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Research Article
Factors Influencing Milk Yield, Quality and Revenue of Dairy Farms in Southern Vietnam

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Abstract

Background and Objective: Dairy production in Vietnam is a relatively new agricultural activity and milk production increased remarkably in recent years. Smallholders are still the main drivers for this development, especially in the Southern part of the country. However, information on the farming practices is very limited. Therefore, this study aimed to determine factors influencing milk yield and quality (milk fat, total solids, solids-not-fat, total number of bacteria and somatic cell count) and revenue of dairy farms in Southern Vietnam. **Materials and Methods:** Collection of data was at the farm level; individual animal records were unavailable. The 539 studied farms were located in the provinces Lam Dong (N = 111 farms), Binh Duong (N = 69 farms), Long An (N = 174 farms) and Ho Chi Minh city (N = 185 farms). The dataset included 9221 monthly test-day records of the farms from January, 2013 to May, 2015. Seasons were defined as rainy and dry. Farms sizes were classified as small (<10 milking cows), medium (10-19 milking cows) and large (≥20 milking cows). The model for each trait contained year-season and farm region-farm size as subclass fixed effects and individual farm and residual as random effects. **Results:** Year-season, region and farm size were determining sources of variation affecting all studied traits. Milk yield was higher in dry than in rainy seasons ($p<0.05$), while it tended to increase from years 2013-2015. Large farms had higher yields (445.6 kg cow^{-1}) than small (396.7 kg cow^{-1}) and medium (428.0 kg cow^{-1}) farms ($p<0.05$). Small farms, in contrast were superior to large farms in terms of milk fat, total solids, solids-not-fat, total number of bacteria and somatic cell count than large farms ($p<0.05$). Revenue per cow was higher in large compared with medium and small farms. **Conclusion:** Large farms achieved higher milk yields and revenues per cow, while small farms were superior in milk quality. Overall, milk yields were low and better training, financial support and marketing opportunities for farmers are needed to improve dairy production and increase farm revenues in Southern Vietnam.

Key words: Milk yield and quality, farm size, season, revenues, somatic cell count

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Dairy cattle were introduced to Vietnam in the early 1920's. Since then, the dairy industry achieved tremendous growth rates[1]. In 2014, the total population of cattle in Vietnam was 5,243,300 animals of which 4.55% were dairy cattle. While the cattle population increased by 0.75% during the past 10 years, the dairy cattle population rose by more than 10%[2]. Milk production in Vietnam rose from 151,300-549,500 t and milk consumption from 8.5-22.5 kg per capita per year during the same period[3]. Dairy production is mainly located in Southern Vietnam, where almost 60% of the countries' milk is produced[2]. This is partly due to the fact, that Ho Chi Minh city was the main target region of the National Dairy Development program, which targeted the improvement of milk marketing, veterinary and extension services and feed resources[4]. From 25,089 heads and a total milk production of 44,200 t year^{-1} in 2000, the dairy herd increased to 88,549 head and 239,400 t of milk[2] in 2013. The dense population of this region allows the sale of fresh milk to customers or to the processing factories, which are located in Ho Chi Minh city and neighboring provinces, Binh Duong and Long An. Many industrial by-products are available and widely used as dairy feed. As a result of the development program, a strong system of veterinary and extension services is in place.

However, the rapid development of dairy production in Vietnam is now considered a high priority in the agricultural development of the whole country. Almost all the dairy cattle in Vietnam are owned by small-scale farmers with usually less than ten animals. It is estimated that 70% of the farmers own 3-5, 25% own 10-15 and only 5% own more than 50 dairy cattle[5]. Nevertheless, not only because of the governmental initiatives it can be expected that herd sizes will increase in the next years and medium- and even large-scale farms being organized in dairy organizations will become more and more common. Despite the rapid growth in production, Vietnam's dairy industry is unable to produce enough milk products to meet local demands. Large efforts are made to improve breeding, feed quality, milking technology and proper collection and storage of milk[6,3]. However, knowledge especially on small farms is poor and profitability and efficiency have to increase in order to overcome the manifold challenges. Especially when high-yielding Holstein-Friesian (HF) are raised, adequate nutrition and management is often not substantiated[7]. When it comes to revenues, not only the overall milk yield plays a role but also factors related to milk quality such as fat percentage, total number of bacteria and somatic cell count. Thus, emphasis has to be given on identifying management factors within farms that lead to lower milk yields and a higher incidence of bacteria in milk as well as mastitis. Studies on factors affecting milk yield and milk quality of dairy cattle in Southern Vietnam have been conducted to date only for smallholders[8-10] and data are rare for medium and large farms. Determination of important factors affecting milk quantity and quality would help dairy farmers to manage their limited resources more effectively and provide opportunities to increase the efficiency of their dairy operations. This information would also help dairy organizations to provide more appropriate and effective support to their members. The objective of this study was to determine factors including season, region and farm size that affect milk yield, milk fat, solids-not-fat, total solids, total number of bacteria, somatic cell count and revenue of dairy farms in Southern Vietnam.

