had higher milk yield and revenue per farm than those supported by a private organization. These results showed a difference in terms of milk production and revenue of the dairy farms supported by a private organization and dairy cooperative. The causes of this difference should be additionally discussed within each and between organizations, and needs to be continuously investigated. Thus, in order to improve milk yield and revenue per farm and per cow from dairy organizations at a regional or national level should exchange their experience and strategy.

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APPENDICES

Appendix A

Analysis trial 1

Appendix Table A1 P-value of year-season and farm location-farm size subclasses for the study traits

Traits	Year-season	Farm size-farm location
Milk yield per farm (kg)	0.0001	0.0001
Milk yield per cow (kg)	0.0001	0.0083
Milk revenue per farm (baht)	0.0001	0.0001
Milk revenue per cow (baht)	0.0001	0.0076
Fat (%)	0.0001	0.0001
Protein (%)	0.0001	0.3007
Lactose (%)	0.0001	0.0006
Solid not fat (%)	0.0001	0.0186
Total solid (%)	0.0001	0.0001
Somatic cell count ($\times 10^3$ cells/ml)	0.0001	0.0001

Appendix Table A2 Variance and variance ratio between farm and residual effect of the study traits

Traits	Farm	Residual	V_f/V_e
Milk yield per farm (kg)	1,497,076	1,365,188	0.52
Milk yield per cow (kg)	8,057	19,247	0.30
Milk revenue per farm (baht)	202,410,000	190,380,000	0.52
Milk revenue per cow (baht)	1,082,181	2,591,973	0.29
Fat (%)	0.05	0.15	0.25
Protein (%)	0.01	0.03	0.28
Lactose (%)	0.01	0.03	0.26
Solid not fat (%)	0.02	0.05	0.34
Total solid (%)	0.09	0.26	0.27
Somatic cell count ($\times 10^3$ cells/ml)	120,054	335,922	0.26

Appendix Table A3 Least squares means and standard errors for milk yield per farm, milk yield per cow, milk revenue per farm, and milk revenue per cow by year-season subclasses

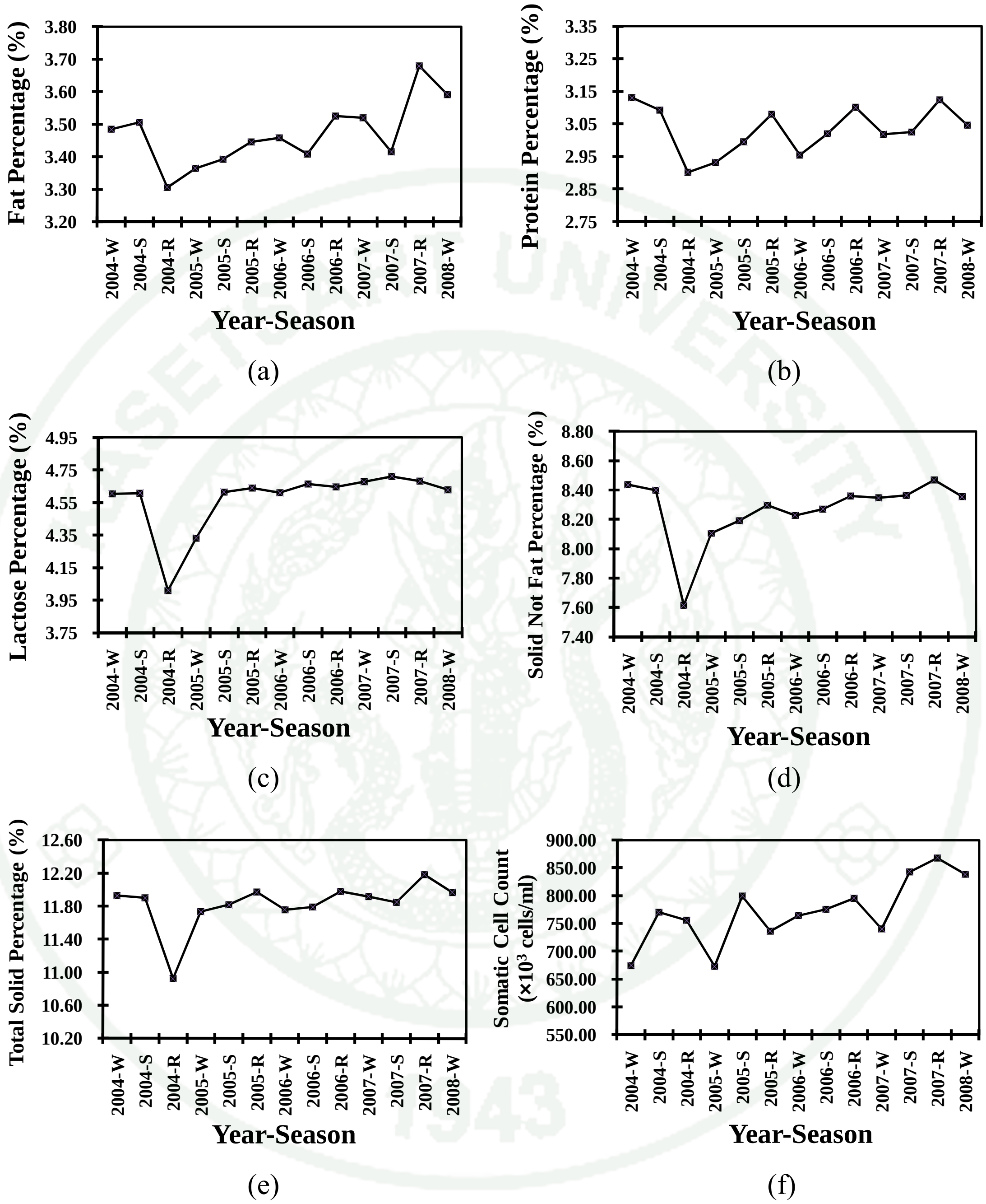
Year-Season Subclasses	Milk yield per farm (kg)	Milk yield per cow (kg)	Milk revenue per farm (baht)	Milk revenue per cow (baht)
2004 - Winter	4,391.72± 91.54	336.15 ± 7.80	50,545.00 ± 1,068.03	3,866.90 ± 90.46
2004 - Summer	4,548.95± 87.17	368.48 ± 7.06	52,192.00 ± 1,015.79	4,220.41 ± 81.89
2004 - Rainy	4,474.27± 86.95	344.77 ± 7.03	51,176.00 ± 1,013.19	3,930.22 ± 81.47
2005 - Winter	4,918.24 ± 84.78	364.01 ± 6.65	56,255.00 ± 987.18	4,156.36 ± 77.13
2005 - Summer	5,027.46± 84.67	368.57 ± 6.63	57,397.00 ± 985.86	4,194.07 ± 76.91
2005 - Rainy	4,938.77 ± 85.35	361.97 ± 6.76	55,903.00 ± 994.05	4,064.52 ± 78.35
2006 - Winter	4,810.69 ± 87.47	337.73 ± 7.13	54,459.00 ± 1,019.37	3,793.02 ± 82.63
2006 - Summer	4,697.28± 89.29	315.47 ± 7.43	53,158.00 ± 1,041.17	3,537.11 ± 86.14
2006 - Rainy	4,351.80 ± 89.51	295.07 ± 7.47	50,322.00 ± 1,043.76	3,429.92 ± 86.56
2007 - Winter	4,631.89 ± 89.94	295.58 ± 7.54	53,992.00 ± 1,048.94	3,476.99 ± 87.40
2007 - Summer	4,764.65± 90.29	317.06 ± 7.60	57,341.00 ± 1,053.15	3,911.97 ± 88.09
2007 - Rainy	4,467.4 ± 91.10	284.30 ± 7.73	56,781.00 ± 1,062.78	3,826.88 ± 89.64
2008 - Winter	4,813.39 ± 98.84	302.16 ± 8.97	65,441.00 ± 1,155.19	4,435.47 ± 104.05

Appendix Table A4 Least squares means and standard errors for milk yield per farm, milk yield per cow, milk revenue per farm, and milk revenue per cow by farm location-farm size subclasses