MATERIALS AND METHODS

Study location: The study was carried out on 539 dairy farms located in Southern Vietnam. Farms were located in Ho Chi Minh city (N = 185 farms), Lam Dong province (N = 111 farms), Binh Duong province (N = 69 farms) and Long An province (N = 174 farms). The region is characterized by a typical monsoonal climate with two different seasons: rainy (from April-November, average rainfall 1828 mm, mean temperature 30.8°C and relative humidity of 80%) and dry (from December-March, average rainfall 112 mm, mean temperature 27°C and relative humidity 70%). During the study period, the rainy seasons had a mean temperature of 27.6-29.7°C, a relative humidity of 77-81% and a THI of 78.1, while the dry seasons had a mean temperatures of 26.8-28.9°C, a relative humidity of 70-73.3% and a THI[11] of 80.2.

Description of studied farms: Feeding and nutritional management of dairy cattle on most farms of this region vary between seasons. In a cut-and-carry system dairy cattle are fed with elephant grass, ruzi grass, guinea grass, legumes such as stylo grass, of which typically approximately 20-40 kg of fresh roughage is given per day. During the dry season, when green roughage is limited, cassava residues, brewery residues, rice straw, hay and silage are used as supplements[12,13]. Commercial concentrate with 14-16% crude protein, at 4-6 kg day^{-1} adjusted to the milk yield is generally given during lactation[14]. Although no information on the breeds of the animals was available for the studied farms, it can be assumed that the vast majority was of at least 75% HF origin[2].

Farmers milked their cows twice a day, once in the morning and again in the afternoon. Almost all farms used machine rather than hand milking. Prior to milking, the udders are cleaned with water and a chlorine solution. Some farmers used an iodine-based dipping agent after milking. After each milking, milk was stored in bulk tanks that were taken to the milk collection centers within the same day.

Data collection and recording: All 539 farms included in this study were members of milk collection centers of two dairy organizations (Friesland Campina and Vinamilk). The dataset was composed of 9,221 monthly farm records of milk yield, milk quality and revenues from January, 2013 to May, 2015. Also, the number of milking cows was provided monthly by each farm. Based on that, farms were classified as small (<10 milking cows), medium (10-19 milking cows) and large (≥20 milking cows). Monthly milk yield was considered as Farm Milk Yield (FMY, kg) as the total amount of milk produced by an individual farm in a particular month and milk yield per cow (MYC, kg) calculated as FMY divided by the number of milking cows at an individual farm in a particular month. In the same manner, monthly milk revenues were expressed as milk revenue per farm (MRF, Dong) as the total revenue by a farm in a particular month and milk revenue per cow (MRC, Dong) as milk yield per farm divided by the average number of milking cows in a particular month. The average exchange rate during the years of the study was 21.342±230 Dong = 1 USD. Quality traits included fat percentage (FAT; %), solids-not-fat percentage (SNF%), total solids percentage (TS%), total number of bacteria (BAC, $\times 10^4$ CFU mL^{-1}) and Somatic Cell Count (SCC, $\times 10^3$ cells mL^{-1}). The FAT, SNF, TS, BAC and SCC were obtained from milk samples taken randomly once a month from bulk milk of each individual farm.

Statistical analysis: The statistical analysis was performed with SPSS for windows version[15] 23.0. After categorizing and coding the data, descriptive statistics were performed for all variables. Linear mixed models were used for all traits (MYF, MYC, MRF, MRC, FAT, SNF and TS) with subclasses of year-season and farm location-farm size as fixed effects, number of milking cows as covariate, farms as random effect and a residual error term. Data of BAC and SCC were not normally distributed and log-transformed prior to analysis. Quantitative variables were compared using Bonferroni t-test to test for significant differences ($p<0.05$) between the four study regions. Chi-squared tests were used to test relationships between categorical variables.

RESULTS AND DISCUSSION

Milk yield per farm (MYF): The year-season by region interaction affected MYF ($p<0.001$, Fig. 1). Farm milk was lower ($p<0.05$) in the rainy than dry season in each year in Ho Chi Minh and Lam Dong. All regions showed an increase ($p<0.05$) in MYF in the course of the study period, of which Lam Dong had the greatest MYF increase (254 kg) and Binh Duong the lowest (31.01 kg).

Furthermore, the region and farm size interaction had an effect on MYF ($p<0.001$). The MYF ranged from 1139±199 kg in Binh Duong to 1551±164 kg in Ho Chi Minh for small farms, from 2780±254 kg in Lam Dong to 3732±205 kg in Ho Chi Minh for medium farms and from 4861±736 kg in Binh Duong to 13763±289 kg in Lam Dong for large farms.

Milk yield per cow (MYC): The year-season and region by farm size interaction affected MYC ($p<0.001$). Overall, mean monthly milk yield per cow was 422±85 kg. The 2013-dry season had the lowest MYC (416±1.79 kg, $p<0.001$), while 2015-dry season had the highest (428±2.33 kg, $p<0.05$). Overall, milk yield per cow was lower ($p = 0.045$) in the rainy season (422±1.37 kg) than dry season (425±1.48 kg), average milk yield per cow was lower ($p<0.05$) in the rainy than dry season in all regions. In every region MYC tended to increase throughout the study period. The average number of cows milked per day increased from 10.02 cows in 2013 to 10.78 cows in 2015.

The MYC separated by farm size and region are presented in Fig. 2. In Ho Chi Minh MYC averaged 474±2.26, 461±2.52 and 407±2.12 kg for large, medium and small farms. Large farms in Lam Dong region were significantly higher for MYC

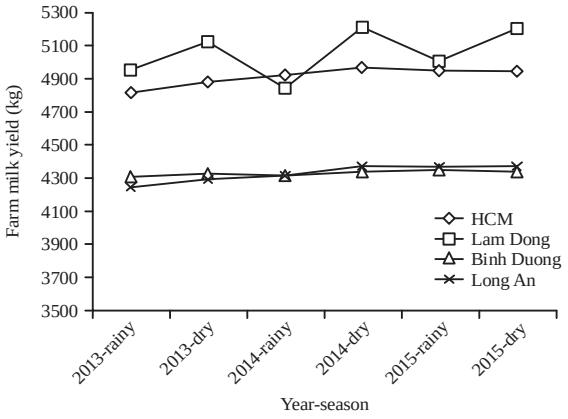

Fig. 1: Least square means for milk yield per farm by region for the different seasons from 2013-2015

(483±3.91 kg) than medium farms (477±3.32 kg) and small farms (453±2.54 kg). In the Binh Duong region, MYC for large farms (409±9.08 kg), medium farms (374±4.36 kg) and small farms (340±2.70 kg). There was no difference for MYC (p> 0.05) among large (414±3.07 kg), medium (3.97±2.66 kg) and small (384±2.05 kg) farms in Long An region.

Milk fat (FAT): The farm region and year-season interaction was an important (p<0.001) source of variation affecting milk fat percentage, while the region-farm size interaction was not (p>0.05). Milk fat percentage was highest in the dry period of 2014 (3.73±0.02%) and lowest in the rainy season of the same year (3.69±0.01%).

Milk fat percentage for the different farm sizes and regions are presented in Table 1. In Lam Dong, Binh Duong and Long An, small farms had the highest milk fat values (3.79±0.02, 3.68±0.02 and 3.62±0.01%, respectively) but these not different (p>0.05) from those of large and medium farms. Medium farms had the higher (3.79±0.02%) milk fat in Ho Chi Minh but were not different from small and large (3.76±0.01 and 3.77±0.01%, respectively. Across farm sizes and regions, small farms in the Lam Dong region had the highest value for milk fat (3.79±0.02%), while large farms in the Long An region had the lowest (3.62±0.01%).