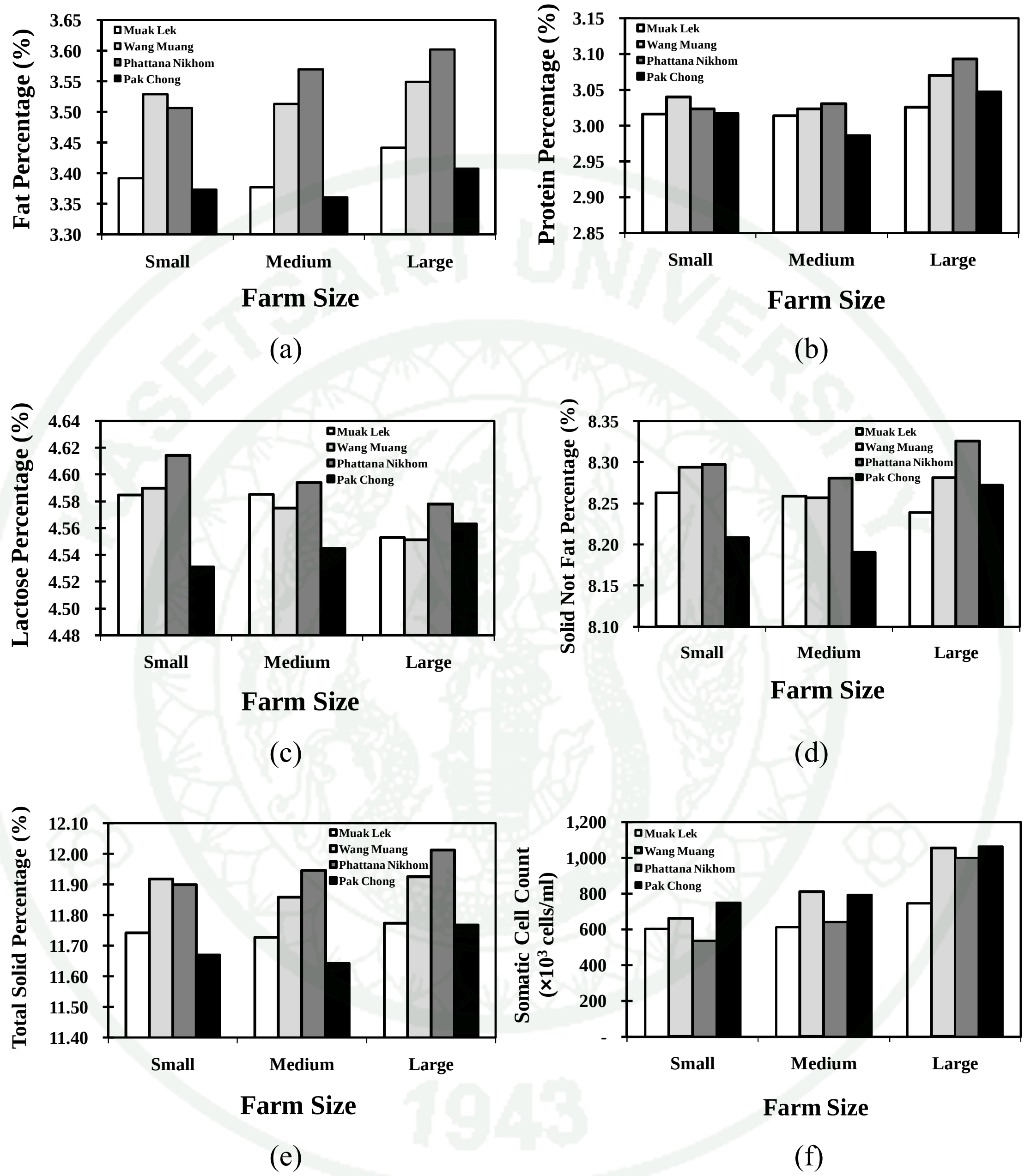
Farm size[1]	Farm location[2]	Milk yield per farm (kg)	Milk yield per cow (kg)	Milk revenue per farm (baht)	Milk revenue per cow (baht)
Small	ML	1,702.88 ± 61.89	349.14 ± 4.75	20,817.00 ± 720.30	4,143.80 ± 55.10
	WM	1,691.00 ± 129.46	341.27 ± 10.08	20,731.00 ± 1,507.33	4,024.98 ± 116.86
	PN	1,566.29 ± 187.54	336.56 ± 14.71	19,449.00 ± 2,184.06	3,996.36 ± 170.57
	PC	1,822.65 ± 135.32	352.53 ± 10.22	21,960.00 ± 1,574.34	4,179.28 ± 118.40
Medium	ML	4,568.04 ± 87.99	355.53 ± 6.67	53,802.00 ± 1,023.86	4,206.40 ± 77.32
	WM	4,598.22 ± 240.64	337.36 ± 18.54	53,672.00 ± 2,801.13	3,978.84 ± 214.90
	PN	4,111.79 ± 286.43	318.83 ± 22.11	47,987.00 ± 3,334.45	3,756.63 ± 256.30
	PC	4,759.10 ± 193.72	378.26 ± 14.52	56,338.00 ± 2,253.49	4,483.70 ± 168.27
Large	ML	8,674.82 ± 228.20	356.04 ± 17.28	100,929.00 ± 2,655.16	4,208.09 ± 200.23
	WM	8,185.23 ± 362.00	321.18 ± 27.57	94,517.00 ± 4,212.37	3,797.10 ± 319.51
	PN	6,157.10 ± 625.08	162.29 ± 47.40	72,015.00 ± 7,273.05	2,015.27 ± 549.33
	PC	8,319.66 ± 391.81	352.21 ± 29.32	97,749.00 ± 4,557.59	4,142.31 ± 339.76

[1] Small = less than 10 milking cows per day; Medium = from 10 to 19 milking cows per day; Large = 20 or more milking cows per day

[2] ML = Muaklek; WM = Wang Muang; PN = Phattana Nikhom; PC = Pak Chong



Appendix Figure A1 Trends for year-season least squares means for fat percentage (a) protein percentage (b), lactose percentage (c), solid not fat percentage (d), total solid percentage (e) and somatic cell count (f) from 2003 to 2007



Appendix Figure A2 Least squares means for fat percentage (a) protein percentage (b), lactose percentage (c), solid not fat percentage (d), total solid percentage (e) and somatic cell count (f) by farm size-farm location subclasses

```
                         Histogram                        #          Boxplot
5.9+*                                                     5             *
   .*                                                    12             *
   .*                                                    18             0
   .*                                                    26             0
   .*                                                    38             0
   .*                                                    76             0
   .**                                                  157             0
   .****                                                370             0
   .******                                              664             |
   .************                                       1329             |
   .**********************                             2422             |
   .***********************************                3841          +-----+
   .*********************************************      4990          |  +  |
   .************************************************   5291          *-----*
   .****************************************           4367          +-----+
   .*************************                          2753             |
   .*************                                      1353             |
   .******                                              596             |
   .**                                                  215             0
2.1+*                                                    89             0
    ----+----+----+----+----+----+----+----+----+---
```

```
                       Normal Probability Plot
5.9+                                                   *
   |                                                   *
   |                                                   *
   |                                                   *
   |                                                   *
   |                                                   *
   |                                                 ***
   |                                             ****++
   |                                          ****+
   |                                      *****
   |                                  *****
   |                              *****
   |                         ******
   |                     *****
   |                ******
   |           ******
   |      ******
   |  *****+
   |***+
2.1+*
    +----+----+----+----+----+----+----+----+----+----+
        -2        -1         0        +1        +2
```

Appendix Figure A3 Histogram, box plot and normal probability plot for fat

```
                      Histogram                       #             Boxplot

3.625+*******                                        386               0
     .***                                            160               0
     .*****                                          251               |
     .******                                         316               |
     .*********                                      480               |
     .************                                   632               |
     .***************                                853               |
     .********************                          1120               |
     .****************************                  1545               |
     .********************************              1787            +-----+
     .**************************************        2113            |     |
3.075+*******************************************   2406            |     |
     .************************************************ 2696         *--+--*
     .**********************************************  2571          |     |
     .********************************************  2498            |     |
     .*****************************************     2326            +-----+
     .**********************************            1887               |
     .****************************                  1541               |
     .********************                          1133               |
     .**************                                 791               |
     .*********                                      489               |
     .******                                         303               |
2.525+********                                       445               |
      ----+----+----+----+----+----+----+----+----+---

                         Normal Probability Plot

       3.625+                                                  ****
            |                                                ** ++
            |                                              ***++
            |                                             **++
            |                                           ***+
            |                                         ***+
            |                                       ***+
            |                                      **
            |                                   ****
            |                                 ***
            |                               ***
       3.075+                             ***
            |                           ***
            |                        ****
            |                      ***
            |                    ***
            |                 ****
            |               ***
            |            ****
            |          ***+
            |        ***
            |     ****
       2.525+****+
             +----+----+----+----+----+----+----+----+----+----+
                 -2        -1         0        +1        +2
```

Appendix Figure A4 Histogram, box plot and normal probability plot for protein

```
                         Histogram                    #           Boxplot

5.05+****                                              459            |
    .***********                                      1261            |
    .***************************                      3351            |
    .**********************************************   5668         +-----+
    .************************************************ 5990         *-----*
    .*********************************                4105         |  +  |
    .******************                               2154         +-----+
    .**********                                       1144            |
    .*******                                           820            |
    .********                                          972            |
    .*********                                        1079            0
    .*******                                           803            0
    .****                                              450            0
3.75+****                                              471            0
     ----+----+----+----+----+----+----+----+----+---

                                  Normal Probability Plot

5.05+                                         ++++ *****
    |                                     ++++******
    |                                  ********
    |                            *******
    |                       ******+
    |                   *****+++
    |                 ***+++
    |               ***+
    |            ++**
    |         +++***
    |     ++++****
    |  +++ ****
    |++  ***
3.75+*****
     +----+----+----+----+----+----+----+----+----+----+
         -2        -1         0        +1        +2
```

Appendix Figure A5 Histogram, box plot and normal probability plot for lactose

```
                    Histogram                          #             Boxplot
9.05+****                                             296                |
    .*****                                            359                |
    .********                                         614                |
    .***************                                 1126                |
    .***********************                         1824                |
    .***********************************             2770                |
    .*******************************************     3429             +-----+
    .************************************************ 3795            |     |
    .*********************************************   3591             *--+--*
8.15+**************************************          2994             |     |
    .****************************                    2198             +-----+
    .*******************                             1454                |
    .*************                                   1011                |
    .**********                                       780                |
    .*********                                        664                |
    .********                                         578                |
    .******                                           479                0
    .****                                             302                0
7.25+******                                           465                0
     ----+----+----+----+----+----+----+----+----+---
```

```
                           Normal Probability Plot
9.05+                                                  ++***
    |                                                +****
    |                                             +****
    |                                          +****
    |                                       +****
    |                                    ****
    |                                 ****
    |                             *****
    |                          ****+
8.15+                       ****+
    |                     ***+
    |                   ***+
    |                 ***
    |              +***
    |           +++**
    |         ++ ***
    |      +++ ***
    |++   ***
7.25+*****
     +----+----+----+----+----+----+----+----+----+----+
          -2        -1         0        +1        +2
```