Total Solids (TS): Year-season and farm region were important (p<0.001) source of variation affecting TS percentage of farms, while the farm size approached significance (p = 0.09). The TS percentage in the 2015 dry had the largest value (12.11±0.02%) and was higher than all other year-season groups, while the 2014 rainy had the lowest TS value (12.04±0.01%).

In Ho Chi Minh, TS did not vary between farm sizes (p>0.05) from those of large and small farms (Table 1). In Lam Dong and Long An, small farms had in tendency, higher values for TS than medium and large farms. Medium farms had, in tendency, higher TS values than large and small farms in Binh Duong. Overall, in Lam Dong highest and in Binh Duong lowest values for TS were found.

Solids-not-fat (SNF): Year-season and farm region both affected SNF (p<0.001). The 2015 dry had the highest SNF value (8.427±0.012%) which was higher (p<0.05) than those of all other year-seasons, while the 2014 rainy had the lowest SNF value (8.357±0.009%).

Least square mean for SNF percentage by farm-size are in Table 1. In Ho Chi Minh, Lam Dong and Long An, farm sizes did not vary in SNF values (p>0.05). In Binh Duong, medium farms had, in tendency, higher SNF values (p = 0.09) than large and small farms, respectively.

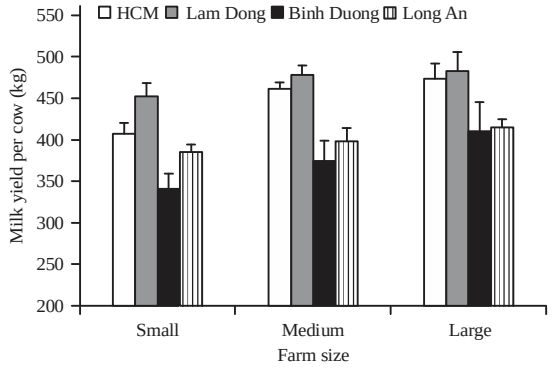

Fig. 2: Least square means for monthly milk yield per cow in the 4 study regions for the different farm sizes

Table 1: Least squares mean for Fat (FAT), Total Solids (TS), solid-not-fat (SNF), bacteria (BAC) and somatic cells (SCC) by farm region-farm size

		Milk quality									
		FAT		TS		SNF		BAC		SCC	
Farm region	Farm size*	%	SE	%	SE	%	SE	Log	SE	Log	SE
HCM#	Large	3.762	0.01	12.12	0.02	8.353	0.01	1.446	.019	2.947	.009
	Medium	3.790	0.02	12.15	0.03	8.362	0.02	1.283	.026	2.943	.013
	Small	3.771	0.01	12.12	0.02	8.353	0.01	1.134	.020	2.877	.010
Lam Dong	Large	3.766	0.02	12.11	0.04	8.353	0.02	1.388	.036	2.933	.018
	Medium	3.778	0.02	12.15	0.03	8.372	0.02	1.28	.032	2.886	.016
	Small	3.794	0.02	12.15	0.03	8.357	0.02	1.203	.025	2.871	.012
Binh Duong	Large	3.675	0.06	11.92	0.09	8.308	0.06	1.279	.092	2.94	.046
	Medium	3.668	0.03	12.05	0.04	8.388	0.03	1.304	.043	2.913	.021
	Small	3.683	0.02	12.04	0.03	8.369	0.02	1.182	.025	2.867	.012
Long An	Large	3.618	0.02	12.10	0.03	8.476	0.02	1.275	.026	2.947	.013
	Medium	3.593	0.02	12.07	0.02	8.466	0.01	1.197	.024	2.892	.012
	Small	3.622	0.01	12.09	0.02	8.466	0.01	1.097	.018	2.808	.009

*Small: <10 cows, Medium: 10-19 cows, Large: >20 cows, #HCM: Ho Chi Minh

Bacteria count (BAC): Year-season, farm region, farm size, farm region-year season and farm region-farm size variables affected BAC ($p<0.001$). The 2013 rainy season had the highest BAC value, which was higher ($p<0.001$) than those of all other year-seasons. Overall years, BAC values were higher in rainy than in dry seasons.