Appendix Figure A6 Histogram, box plot and normal probability plot for solid not fat

```
                      Histogram                        #             Boxplot

13.9+**                                               103               0
    .*                                                 55               0
    .**                                               116               0
    .***                                              217               |
    .******                                           401               |
    .*********                                        622               |
    .***************                                 1114               |
    .***********************                         1720               |
    .********************************                2395               |
    .******************************************      3155            +-----+
    .************************************************ 3618           |     |
    .************************************************ 3639           *--+--*
    .********************************************    3298            |     |
    .***********************************             2622            +-----+
    .**************************                      1901               |
    .******************                              1353               |
    .*************                                    924               |
    .********                                         599               |
    .*****                                            376               |
10.1+*******                                          472               0
    ----+----+----+----+----+----+----+----+----+---
```

```
                        Normal Probability Plot

13.9+                                                 *
    |                                                 *
    |                                               ***
    |                                             ***+
    |                                           ***
    |                                         ****
    |                                      ****
    |                                   ****
    |                                ****
    |                             ****
    |                          ****
    |                       ****
    |                   *****
    |                ****
    |              ***
    |           ****
    |        +***
    |     +****
    |  ++***
10.1+*****
     +----+----+----+----+----+----+----+----+----+----+
          -2        -1         0        +1        +2
```

Appendix Figure A7 Histogram, box plot and normal probability plot for total solid

```
                      Histogram                         #             Boxplot

3900+***                                                293               *
    .*                                                   43               *
    .*                                                   47               *
    .*                                                   64               *
    .*                                                   94               *
    .*                                                   89               *
    .*                                                  121               *
    .**                                                 155               0
    .**                                                 199               0
    .**                                                 266               0
    .***                                                300               0
    .***                                                413               0
    .****                                               570               |
    .******                                             843               |
     .*********                                        1245               |
     .**************                                   1898            +-----+
     .*********************                            2935            |  +  |
     .*******************************                  4404            *-----*
     .************************************************ 6847            +-----+
  100+*************************************            5277               |
      ----+----+----+----+----+----+----+----+----+---
```

```
                         Normal Probability Plot

3900+                                                ***
    |                                               **
    |                                               *
    |                                              **
    |                                             **
    |                                             *
    |                                            **
    |                                           **
    |                                          **    +++
    |                                         **  +++
    |                                        **+++
    |                                       **+
    |                                    ++**
    |                                  ++***
    |                               +++***
    |                            +++ ***
    |                         +++*****
    |                      ++*****
    |                 ********
 100+******************+
     +----+----+----+----+----+----+----+----+----+----+
         -2        -1         0        +1        +2
```

Appendix Figure A8 Histogram, box plot and normal probability plot for somatic cell count

```
                         Histogram                           #               Boxplot

22500+*                                                     1             *
     .*                                                     5             *
     .*                                                     1             *
     .*                                                     2             *
     .*                                                     6             *
     .*                                                    13             *
     .*                                                    14             *
     .*                                                    35             *
     .*                                                    57             0
     .*                                                    79             0
11500+**                                                  138             0
     .**                                                  228             0
     .***                                                 322             0
     .*****                                               483             0
     .*******                                             774             |
     .*********                                           959             |
     .***********                                        1217             |
     .*******************                                2195          +-----+
     .**************************                         2960          |  +  |
     .****************************************           4574          *-----*
     .************************************************   5545          +-----+
  500+*****************************                      3362             |
       ----+----+----+----+----+----+----+----+----+---
```

Normal Probability Plot

```
22500+                                                  *
     |
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                 **
11500+                                               ***
     |                                             ***
     |                                           ***  +++
     |                                         ***++++
     |                                      ****++
     |                                    ***+
     |                                ++***
     |                            +++****
     |                         ++*****
     |                     +******
     |              *********
  500+***************++
      +----+----+----+----+----+----+----+----+----+----+
          -2        -1         0        +1        +2
```

Appendix Figure A9 Histogram, box plot and normal probability plot for milk yield per farm

```
                     Histogram                          #             Boxplot

  1550+*                                                4                *
      .*                                               16                *
      .*                                               29                *
  1250+*                                               25                *
      .*                                               37                *
      .*                                               57                *
   950+*                                               88                0
      .**                                             187                0
      .***                                            344                0
   650+******                                         796                |
      .***************                               2076                |
      .********************************              4464             +-----+
   350+************************************************ 6710          *--+--*
      .******************************************    5742             +-----+
      .***************                               1986                |
    50+***                                            409                |
       ----+----+----+----+----+----+----+----+----+---
```

```
                         Normal Probability Plot

   1550+                                                  *
       |                                                  *
       |                                                  *
   1250+                                                  *
       |                                                  *
       |                                                 **
    950+                                                **
       |                                              ***
       |                                           ****++++
    650+                                        ****++
       |                                  +******
       |                           ++*******
    350+                     *********
       |            **********
       |    *********++
     50+*****++++
        +----+----+----+----+----+----+----+----+----+----+
            -2        -1         0        +1        +2
```

Appendix Figure A10 Histogram, box plot and normal probability plot for milk yield per cow

Histogram # Boxplot

```
310000+*                                                     1               *
      .
      .*                                                     1               *
250000+
      .*                                                     4               *
      .*                                                     7               *
190000+*                                                    25               *
      .*                                                    69               *
      .*                                                   122               0
130000+**                                                  282               0
      .****                                                558               0
      .********                                           1174               |
 70000+************                                       1833               |
      .************************                           3818            +-----+
      .************************************************   7630            *--+--*
 10000+************************************************   7528            +-----+
       ----+----+----+----+----+----+----+----+----+---
```

Normal Probability Plot

```
310000+                                                  *
      |
      |                                                  *
250000+
      |                                                  *
      |                                                  *
190000+                                                  *
      |                                                  *
      |                                                ***
130000+                                             ****
      |                                          ****+++++
      |                                      *****+++
 70000+                                 +******+
      |                          +++******
      |                    +*********
 10000+**********************
       +----+----+----+----+----+----+----+----+----+----+
           -2        -1         0        +1        +2
```

Appendix Figure A11 Histogram, box plot and normal probability plot for milk revenue per farm

Histogram # Boxplot

```
19500+*                                                      1                *
      .
      .*                                                     8                *
      .*                                                    14                *
      .*                                                    19                *
      .*                                                    27                *
      .*                                                    29                *
      .*                                                    44                *
      .*                                                    50                0
      .*                                                   105                0
      .**                                                  193                0
      .***                                                 346                0
      .******                                              738                |
      .**************                                     1606                |
      .***************************                        3253            +-----+
      .*******************************************        5218            *--+--*
      .************************************************   5860            +-----+
      .********************************                   3864                |
      .***********                                        1274                |
  500+****                                                 403                |
        ----+----+----+----+----+----+----+----+----+---
```

Normal Probability Plot

```
19500+                                                  *
     |
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                 **
     |                                               ***
     |                                             ***
     |                                           ***+++++
     |                                        ****+
     |                                   +*****
     |                             ++******
     |                        +*******
     |                  ********
     |          *********
     |    *******+++
  500+*****+++
      +----+----+----+----+----+----+----+----+----+----+
          -2        -1         0        +1        +2
```

Appendix Figure A12 Histogram, box plot and normal probability plot for milk revenue per cow