Least square means for SNF percentage by farm-size are presented in Table 1. In all regions, differences between farm sizes were found ($p<0.05$) for BAC with small farms having the lowest values, followed by medium and large farms. In Ho Chi Minh, large farms had the highest BAC values and were significantly different ($p<0.05$) from those of medium and small farms. In Lam Dong, large farms had the highest BAC values and were significantly different ($p<0.05$) from those of medium and small farms. In Binh Duong, large farms had the highest BAC values and were significantly different ($p<0.05$) from those of medium and small farms. In Long An, large farms had the highest BAC values and were significantly different ($p<0.05$) from those of medium and small farms. Across regions and farm sizes, small and large farms in Ho Chi Minh had the lowest and highest value for BAC, respectively).

Somatic Cell Count (SCC): Year-season with farm region by farm size variables affected SCC ($p<0.001$). The 2015 rainy season had the highest SCC value which was higher ($p<0.001$) than those of all other year-seasons, while the 2014 dry season had the lowest SCC value. The overall mean value of SCC in rainy season is higher than in dry season.

Least square means for SCC by farm region and farm size is presented in Table 1. In Ho Chi Minh, large farms had the highest SCC values and but they were not different ($p>0.05$) from those of medium and small farms. In Lam Dong, small farms had the lower ($p<0.05$) for SCC value than all other farms, while there was not different ($p>0.05$) between medium and large farms. In Binh Duong, small farms had the lowest SCC values and differed ($p<0.05$) from those of medium and large farms. In Long An, small farms had the lowest SCC values and were significantly different ($p<0.05$) from those of medium and large farms. Across regions and farm sizes, small farms in the Long An had the lowest value for SCC, while large farms in the Long An region had the highest.

Milk revenues

Milk revenue per farm (MRF): The interaction between region and farm size for MRF is presented in Fig. 3. Region-farm size LSM for MRF ranged from 52,948 thousand dong in Binh Duong to 156,356 thousand dong in Lam Dong for large farms. In medium farms, MRF ranged from 29,948 thousand dong in Binh Duong to 39,094 thousand dong in Ho Chi Minh. Small farms, LSM for MRF ranged from 11,131 thousand dong in Binh Duong to 20,768 thousand dong in Ho Chi Minh.

Year-season LSM for farms revenues ranged from 53,540 thousand dong (2013-Rainy season) to 57,749 thousand dong (2014-Dry season) for MRF. There was an increase of 4,209 thousand dong year^{-1} for MRF from 2013 to 2015.

Milk revenue per cow (MRC): The year-season and farm region by farm size interaction had a significant effect on the MRC ($p<0.001$). Least square means for MYC by year-season and farm region are presented in Fig. 4. The 2013 rainy season had the lowest MRC (4,680 thousand dong), while the 2015 dry season had the highest (4,839 thousand dong). The region-farm size interaction for MRC is presented in Fig. 5. The MRC ranged from 3,803 thousand dong in Binh Duong to 5,068 thousand dong in Lam Dong region for small farms. In medium farms, MRC ranged 4,199 thousand dong in Binh Duong to 5,391 thousand dong in Lam Dong. For large

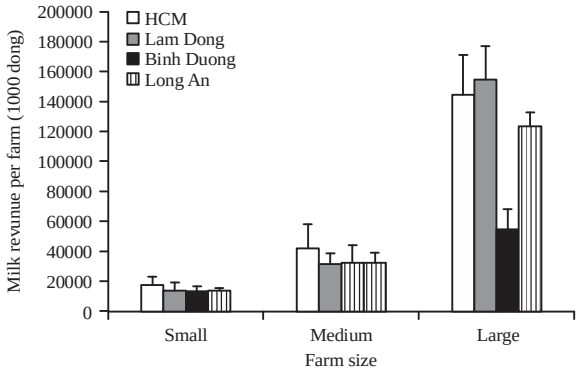

Fig. 3: Least square means for milk revenue per farm separated by farm size

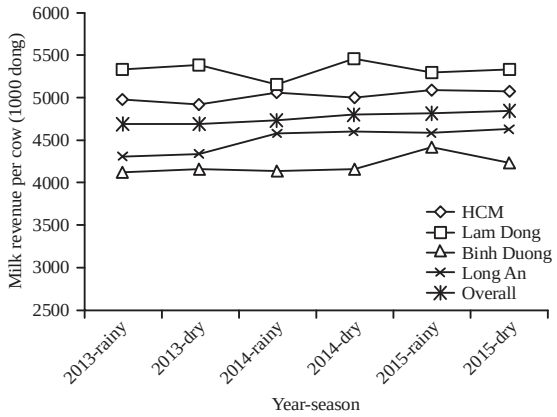

Fig. 4: Least square means for monthly milk revenue per cow by year and season

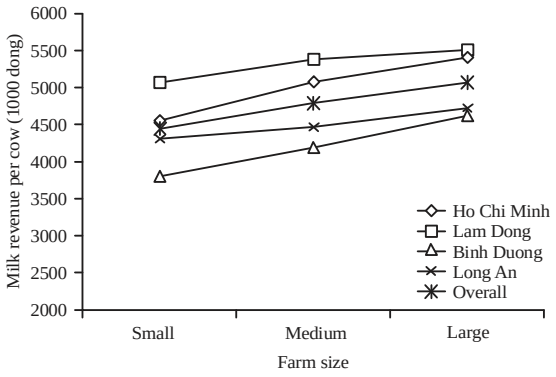

Fig. 5: Least square means for milk revenue per cow by farm size

farms values of 4,615 thousand dong in Binh Duong to 5,507 thousand dong in Lam Dong were recorded.

Milk yield: The fact, that the average milk yield values were higher in the dry than rainy season is likely due to heat stress and its effects on milk production. This might be mainly due to the fact that the dairy cows of the studied farms were mainly of HF origin and are less adapted to the local environmental conditions. However, the extent of milk yield decline observed in heat-stressed cows depends on a series of factors (i.e., breed, individual animal, yielding capacity, stage of lactation and feeding). Previous studies in Vietnam have shown that high relative humidity and temperature negatively affected daily milk yield of HF cattle[16,17]. The average daily THI of the majority of the days with THI values between 78.3 and 84.7 in Southern Vietnam can be designated as mildly heat stressing according to thresholds proposed by Berman[18]. With the use of evaporative cooling through cooling systems in combination with ventilation, reduced the barn temperature from 33.1-28.7°C and increased milk production by up to 0.7 kg day^{-1} cow^{-1}, equaling to a 5% increase compared to the control group[16]. Rios-Utrera *et al.*[19] compared non-lactating cows with low-yielding (18.5 kg day^{-1}) and high-yielding cows (31.6 kg day^{-1}) and found low- and high-yielding cows producing 27 and 48% more heat than non-lactating cows despite of having lower BW (752, 624 and 597 kg for non-lactating, low and high producers, respectively). Under consideration of increasing milk yields, which increases the sensitivity to thermal stress[19] and the scenario of global warming, heat stress may intensify under the Vietnamese conditions and differences between seasons might become more pronounced in the future. The HF crossed with local breeds performs better under tropical and subtropical condition than purebred HF and this superiority of crossbreds might become more pronounced in the future[20]. Effects of the genotype could not be assessed in this study, but warrants further studies to identify the optimal proportion of HF origin under the specific conditions of Southern Vietnam.

In addition to the effect of climate on milk yield per cow, calving season, seasonality of mating may also contribute to lower milk yield during rainy season. Cows that calved in the dry season had greater milk yields (3691 kg) than cows that calved in the rainy season (3623 kg)[21]. Seasonality of cows that mated during the rainy season achieved lower milk yields and conception rates than those that mates in summer and winter seasons[22], which reported that HF cows produced 195 l during the rainy and 192 l during the dry season. However, the seasonal effect on milk yield observed in the present investigation is not in agreement with that of Pasaribu *et al.*[22]. Thus, if dairy cattle have higher conception rates in the dry season when THI are lower, a higher percentage of cows would reach their later stages of lactation at the end of the rainy season and during the dry season. Cows in late lactation during the rainy seasons would have lower milk yields than in the dry season, as might be expected from the present findings.