The SAS program for analysis trial 1

```
*=================================================================;
* STRUCTURE OF MIDLAND WORKFILE;
*=================================================================;
/*
General Factors
FARM         = Farm ID
MY           = Measuring year (2004; 2005; 2006; 2007)
MM           = Measuring month (1=Jan, 2=Feb, ..., 12=Dec)
YS           = Year × Season subclasses
NMC          = Number of Milking Cows in the farm
Exp          = Experiance (year)
Edu          = Education (1 = primary school and no education;
               2 = high school; 3 = Bachelor degrees and higher)
FS           = Farm Size (1 = small - less than 10 milking cows;
               2 = medium - from 10 to 19 milking cows; 3 = large –
               more than 19 milking cows)
FL           = Farm Location (11 = Muaklek; 12 = Wang Muang;
               21 = Phattana Nikom; 31 = Pak Chong)
MSEAS        = Measuring season (1=Summer; 2=Rainy; 3=Winter)

Milk Quality Traits
FAT          = Milk fat (%)
PROT         = Milk protein (%)
LACT         = Lactose (%)
SNF          = Solid not fat (%)
TS           = Total solid (%)
CELL         = Somatic cell count

Milk Production Traits (Monthly basis from all milking cows)
MMILK        = Morning milk yield (kg)
EMILK        = Evening milk yield (kg)
MYF          = Milk yield per farm (kg)

Economic Traits (Factors)
PRICE        = Milk price (baht/kg)
MRF          = Milk revenue per farm (baht)
MFOOD        = Expenditure for food (baht)
```

```
MVET        = Expenditure for veterinary service (baht)
MLOAN       = Farmer loan (baht)
MTAX        = Tax from selling milk (baht)
MEXP        = Expenditure (baht)
MNET        = Net income (baht)

Average values per milking cow
MYC         = Milk yield per cow (kg)
MRC         = Milk revenue per cow (baht)
*=================================================================;
*/

DATA T1;
INFILE 'D:\Suphawadee\Chapter I Factor affecting\Raw
       Data_New\20081112_Data.txt' DLM = '09'x;
INPUT  FARM MY MM YS NMC Exp Edu FS FL MSEAS FAT PROT LACT SNF TS
       CELL MMILK EMILK MYF PRICE MRF MFOOD MVET MROAN MTAX MEXP
       MNET MYC MRC;

* Eliminated VERY LARGE SIZE FARM - 3154 and 3155 = NUM FON FARM;
      If FARM = 3154 then delete;
      If FARM = 3155 then delete;

      If Edu = 0 then Edu = 1;
      If Edu = 4 then Edu = 3;

*Recode edu| edu = edu+1;
*Define expsub = subclasses exp and create subclasses for exp;
      if exp eq 0 then expsub=1;
      if exp eq 1 then expsub=2;
      if exp eq 2 or exp eq 3 then expsub=3;
      if exp ge 4 and exp le 7 then expsub=4;
      if exp ge 8 and exp le 11 then expsub=5;
      if exp ge 12 and exp le 15 then expsub=6;
      if exp ge 16 and exp le 19 then expsub=7;
      if exp ge 20 and exp le 24 then expsub=8;
      if exp ge 24 then expsub=9;
```

```
Proc Univariate data=T1 plot;
      var FAT PROT LACT SNF TS CELL PRICE MYF MYC MRF MRC;

Proc Means data=T1;
      var FAT PROT LACT SNF TS CELL PRICE MYF MYC MRF MRC;

Proc Corr data=T1;
      var FAT PROT LACT SNF TS CELL PRICE MYF MYC MRF MRC;

Proc sort data=T1; by YS;
Proc means data=T1; by YS;
      var NMC;
      Output out = A n=n mean=mean std=std min=min max=max;
      Proc print data = A;

PROC Mixed Covtest;
      CLASS MY MSEAS YS FL FS FARM;
      MODEL MYF = YS FL*FS;
      Random FARM;
      LSMEANS YS FL*FS/pdiff adjust=bon;

PROC Mixed Covtest;
      CLASS MY MSEAS YS FL FS FARM;
      MODEL MRF = YS FL*FS;
      Random FARM;
      LSMEANS YS FL*FS/pdiff adjust=bon;

PROC Mixed Covtest;
      CLASS MY MSEAS YS FL FS FARM;
      MODEL MYC = YS FL*FS;
      Random FARM;
      LSMEANS YS FL*FS/pdiff adjust=bon;

PROC Mixed Covtest;
      CLASS MY MSEAS YS FL FS FARM;
      MODEL MRC = YS FL*FS;
      Random FARM;
      LSMEANS YS FL*FS/pdiff adjust=bon;
```

```
PROC Mixed Covtest;
      CLASS MY MSEAS YS FL FS FARM;
      MODEL FAT = YS FL*FS;
      Random FARM;
      LSMEANS YS FL*FS/pdiff adjust=bon;

PROC Mixed Covtest;
      CLASS MY MSEAS YS FL FS FARM;
      MODEL PROT = YS FL*FS;
      Random FARM;
      LSMEANS YS FL*FS/pdiff adjust=bon;

PROC Mixed Covtest;
      CLASS MY MSEAS YS FL FS FARM;
      MODEL LACT = YS FL*FS;
      Random FARM;
      LSMEANS YS FL*FS/pdiff adjust=bon;

PROC Mixed Covtest;
      CLASS MY MSEAS YS FL FS FARM;
      MODEL SNF = YS FL*FS;
      Random FARM;
      LSMEANS YS FL*FS/pdiff adjust=bon;

PROC Mixed Covtest;
      CLASS MY MSEAS YS FL FS FARM;
      MODEL TS = YS FL*FS;
      Random FARM;
      LSMEANS YS FL*FS/pdiff adjust=bon;

PROC Mixed Covtest;
      CLASS MY MSEAS YS FL FS FARM;
      MODEL CELL = YS FL*FS;
      Random FARM;
      LSMEANS YS FL*FS/pdiff adjust=bon;

RUN;
QUIT;
```

Appendix B

Analysis trial 2

Appendix Table B1 P-value of year-season, farm location-farm size, experience, education, record keeping, labor and decision making subclasses for the study traits

Traits	Milk yield per farm (kg)	Milk yield per cow (kg)	Milk revenue per farm (baht)	Milk revenue per cow (baht)
Year-Season	<.0001	<.0001	<.0001	<.0001
Farm size-Farm location	<.0001	<.0001	<.0001	<.0001
Experience	<.0001	<.0001	<.0001	<.0001
Education	0.1939	0.0102	0.2554	0.008
Record Keeping	0.0457	0.0607	0.0337	0.0601
Labor	<.0001	0.0001	<.0001	0.0001
Decision Making	0.8632	0.7145	0.8727	0.7941

Appendix Table B2 Descriptive statistics for monthly milk quantity and milk revenues

Traits	Number of records	Mean	Standard Deviation	Min	Max
Milk yield per farm (kg)	32,320	3,551.48	2,681.30	201.00	20,366.00
Milk yield per cow (kg)	30,549	338.01	124.14	60.14	669.98
Milk revenue per farm (baht)	32,444	44,789.45	34,994.96	1,010.80	313,443.68
Milk revenue per cow (baht)	31,686	4,398.04	1,850.46	501.60	11,398.00

Appendix Table B3 Least squares means and standard errors for milk yield per farm, milk yield per cow, milk revenue per farm, and milk revenue per cow by year-season subclasses

Year-Season Subclasse	Milk yield per farm (kg)	Milk yield per cow (kg)	Milk revenue per farm (baht)	Milk revenue per cow (baht)
2004 - Winter	3,980.35 ± 197.19	331.35 ± 10.26	49,374.00 ± 2,480.48	3,853.42 ± 147.26
2004 - Summer	4,143.74 ± 192.84	352.16 ± 9.77	50,992.00 ± 2,419.60	4,167.41 ± 139.72
2004 - Rainy	4,045.44 ± 192.64	331.79 ± 9.74	49,701.00 ± 2,417.16	3,887.97 ± 139.36
2005 - Winter	4,486.28 ± 191.00	356.02 ± 9.55	54,548.00 ± 2,394.18	4,129.34 ± 136.43
2005 - Summer	4,561.86 ± 190.00	360.34 ± 9.55	55,324.00 ± 2,392.80	4,281.85 ± 136.29
2005 - Rainy	4,446.86 ± 191.14	359.56 ± 9.57	53,488.00 ± 2,396.23	4,198.92 ± 136.74
2006 - Winter	4,473.19 ± 190.77	352.43 ± 9.54	53,911.00 ± 2,391.05	4,205.25 ± 136.14
2006 - Summer	4,384.51 ± 190.74	338.73 ± 9.53	52,699.00 ± 2,390.62	4,053.03 ± 136.09
2006 - Rainy	3,965.87 ± 190.69	309.50 ± 9.52	49,500.00 ± 2,389.91	3,759.90 ± 135.97
2007 - Winter	4,328.01 ± 190.63	324.85 ± 9.51	53,683.00 ± 2,389.16	3,940.77 ± 135.88
2007 - Summer	4,420.33 ± 190.61	334.35 ± 9.52	56,901.00 ± 2,388.75	4,311.92 ± 135.91
2007 - Rainy	3,985.47 ± 190.59	299.24 ± 9.50	55,125.00 ± 2,388.47	4,311.92 ± 135.91
2008 - Winter	4,234.58 ± 190.59	314.89 ± 9.51	62,982.00 ± 2,388.27	4,624.98 ± 135.78
2008 - Summer	4,082.72 ± 190.77	314.27 ± 9.54	61,161.00 ± 2,390.98	4,653.25 ± 136.15
2008 - Rainy	3,737.67 ± 191.39	289.56 ± 9.59	61,659.00 ± 2,399.49	4,680.25 ± 137.10
2009 - Winter	4,242.83 ± 194.01	319.43 ± 9.92	72,930.00 ± 2,436.00	5,399.72 ± 141.98

Appendix Table B4 Least squares means and standard errors for milk yield per farm, milk yield per cow, milk revenue per farm, and milk revenue per cow by experience, education, record keeping, labor, and decision making subclasses

Item	Milk yield per farm (kg)	Milk yield per cow (kg)	Milk revenue per farm (baht)	Milk revenue per cow (baht)
Experience				
No experience	2,670.66 ± 245.08	269.08 ± 15.40	37,575.00 ± 3,134.21	3,405.34 ± 220.82
1 year	3,448.73 ± 201.55	308.20 ± 10.74	48,118.00 ± 2,539.77	4,112.44 ± 134.66
2-5 years	4,006.82 ± 190.68	321.54 ± 9.44	53,232.00 ± 2,388.90	4,183.00 ± 134.66
6-10 years	4,452.30 ± 188.00	338.20 ± 9.17	56,695.00 ± 2,352.09	4,344.31 ± 130.83
11-15 years	4,858.20 ± 189.20	350.32 ± 9.29	62,267.00 ± 2,368.73	4,493.58 ± 132.66
16-20 years	4,995.29 ± 194.93	360.57 ± 9.83	64,725.00 ± 2,447.24	4,611.12 ± 140.45
> 21 years	5,107.89 ± 208.77	365.79 ± 11.20	68,503.00 ± 2,637.19	4,724.15 ± 160.75
Education				
Primary school or no education	4,031.21 ± 192.47	314.00 ± 9.43	53,738.00 ± 2,408.94	4,028.65 ± 134.69
High school	4,120.00 ± 225.08	330.38 ± 10.84	54,707.00 ± 2,813.42	4,242.70 ± 154.65
Bachelor or higher degree	4,508.74 ± 285.48	347.21 ± 13.65	59,175.00 ± 3,565.30	4,531.78 ± 193.97

Appendix Table B4 (Continued)

Item	Milk yield per farm (kg)	Milk yield per cow (kg)	Milk revenue per farm (baht)	Milk revenue per cow (baht)
Record keeping				
With record	4,408.70 ± 230.95	338.80 ± 11.15	58,375.00 ± 2,886.98	4,385.60 ± 158.88
Without record	4,031.26 ± 188.28	322.26 ± 9.20	53,373.00 ± 2,356.01	4,149.82 ± 131.40
Labor				
Family	4,147.44 ± 184.91	329.67 ± 8.82	54,460.00 ± 2,309.35	4,231.87 ± 125.60
Hired people	4,608.14 ± 215.14	344.43 ± 12.09	62,028.00 ± 2,726.20	4,499.37 ± 174.26
Family & hired people	3,904.37 ± 187.45	317.48 ± 9.14	51,132.00 ± 2,344.67	4,071.88 ± 130.19
Decision making on sire selection				
Farmers themselves	4,274.80 ± 145.51	330.23 ± 7.33	56,053.00 ± 1,824.64	4,295.41 ± 104.59
Government officials	4,069.02 ± 415.99	323.63 ± 19.56	54,420.00 ± 5,190.93	4,152.95 ± 278.72
Organization advisor	4,316.14 ± 237.94	337.73 ± 11.45	57,148.00 ± 2,973.79	4,354.76 ± 163.24

Appendix Table B5 Number of observation of experience, education, record keeping, labor, decision making and farm location by farm size

Items[1]	Farm size[2]		
	Small	Medium	Large
Experience			
No experience	12	5	1
	(1%)	(0%)	(0%)
1 year	68	16	4
	(5%)	(1%)	(0%)
2-5 years	168	85	17
	(12%)	(6%)	(1%)
6-10 years	188	170	55
	(13%)	(12%)	(4%)
11-15 years	115	141	57
	(8%)	(10%)	(4%)
16-20 years	78	95	43
	(6%)	(7%)	(3%)
> 21 years	30	33	20
	(2%)	(2%)	(1%)
Education			
Primary school or no education	189	136	25
	(35%)	(25%)	(5%)
High school	72	45	10
	(13%)	(8%)	(2%)
Bachelor or higher degree	28	23	6
	(5%)	(4%)	(1%)
Record keeping			
With record	81	54	14
	(12%)	(8%)	(2%)
Without record	290	195	34
	(43%)	(29%)	(5%)

Appendix Table B5 (Continued)

Items[1]	Farm size[1]		
	Small	Medium	Large
Labor			
Family	338	170	26
	(54%)	(27%)	(4%)
Hired people	6	17	3
	(1%)	(2%)	(1%)
Family & hired people	16	35	14
	(3%)	(6%)	(2%)
Decision making on sire selection			
Farmers themselves	302	191	40
	(46%)	(30%)	(6%)
Government officials	14	8	1
	(2%)	(1%)	(0%)
Organization advisor	49	44	7
	(7%)	(7%)	(1%)
Farm location			
Muak Lek	312	201	32
	(37%)	(24%)	(4%)
Wang Muang	72	36	13
	(9%)	(4%)	(2%)
Phatthana Nikhom	40	26	3
	(5%)	(3%)	(0%)
Pak Chong	54	36	8
	(6%)	(4%)	(1%)

[1] Unit (farm)

[1] Farm size: Small, less than 10 milking cows; Medium, between 10 to 20 milking cows; Large, more than 20 milking cows

Appendix Table B6 Number of observation of experience, record keeping, labor, decision making and farm location by education of the farmer

Items[1]	Education		
	Primary school or no education	High school	Bachelor or higher degree
Experience			
No experience	4	5	4
	(1%)	(1%)	(1%)
1 year	41	20	11
	(3%)	(2%)	(1%)
2-5 years	111	51	25
	(12%)	(6%)	(3%)
6-10 years	165	70	23
	(18%)	(8%)	(2%)
11-15 years	138	51	17
	(15%)	(6%)	(2%)
16-20 years	98	25	13
	(11%)	(3%)	(1%)
> 21 years	40	7	7
	(4%)	(1%)	(1%)
Record keeping			
With record	68	27	15
	(23%)	(5%)	(3%)
Without record	263	99	36
	(52%)	(19%)	(7%)
Labor			
Family	338	170	26
	(54%)	(27%)	(4%)
Hired people	6	17	3
	(1%)	(2%)	(1%)
Family & hired people	16	35	14
	(3%)	(6%)	(2%)

Appendix Table B6 (Continued)

Items[1]	Education		
	Primary school or no education	High school	Bachelor or higher degree
Labor			
Farmers themselves	270	101	44
	(54%)	(20%)	(9%)
Government officials	16	4	4
	(2%)	(1%)	(1%)
Organization advisor	48	20	2
	(10%)	(4%)	(0%)
Farm location			
Muak Lek	229	88	33
	(45%)	(17%)	(6%)
Wang Muang	55	12	5
	(11%)	(2%)	(1%)
Phatthana Nikhom	31	10	7
	(6%)	(2%)	(1%)
Pak Chong	16	16	6
	(3%)	(3%)	(1%)

[1] Unit (farm)

Appendix Table B7 Number of observation of experience, record keeping, decision making and farm location by labor of the farmer

Items[1]	Labor		
	Family	Hired people	Family and hired people
Experience			
No experience	11	1	2
	(1%)	(0%)	(0%)
1 year	67	2	4
	(7%)	(0%)	(0%)
2-5 years	172	6	10
	(18%)	(1%)	(1%)
6-10 years	221	12	26
	(24%)	(1%)	(3%)
11-15 years	165	8	33
	(18%)	(1%)	(4%)
16-20 years	110	6	20
	(12%)	(1%)	(2%)
> 21 years	45	2	7
	(5%)	(0%)	(1%)
Record keeping			
With record	113	6	11
	(18%)	(1%)	(3%)
Without record	420	21	48
	(67%)	(3%)	(8%)
Decision Making on sire selection			
Farmers themselves	431	24	53
	(69%)	(4%)	(9%)
Government officials	19	-	3
	(3%)		(0%)
Organization advisor	79	3	9
	(13%)	(0%)	(1%)

[1] Unit (farm)

Appendix Table B7 (Continued)

Items[1]	Labor		
	Family	Hired people	Family and hired people
Farm location			
Muak Lek	355	22	42
	(57%)	(4%)	(7%)
Wang Muang	75	3	8
	(12%)	(0)	(1%)
Phatthana Nikhom	47	-	4
	(8%)		(1%)
Pak Chong	56	2	11
	(9%)	(0%)	(2%)

[1] Unit (farm)

Appendix Table B8 Number of observation of experience, decision making and farm location by record keeping of the farmer

Items[1]	Record keeping	
	No records	Kept records
Experience		
No experience	10	4
	(1%)	(0%)
1 year	59	14
	(6%)	(2%)
2-5 years	143	45
	(15%)	(5%)
6-10 years	199	59
	(21%)	(6%)
11-15 years	165	41
	(18%)	(4%)
16-20 years	113	23
	(12%)	(2%)
> 21 years	47	7
	(5%)	(1%)
Decision Making on sire selection		
Farmers themselves	396	112
	(64%)	(18%)
Government officials	18	3
	(3%)	(0%)
Organization advisor	72	19
	(12%)	(3%)
Farm location		
Muak Lek	333	86
	(53%)	(14%)
Wang Muang	70	161
	(11%)	(3%)
Phatthana Nikhom	35	16
	(6%)	(3%)
Pak Chong	51	17
	(8%)	(3%)

[1] Unit (farm)

Appendix Table B9 Number of observation of experience and farm location by decision making of the farmer

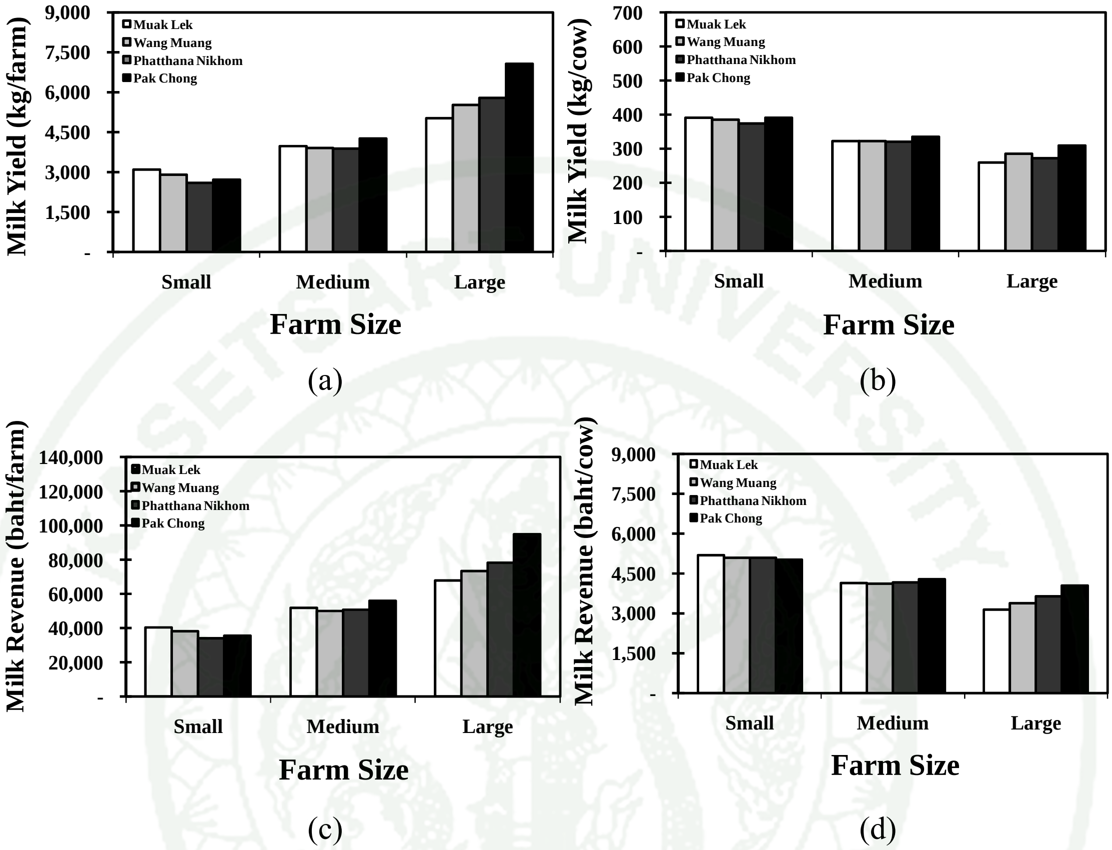
Items[1]	Decision making		
	Farmers themselves	Government officials	Organization advisor
Experience			
No experience	11	1	2
	(1%)	(0%)	(0%)
1 year	67	2	4
	(7%)	(0%)	(0%)
2-5 years	172	6	10
	(18%)	(1%)	(1%)
6-10 years	221	12	26
	(24%)	(1%)	(3%)
11-15 years	165	8	33
	(18%)	(1%)	(4%)
16-20 years	110	6	20
	(12%)	(1%)	(2%)
> 21 years	45	2	7
	(5%)	(0%)	(1%)
Farm location			
Muak Lek	347	13	56
	(56%)	(2%)	(9%)
Wang Muang	71	2	12
	(11%)	(0%)	(2%)
Phatthana Nikhom	39	2	10
	(6%)	(0%)	(2%)
Pak Chong	51	4	13
	(8%)	(1%)	(2%)