Although the detailed breed composition was unavailable in this study, it can be assumed that the animals included in the study were of at least 75% HF origin. Tran *et al.*[23] reported that crossbred HF cows with 62.5-75% HF in Southern Vietnam had the highest milk yield (4236-4318 kg/305 day), while the group of cows with ≥87.5% HF the lowest milk yield (3896-4178 kg/305 day), indicating that 62.5-75% HF origin may be more appropriate to the environmental conditions in Southern Vietnam than higher HF percentage[2,6]. The average milk yield per lactation of HF Friesian crossbred cows in Vietnam increased steadily[24] from 3250 kg in 2001 to 4288 kg in 2013. This is likely to be associated with the increase in the proportion of imported dairy cattle with high genetic milk production potential rather than improved environmental and management factors such as expansion of pastured land or dairy farmer's skill[25]. Nevertheless, the average monthly milk yield per farm and per cow in the two study areas Binh Duong and Long An could be due to low grade of HF origin, poor feed quality and experience of farmers.

The greater milk yields per cow in large than in small farms in all of the studied regions is consistent with a previous studies in Vietnam. In these studies, monthly milk yields per cow were 374 kg[24] and 392 kg[8], which are lower than the yield of small farms in Ho Chi Minh (407 kg) and Lam Dong (456 kg), but higher than that of small farms in Binh Duong (341 kg). Lam *et al.*[26] reported that monthly milk yields of 480 kg in smallholder farms; similar to the yields of small farms in Ho Chi Minh (483 kg) and medium farms in Lam Dong

(481 kg), but lower than that of large farms in Lam Dong (494 kg). However, only limited research has been conducted to investigate the effect of farms size in Southern Vietnam, primarily due to the fact that previous studies only focused on small-scale farms and did not cover medium and large farms. Almost all dairy farms in Vietnam are smallholder farms, which changed from traditional paddy farmers about four decades ago[1]. After several years of dairy farming, generally single dairy farms expanded into several farms occupating the same plot of land due to traditional family expansion. Generally, owners of medium and large farms had more experience in dairy production than the owners of small farms[27]. Suzuki *et al.*[28] reported that farmers with more experience are able to manage their dairy herds more appropriately under tough climatic and economic conditions than less experienced farmers. More experienced farmers fed and managed their herd better and consequently produce more milk than less experienced farmers. With respect to the feeding systems, small farmers utilized agricultural by-products more commonly[29,17]. Thus, low quality feed in small farms may be the main explanation for the lower milk yield compared with large and medium farms.

During the study period from 2013-2015 there was an increased milk yield per farm observed, which can be on the one hand explained by an increase in the number of cows milked per day by 7.6% in the studied farms and an increased milk yield per cow. Due to the rapid increase in the demand for milk, farmers were encouraged by the governmental institutions to expand their production. This emphasizes that farm sizes will steadily grow and medium and large farms become more and more common in the next years. Besides, additional training on improving the efficiency of milk production, feeding, management and health care practices of dairy farmers by governmental organizations can be associated with increased milk production on farms.

Milk quality: The observed mean values of milk quality parameters (FAT, TS, SNF) comply with standard values[30]. The reason that small farms in Lam Dong and Long An regions had higher FAT percentage than medium and large farms is supposedly caused by a greater amount of fresh cut forage in small farms, whereas larger farms fed a higher quantity of lower quality forage such as rice straw, though this contrasts the higher milk yields found on large farms. Although milk fat decreased over the study period, the changes were limited.

Lower feed intake, selective consumption of concentrates and minimal intake of forages predispose cows to ruminal acidosis and lower milk fat values[21,12,13,31]. The variability of FAT across regions and farm sizes might be associated to weather patterns, availability of roughage, agricultural activities, irrigation of pasture and the ability of farmers to manage and utilization of local feed resources[9].