[1] Unit (farm)

Appendix Table B10 Number of observation of experience by farm location of the farmer

Items[1]	Farm location			
	Muak Lek	Wang Muang	Phatthana Nikhom	Pak Chong
Experience				
No experience	10	1	1	-
	(1%)	(0%)	(0%)	
1 year	47	12	12	2
	(5%)	(1%)	(1%)	(0%)
2-5 years	126	27	21	14
	(14%)	(3%)	(2%)	(2%)
6-10 years	186	31	14	27
	(20%)	(3%)	(2%)	(3%)
11-15 years	146	28	17	15
	(16%)	(3%)	(2%)	(2%)
16-20 years	96	20	14	6
	(10%)	(2%)	(2%)	(1%)
> 21 years	38	9	3	4
	(4%)	(1%)	(0%)	(0%)

[1] Unit (farm)



Appendix Figure B1 Least squares means for milk yield per farm (a), milk yield per cow (b), milk revenue per farm (c), and milk revenue per cow (d) by level of farm location-farm size subclasses

Histogram # Boxplot

```
20500+*                                                1         *
     .*                                                3         *
18500+*                                                3         *
     .*                                               17         *
16500+*                                               22         *
     .*                                               25         *
14500+*                                               56         0
     .*                                               80         0
12500+**                                             137         0
     .**                                             206         0
10500+***                                            318         0
     .*****                                          472         0
 8500+*******                                        678         |
     .*********                                      986         |
 6500+************                                  1271         |
     .***************                               1648         |
 4500+**************************                    2901      +-----+
     .********************************              3530      |  +  |
 2500+********************************************  4908      *-----*
     .************************************************  5371      +-----+
  500+********************                          2188         |
      ----+----+----+----+----+----+----+----+----+---
      * may represent up to 112 counts
```

Normal Probability Plot

```
20500+                                                  *
     |                                                  *
18500+                                                  *
     |                                                  *
16500+                                                  *
     |                                                  *
14500+                                                  *
     |                                                 **
12500+                                               ***
     |                                             ***
10500+                                           ***     ++
     |                                         *** ++++
 8500+                                       ***+++
     |                                     ***+
 6500+                                  ****
     |                              ++***
 4500+                           ++****
     |                       ++*****
 2500+                   +******
     |           **********
  500+************+++
      +----+----+----+----+----+----+----+----+----+----+
          -2        -1         0        +1        +2
```

Appendix Figure B2 Histogram, box plot and normal probability plot for milk yield per farm

```
                  Histogram                                #             Boxplot

675+**                                                  147                |
   .******                                              458                |
   .***********                                         820                |
   .*****************                                  1283                |
   .*************************                          1897                |
   .*********************************                  2515             +-----+
375+*********************************************      3436             |     |
   .************************************************   3721             *--+--*
   .**********************************************     3532             +-----+
   .************************************               2773                |
   .**********************                             1701                |
   .************                                        875                |
 75+*****                                               367                |
    ----+----+----+----+----+----+----+----+----+---
    * may represent up to 78 counts
```

```
                  Normal Probability Plot

675+                                                  *
   |                                            *******
   |                                         ****+
   |                                     ****+
   |                                  ****
   |                              *****
375+                          *****
   |                      *****
   |                  *****
   |              *****
   |         ******
   |   *******
 75+****++
    +----+----+----+----+----+----+----+----+----+----+
        -2       -1         0       +1        +2
```

Appendix Figure B3 Histogram, box plot and normal probability plot for milk yield per cow

```
                   Histogram                         #             Boxplot

310000+*                                             1                *
      .*                                             6                *
      .*                                             2                *
250000+*                                            11                *
      .*                                            20                *
      .*                                            39                *
190000+*                                            73                *
      .**                                          169                0
      .**                                          284                0
130000+****                                        514                0
      .******                                      947                |
      .**********                                 1656                |
 70000+*****************                          2729             +-----+
      .******************************             4980             |  +  |
      .************************************************ 7935       *-----*
 10000+**********************************         5504                |
       ----+----+----+----+----+----+----+----+----+---
       * may represent up to 166 counts
```

```
                       Normal Probability Plot

        310000+                                                   *
              |                                                   *
              |                                                   *
        250000+                                                   *
              |                                                   *
              |                                                   *
        190000+                                                   *
              |                                                ****
              |                                              ***
        130000+                                         ****+++++
              |                                      ****+++
              |                                  *****+
         70000+                            ++*****
              |                       ++******
              |                ***********
         10000+*****************
               +----+----+----+----+----+----+----+----+----+----+
                   -2        -1         0        +1        +2
```

Appendix Figure B4 Histogram, box plot and normal probability plot for milk revenue per farm

```
                    Histogram                        #             Boxplot

11250+*                                                48             0
     .**                                               76             0
     .**                                               91             0
     .***                                             138             0
     .***                                             174             0
     .****                                            240             0
     .******                                          317             |
 7750+*******                                         425             |
     .**********                                      616             |
     .**************                                  847             |
     .********************                           1205             |
     .**************************                     1579             |
     .**********************************             2092          +-----+
     .****************************************       2501          |     |
 4250+**********************************************  2890          *--+--*
     .************************************************2985          |     |
     .*********************************************  2798          +-----+
     .************************************           2206             |
     .*************************                      1546             |
     .***************                                 925             |
     .********                                        459             |
  750+*****                                           263             |
      ----+----+----+----+----+----+----+----+----+---
      * may represent up to 63 counts
```

```
                    Normal Probability Plot

     11250+                                                  *
          |                                                  *
          |                                                 **
          |                                               ***
          |                                             ***
          |                                           **   +++
          |                                         ***+++
      7750+                                       ***++
          |                                      **++
          |                                    ***
          |                                 +***
          |                               ***
          |                            +***
          |                         +****
      4250+                      +****
          |                    ****
          |                ****
          |             ****
          |         *****
          |     *****+
          | *****+++
       750+*** +++
           +----+----+----+----+----+----+----+----+----+----+
                -2        -1         0        +1        +2
```

Appendix Figure B5 Histogram, box plot and normal probability plot for milk revenue per cow