Milk BAC and SCC is the most important indicator for inflammation of the udder and is mainly influenced by the prevalence and incidence of subclinical and clinical mastitis. Values found here were higher than that of Hillerton and Berry[32]. In this study, trends of BAC and SCC showed a large variability and levels above the standard of BAC>10×10^4 CFU mL^{-1} and SCC>400×10^3 cells mL^{-1}, indicated a lack of regular tests to prevent mastitis and a high prevalence of clinical and subclinical mastitis[33]. Milk with a high SCC is known to have shorter shelf life due to high activity of enzymes[34,35]. The high BAC and SCC values observed in the rainy season may have been due to deficient floor hygiene, insufficient drainage from pens and muddy resting areas as identified by Millogo *et al.*[36]. On the other hand, 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, location and farm size. However, detailed information on management at the farm level was unavailable for this study. Thus, variability in environmental conditions across year-seasons should be accounted for when considering management strategies to improve milk quality in Southern Vietnam.

One reason for high SCC might be that fingers are put in the bucket during milking as it is easier to milk with the pull-down technique if the teats and hands are wet[37]. Additionally, the high SCC could be associated with milking management and probably stems from unhygienic milk practices in combination with heat stress. A reduction of SCC below the recommended maximum should be a priority for dairy farmers and one of the main goals for advisory services. This will likely increase milk production, too.

The reasons for larger farms having higher BAC and SCC values than smaller farms remain unclear. According to Fuentes *et al.*[37] not more than 35% of the milk samples from small-scale farmers and less than 20% from large farms were found with SCC values above the mentioned threshold. Large farms might have a poorer hygiene due to a lack of labor investment and a lacking bonus for producing hygienic milk. Besides, a limited training of employees of large farms may be another explanation for lower hygienic standards on large farms. Therefore, especially on large farms, an improvement in the milking management and sanitary conditions is necessary.

Milk revenues: Revenues per farm and cow were higher in the dry season than rainy season in all years and tended to

increase in all regions from 2013-2015, while the standard milk price remained constant during the study at 11.250 dong kg^{-1}. Because the milk revenue system in Vietnam depends primarily on milk quantity, revenues were proportional to amounts of milk purchased by the milk collection center. Milk prices are determined by the dairy organizations and typical additions/deductions are mainly based on FAT, SNF and milk quality factors such as BAC and SCC.

The higher milk revenues of farms in HCM and Lam Dong compared to Binh Duong and Long An were due to higher MYF and average MYC. In addition, a longer history of commercial dairy production in the HCM and Lam Dong, where farms have more productive animals and operations, may have contributed to these higher milk yields[2]. The large difference in revenue was primarily due to an increase in MYC and MYF over the study period.

As with MYF and MYC, low LSM values for MRF and MRC in Binh Duong and Long An were likely due to low quality and quantity of feed given to cows. Thus, feed and management strategies must be improved to increase milk production and revenues in this region. Given that the price for raw milk yield remained constant, production costs (e.g., feed, fuel, labor, equipment and services) and living expenses (e.g., food, clothes and health care) increased dramatically[38] from 2013-2015. In order to maintain their revenue, farmers were forced to increase their herd size which could have also led to their inability to supply the required inputs for production resulting in lower yields and altered milk quality. Furthermore, increased costs may have forced farmers to decrease the quantity and quality of feed supplied to cows and perhaps altered 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 milk yields.

CONCLUSION

Based on a large data set of more than 500 farms, the present study showed differences in milk yield between farm sizes (<10, 10-19 and >20 milking cows) of almost 50 kg cow^{-1} between smallest and largest farms. In the dry season yields were higher than in the rainy season. Despite a higher milk yield in large farms, small farms were superior in terms of milk quality. Overall, milk yields were low and better training, financial support and marketing opportunities for farmers are needed to stimulate improvements in dairy production and farm revenues in Southern Vietnam.

SIGNIFICANCE STATEMENTS

- Dairy production in Vietnam is a relatively new agricultural activity and milk production increased remarkably in recent years as a consequence of governmental activities
- Under the current high level of economic competition, farmers are forced to increase the production of high quality milk and at the same time decrease production costs to improve their profitability
- In Vietnam, smallholders are still the main drivers for this development, especially in the southern part of the country. But, information on the management and farming practices of smallholders are very limited
- The present study clearly demonstrated that large farms achieved higher milk yields and revenues per cow, while small farms were superior in milk quality. Overall, milk yields were low and better training, financial support and marketing opportunities for farmers are needed to improve dairy production and increase farm revenues in Southern Vietnam

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