The SAS program for analysis trial 2

```
*==============================================================;
* STRUCTURE OF MIDLAND WORKFILE;
/*
*==============================================================;
FARM        = Farm ID
MY          = Measuring year (2004; 2005; 2006; 2007; 2008)
MM          = Measuring month (1=Jan, 2=Feb, ..., 12=Dec)
Exp         = Experiance (year)
Edu         = Education (1 = primary school and no education; 2 =
              high school; 3 = Bachelor degrees and higher)
TRA         = Training (1 = On farm; 2 = College and University; 3 =
              DPO and MDLP)
REC         = Record keeping for milk production and animals pedigree
              of the farm 1= kept record; 2= no record)
CAL         = Calculation (1 = Calculation and 2 = No calculation)
CUL         = Culling Problem in Cows (1= low milk; 2 = Reproductive;
              3 = Disease and health)
HEA         = Health of milking cow (1 = Mastitis; 2 = Reproductive;
              3 = Tick fever; 4 = Parasites)
LA          = Types of workers that participated in dairy farming (1=
              family; 2= hired people; 3= family and hired people
DM          = Decision making on sires selection (1= farmer
              themselves; 2= the government officers; 3= the
              staff of the supporting organization)
AREA        = Area of grass (Rai)
FML         = Family Labor (Head)
HL          = Hire Labor (Head)
TL          = Total Labor (Head)
NMC         = Number of Milking Cows in the farm
FS          = Farm Size (1 = small - less than 10 milking cows; 2 =
              medium - from 10 to 19 milking cows; 3 = large - more
              than 19 milking cows)
FL          = Farm location (11 = Muaklek; 12 = Wang Muang; 21 =
              Phattana Nikom; 31 = Pak Chong)
YS          = Year × Season subclasses
MSEAS       = Measuring season (1=Summer; 2=Rainy; 3=Winter)
```

```
FAT         = Milk fat (%)
PROT        = Milk protein (%)
LACT        = Lactose (%)
SNF         = Solid not fat (%)
TS          = Total solid (%)
CELL        = Somatic cell count (×10^3 cells/ml)
MMILK       = Morning milk yield (kg)
EMILK       = Evening milk yield (kg)
MYF         = Milk yield per farm (kg)
PRICE       = Milk price (baht/kg)
MRF         = Milk Revenue per farm (baht)
MFOOD       = Expenditure for food (baht)
MVET        = Expenditure for veterinary service (baht)
MLOAN       = Farmer loan (baht)
MTAX        = Tax from selling milk (baht)
MEXP        = Expenditure (baht)
MNET        = Net income (baht)
MYC         = Milk yield per cow (kg)
MRC         = Milk revenue per cow (baht)
*================================================================;
*/

DATA T2;
INFILE 'D:\Suphawadee\Chapter
II\Elzo\20090210_Kung\M2_SYData_Mean_Aug_26
_2009_NOTITLE.csv'delimiter=',' missover recfm=v lrecl=40000;
INPUT FARM MY MM Exp Edu TRA REC CAL CUL HEA XLA DM AREA FML HL TL
       NMC XFS FL YS MSEAS FAT PROT LACT SNF TS CELL MMILK EMILK MYF
       PRICE MRF MFOOD MVET MLOAN MTAX MEXP MNET MYC MRC;

*Eliminated LARGE SIZE FARM IN PATTANANIKOM;
      If FARM = 1003 then delete;
      If FARM = 1017 then delete;

*Eliminated VERY LARGE SIZE FARM - 3154 and 3155 = NUM FON FARM;
      If FARM = 3154 then delete;
      If FARM = 3155 then delete;
```

```
* Define Education;
      If Edu = 0 then Edu = 1;
      If Edu = 4 then Edu = 3;

* Number of labors;
      npers = FML + HL;
      If npers = 0 then npers =".";

* Define Type of Labors;
      If HL = 0 or "." then LA = 1; *LA = Family only;
      Else if FML = 0 or "." then LA = 2; *LA = Hired only;
      Else LA = 3; *LA = Both Family and Hired;
*Number of Milking Cows;
      If nmc = 0 then nmc =".";

*Net income per cow;
      anet = mnet/nmc;

*Average milk yield per cow;
      MYC = MYF / nmc;

*Average milk revenue per cow;
      MRC = MRF / nmc;

* Limiting range of MYF and MRF;
      IF MYF le 200.00 then MYF = ".";
      IF MRF le 1000.00 then MRF =".";

* Limiting range of MYC and MRC;
      IF MYC le 60.00 then MYC = ".";
      IF MYC ge 670.00 then MYC = ".";
      IF MRC le 500.00 then MRC = ".";
      If MRC ge 11400.00 then MRC = ".";

*Define Expsub = subclasses Exp and create subclasses for Exp;
      if Exp eq 0 then Expsub=1;
      if Exp eq 1 then Expsub=2;
      if Exp ge 2 and Exp le 5 then Expsub=3;
      if Exp ge 6 and Exp le 10 then Expsub=4;
```

```
      if Exp ge 11 and Exp le 15 then Expsub=5;
      if Exp ge 16 and Exp le 20 then Expsub=6;
      if Exp ge 21 then Expsub=7;

*Define FS = FS create from NMC;
      if NMC eq 0 then delete;
      if NMC ge 1 and NMC le 9 then FS=1;
      if NMC ge 10 and NMC le 19 then FS=2;
      if NMC ge 20 then FS=3;

*Redefine health;
      if hea ne . then hea=hea+1;
      if hea = . then hea=1;

Proc Univariate data=T2 plot;
      var MYF MYC MRF MRC;

Proc Means data=T2;
      var MYF MYC MRF MRC;

Proc Corr data=T2;
      var MYF MYC MRF MRC;

PROC Mixed data=T2 METHOD=REML ASYCOV Maxiter=50 Ratio Covtest;
      CLASS MY MSEAS YS FL FS Expsub Edu REC LA DM FARM;
      MODEL MYF = YS FL*FS Expsub Edu REC LA DM;
      Random FARM;
      LSMEANS YS FL*FS Expsub Edu REC LA DM/ pdiff adjust=bon;

PROC Mixed data=T2 METHOD=REML ASYCOV Maxiter=50 Ratio Covtest;
      CLASS MY MSEAS YS FL FS Expsub Edu REC LA DM FARM;
      MODEL MYC = YS FL*FS Expsub Edu REC LA DM;
      Random FARM;
      LSMEANS YS FL*FS Expsub Edu REC LA DM/ pdiff adjust=bon;

PROC Mixed data=T2 METHOD=REML ASYCOV Maxiter=50 Ratio Covtest;
      CLASS MY MSEAS YS FL FS Expsub Edu REC LA DM FARM;
      MODEL MRF = YS FL*FS Expsub Edu REC LA DM;
      Random FARM;
```

```
      LSMEANS YS FL*FS Expsub Edu REC LA DM/ pdiff adjust=bon;

PROC Mixed data=T2 METHOD=REML ASYCOV Maxiter=50 Ratio Covtest;
      CLASS MY MSEAS YS FL FS Expsub Edu REC LA DM FARM;
      MODEL MRC = YS FL*FS Expsub Edu REC LA DM;
      Random FARM;
      LSMEANS YS FL*FS Expsub Edu REC LA DM/ pdiff adjust=bon;

run;
quit;
```

Appendix C

Analysis trial 3

Appendix Table C1 P-value of year-season farm location-farm size and organization -farm size subclasses for the study traits

Traits	Year-Season	Farm size-Farm location	Organization-Farm size
Milk yield per farm (kg)	<.0001	<.0001	<.0001
Milk yield per cow (kg)	<.0001	0.0080	<.0001
Milk revenue per farm (baht)	<.0001	<.0001	<.0001
Milk revenue per cow (baht)	<.0001	0.0016	<.0001

Appendix Table C2 Descriptive statistics for milk productions and revenues by both organizations

Traits	Number of Observation	Mean	Standard Deviation	Min	Max
Milk yield per farm (kg)	56,455	3,893.37	3,167.29	201.00	35,940.00
Milk yield per cow (kg)	45,034	304.00	102.16	101.00	599
Milk revenue per farm (baht)	56,473	52,589.22	43,312.38	1,010.00	379,176
Milk revenue per cow (baht)	45,641	4,123.20	1,507.35	1,002.00	8,399

Appendix Table C3 Least squares means and standard errors for milk yield per farm, milk yield per cow, milk revenue per farm, and milk revenue per cow by year-season subclasses

Year-Season Subclasses	Milk yield per farm (kg)	Milk yield per cow (kg)	Milk revenue per farm (baht)	Milk revenue per cow (baht)
2006 - Winter	4,739.02 ± 98.32	317.68 ± 3.91	55,722.00 ± 1,344.15	3,714.39 ± 55.64
2006 - Summer	4,721.70 ± 94.97	317.82 ± 3.68	55,603.00 ± 1,296.55	3,719.02 ± 52.47
2006 - Rainy	4,201.12 ± 94.56	293.75 ± 3.68	50,891.00 ± 1,295.34	3,500.78 ± 52.36
2007 - Winter	4,640.28 ± 94.80	310.61 ± 3.67	56,021.00 ± 1,294.02	3,727.90 ± 52.29
2007 - Summer	4,767.34 ± 94.78	315.40 ± 3.66	59,104.00 ± 1,293.77	3,889.70 ± 52.25
2007 - Rainy	4,166.22 ± 94.65	288.55 ± 3.66	55,800.00 ± 1,291.94	3,819.74 ± 52.12
2008 - Winter	4,446.23 ± 94.60	305.09 ± 3.65	63,741.00 ± 1,291.11	4,323.06 ± 52.11
2008 - Summer	4,366.97 ± 94.58	306.48 ± 3.65	63,133.00 ± 1,290.92	4,383.46 ± 52.11
2008 - Rainy	3,983.35 ± 94.64	283.46 ± 3.65	62,879.00 ± 1,291.67	4,409.67 ± 52.15
2009 - Winter	4,559.58 ± 94.78	314.04 ± 3.66	74,058.00 ± 1,293.73	4,958.20 ± 52.39
2009 - Summer	4,772.36 ± 94.94	327.81 ± 3.68	71,958.00 ± 1,296.21	4,793.42 ± 52.54
2009 - Rainy	4,393.61 ± 95.08	309.54 ± 3.69	66,622.00 ± 1,298.32	4,523.74 ± 52.68
2010 - Winter	4,642.82 ± 102.99	321.40 ± 4.17	70,947.00 ± 1,411.88	4,773.72 ± 59.92

Appendix Table C4 Least squares means and standard errors for milk yield per farm, milk yield per cow, milk revenue per farm, and milk revenue per cow by farm location-farm size subclasses

Farm size[1]	Farm location[2]	Milk yield per farm (kg)	Milk yield per cow (kg)	Milk revenue per farm (baht)	Milk revenue per cow (baht)
Small	ML	2,721.17 ± 89.35	322.26 ± 3.40	37,568.00 ± 1,220.46	4,403.74 ± 48.61
	WM	2,291.78 ± 238.29	330.43 ± 9.11	31,161.00 ± 3,251.47	4,514.64 ± 129.97
	PC	2,103.17 ± 188.62	327.64 ± 7.34	27,730.00 ± 2,578.05	4,415.08 ± 104.71
Medium	ML	4,022.57 ± 88.57	300.52 ± 3.38	54,953.00 ± 1,209.35	4,065.37 ± 48.26
	WM	3,896.36 ± 241.44	290.04 ± 9.30	53,280.00 ± 3,296.29	3,908.52 ± 132.85
	PC	4,280.29 ± 193.93	323.91 ± 7.67	58,061.00 ± 2,654.99	4,475.88 ± 109.75
Large	ML	6,513.76 ± 110.17	295.10 ± 4.32	88,021.00 ± 1,512.36	3,982.46 ± 61.98
	WM	6,948.98 ± 280.31	283.67 ± 11.36	95,843.00 ± 3,847.20	3,896.16 ± 162.98
	PC	7,653.12 ± 285.96	303.71 ± 11.32	117,713.00 ± 3,915.41	4,094.38 ± 163.55

[1] Small = less than 10 milking cows per day; Medium = 10 to 19 milking cows per day; Large = 20 or more milking cows per day

[2] ML = Muaklek; WM = Wang Muang; PN = Phattana Nikhom; PC = Pak Chong

Appendix Table C5 Least squares means and standard errors for milk yield per farm, milk yield per cow, milk revenue per farm, and milk revenue per cow by farm size-organization subclasses

Farm size[1]	Organization[2]	Milk yield per farm (kg)	Milk yield per cow (kg)	Milk revenue per farm (baht)	Milk revenue per cow (baht)
Small	DC	1,995.46 ± 147.70	320.40 ± 5.59	26,419.00 ± 2,013.15	4,396.88 ± 79.68
	PO	2,748.61 ± 120.51	333.15 ± 4.63	37,888.00 ± 1,646.03	4,492.09 ± 66.15
Medium	DC	3,863.53 ± 149.05	284.65 ± 5.64	53,510.00 ± 2,031.82	3,901.06 ± 80.41
	PO	4,269.29 ± 123.07	324.99 ± 4.79	57,353.00 ± 1,682.52	4,398.79 ± 68.50
Large	DC	8,046.86 ± 186.86	183.50 ± 7.18	112,239.00 ± 2,551.87	3,884.75 ± 102.47
	PO	6,030.38 ± 157.43	304.82 ± 6.39	84,813.00 ± 2,164.63	4,097.25 ± 92.43

[1] Small = less than 10 milking cows per day; Medium = 10 to 19 milking cows per day; Large = 20 or more milking cows per day

[2] DC = Dairy Cooperative; PO = Private Organization

```
                  Histogram                      #              Boxplot

35000+*                                             6              *
     .*                                             4              *
     .*                                             7              *
     .*                                            12              *
     .*                                            12              *
     .*                                            11              *
     .*                                            22              *
     .*                                            46              *
     .*                                           101              *
     .*                                           225              *
     .*                                           367              0
     .**                                          650              0
     .****                                       1394              0
     .********                                   2731              |
     .**************                             5081              |
     .***************************                9980           +-----+
     .************************************************ 18278    *--+--*
 1000+***********************************************  17528    +-----+
      ----+----+----+----+----+----+----+----+----+---
      * may represent up to 381 counts
```

```
                       Normal Probability Plot

35000+                                                  *
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                  *
     |                                                 **
     |                                              ***
     |                                           ****
     |                                        ****++++++
     |                                     ****+++
     |                               ++*****
     |                         ++*******
     |                    *********
 1000+*********************
      +----+----+----+----+----+----+----+----+----+----+
          -2        -1         0        +1        +2
```

Appendix Figure C1 Histogram, box plot and normal probability plot for milk yield per farm

Histogram   #   Boxplot

```
590+****                                              223         0
   .****                                              288         |
   .******                                            372         |
   .*******                                           453         |
   .********                                          567         |
   .***********                                       776         |
   .**************                                    974         |
   .*****************                                1219         |
   .*********************                            1486         |
   .***********************                          1646         |
   .********************************                 2264         |
   .***********************************              2519      +-----+
350+**************************************           2731      |     |
   .*********************************************    3192      |     |
   .***********************************************  3348      |  +  |
   .***********************************************  3325      *-----*
   .************************************************ 3448      |     |
   .**********************************************   3306      |     |
   .*******************************************      3068      +-----+
   .****************************************         2810         |
   .******************************                   2124         |
   .**************************                       1848         |
   .********************                             1370         |
   .**************                                    979         |
110+**********                                        698         |
    ----+----+----+----+----+----+----+----+----+---
    * may represent up to 72 counts
```

Normal Probability Plot

```
590+                                                  *
   |                                                ***
   |                                              ***++
   |                                            ***++
   |                                          ***++
   |                                         **++
   |                                       ***+
   |                                     ***+
   |                                    **+
   |                                  ***
   |                                ***
   |                               **
350+                             ***
   |                           ***
   |                         ***
   |                       ***
   |                     ***
   |                   ***
   |                 ***
   |               ***
   |             ***
   |          ****
   |       ****
   |   *****+
110+**** ++
    +----+----+----+----+----+----+----+----+----+----+
        -2        -1         0        +1        +2
```

Appendix Figure C2 Histogram, box plot and normal probability plot for milk yield per cow

```
                     Histogram                        #          Boxplot

370000+*                                                  3         *
      .*                                                 16         *
      .*                                                 29         *
      .*                                                 30         *
      .*                                                 51         *
      .*                                                 61         *
      .*                                                119         *
      .*                                                175         *
      .*                                                229         0
190000+**                                               378         0
      .**                                               578         0
      .***                                              975         0
      .*****                                           1647         0
      .********                                        2616         |
      .************                                    4042         |
      .********************                            6579      +-----+
      .*********************************              11034      *--+--*
      .************************************************ 16191    +-----+
 10000+***********************************            11720         |
       ----+----+----+----+----+----+----+----+----+---
       * may represent up to 338 counts
```

```
                     Normal Probability Plot

370000+                                                    *
      |                                                    *
      |                                                    *
      |                                                    *
      |                                                    *
      |                                                    *
      |                                                    *
      |                                                   **
      |                                                 ***
190000+                                                **
      |                                             ***    +
      |                                           *** ++++
      |                                        ****+++
      |                                     +***+
      |                                 ++****
      |                            +++*****
      |                        ++******
      |                  *********
 10000+******************
       +----+----+----+----+----+----+----+----+----+----+
           -2        -1         0        +1        +2
```

Appendix Figure C3 Histogram, box plot and normal probability plot for milk revenue per farm

Histogram # Boxplot

```
8250+****                                             379         0
    .******                                           707         |
    .********                                         966         |
    .***********                                     1383         |
    .*****************                               2078         |
    .***********************                         2835         |
    .*******************************                 3904      +-----+
4750+***************************************         4797      |     |
    .********************************************    5525      |  +  |
    .************************************************6015      *-----*
    .***********************************************  5874      +-----+
    .***************************************         4896         |
    .***************************                     3309         |
    .****************                                1912         |
1250+*********                                       1061         |
     ----+----+----+----+----+----+----+----+----+---
     * may represent up to 126 counts
```

Normal Probability Plot

```
8250+                                                 **
    |                                             *****+
    |                                          ****++
    |                                       ****++
    |                                     ***+
    |                                  ****
    |                               ****
4750+                            ****
    |                         ****
    |                     +****
    |                  *****
    |              *****
    |          *****
    |     ******
1250+******++
     +----+----+----+----+----+----+----+----+----+----+
         -2        -1        0        +1        +2
```

Appendix Figure C4 Histogram, box plot and normal probability plot for milk revenue per cow

The SAS program for analysis trial 3

```
*==============================================================;
* STRUCTURE OF MIDLAND WORKFILE;
/*
*==============================================================;
ORG         =     Organization (Dairy cooperative; Private
                  Organization)
MY          =     Measuring year (2006; 2007; 2008; 2009)
MM          =     Measuring month (1=Jan, 2=Feb, ..., 12=Dec)
FARM        =     Farm ID
MSEAS       =     Measuring season (1=Summer; 2=Rainy; 3=Winter)
YS          =     Year × Season subclasses
YM          =     Year × Month subclasses
FL          =     Farm location (11 = Muaklek; 12 = Wang Muang;
                  31 = Pak Chong)
NMC         =     Number of Milking Cows in the farm
FS          =     Farm Size (1 = small - less than 10 milking cows;
                  2 = medium - from 10 to 19 milking cows;
                  3 = large - more than 19 milking cows)
MYF         =     Milk yield per farm (kg)
PRICE       =     Milk price (baht/kg)
MRF         =     Milk revenue per farm (baht)
MYC         =     Milk yield per cow (kg)
MRC         =     Milk revenue per cow (baht)
*==============================================================;
*/

DATA T3;
INFILE "D:\Suphawadee\Chapter
IIII\Rawdata\20100611_Analysis\SAS\20110131_AnalyOrg-SPY.TXT" DLM =
'09'X;
INPUT ORG$ MY MM FARM$ MSEAS YS YM FL NMC FS MYF PRICE MRF MYC MRC;

* Eliminated VERY LARGE SIZE FARM - 3154 and 3155 = NUM FON FARM;
      If FARM = P3154 then delete;
      If FARM = P3155 then delete;
```

```
* Limiting range of MYF and MRF;
      IF FL = 13 then FL = “.”;
      IF FL = 21 then FL = “.”;

* Limiting range of MYF and MRF;
      IF MYF le 200.00 then MYF = “.”;
      IF MRF le 1000.00 then MRF = “.”;
      IF MRF ge 400000.00 then MRF = “.”;

* Limiting range of MYC and MRC;
      IF MYC le 100.00 then MYC = “.”;
      IF MYC ge 600.00 then MYC = “.”;
      IF MRC le 1000.00 then MRC = “.”;
      If MRC ge 8400.00 then MRC = “.”;

Proc Univariate data=T3 plot;
      var MYF PRICE MRF MYC MRC;

Proc Means data=T3;
      var MYF PRICE MRF MYC MRC;

Proc sort data=T3; by ORG;
Proc Means data=T3;
      var MYF PRICE MRF MYC MRC;
      by ORG;

PROC MIXED covtest;
      Class FARM YS ORG FL FS;
      Model MYF = YS FL*FS ORG ORG*FS;
      Random FARM;
      LSMEANS YS FL*FS ORG ORG*FS/pdiff adjust=bon;

PROC MIXED covtest;
      Class FARM YS ORG FL FS;
      Model MRF = YS FL*FS ORG ORG*FS;
      Random FARM;
      LSMEANS YS FL*FS ORG ORG*FS/pdiff adjust=bon;
```

```
PROC MIXED covtest;
      Class FARM YS ORG FL FS;
      Model MYC = YS FL*FS ORG ORG*FS;
      Random FARM;
      LSMEANS YS FL*FS ORG ORG*FS/pdiff adjust=bon;

PROC MIXED covtest;
      Class FARM YS ORG FL FS;
      Model MRC = YS FL*FS ORG ORG*FS;
      Random FARM;
      LSMEANS YS FL*FS ORG ORG*FS/pdiff adjust=bon;

run;
quit;
```

CURRICULUM VITAE

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1998	Rajamangala Institute of Technology	B.Sc. (Animal Science)
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PUBLICATIONS

1. Yeamkong, S., S. Koonawootrittriron, M.A. Elzo and T. Suwanasopee. 2010. Milk Quantity, quality and revenue in dairy farms supported by a private organization in Central Thailand. **Livest. Rural Dev.** 22 (02).

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