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A Typological Analysis of Dairy Farms Based on Bulk Milk Price

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ABSTRACT

This study sought to examine the relationship between typological characteristics of dairy farms and the price received per liter of bulk milk in transactions with processing companies. During a period from January to March 2018, a total of 143 dairy farmers in western São Paulo State were interviewed on-site using a semi-structured questionnaire containing questions regarding structural, productive, and socioeconomic characteristics of farms and farm operators. Dairy farms were classified into two groups: G1 (n= 129), farms paid below the regional average price per liter of milk; and G2 (n= 14), farms paid above the regional average price per liter of milk. Then, factor analysis was used to extract factors associated with each dairy farm group. Three factors were identified: F1, Milk volume and quality; F2, Road conditions; and F3, Production area. Mean factor scores were compared by the Mann–Whitney U-test (p<0.05). G1 and G2 dairy farms differed significantly in Milk volume and quality (F1). There were no significant differences between G1 and G2 for the other factors. Dairy farms that produced a greater volume of milk and invested more in milk quality secured better prices in transactions with the industry. Based on these findings, it is concluded that actions to increase the scale of production and improve milk quality should be regarded as a priority, thereby increasing the likelihood that dairy farms will remain in business in the long term.

Keywords: dairy farmers; price received; transactions with the industry

INTRODUCTION

The milk production chain is one of the most important in the Brazilian agricultural sector, generating about R$ 35 billion annually and employing more than 4 million people (MDA, 2020). In 2019, the country produced over 25 billion liters of milk (IBGE, 2021). Since the 1990s, dairy production has been undergoing important transformations in institutional and market environments (Souza *et al.*, 2013; Bánkuti & Caldas, 2018), associated with market opening, deregulation of bulk milk prices, and economic stabilization (Vilela *et al.*, 2017; Nogueira *et al.*, 2018). In the following decades, the Brazilian government established new requirements for milk quality, transportation, and processing conditions through Normative Instructions Nos. 51, 62, and 76 (Brasil, 2002, 2011, 2018).

With these changes, new dynamics were established in transactions between dairy farmers and processing companies. For instance, new criteria were set to determine the price of bulk milk paid to farmers, related to raw milk quality and production volume, as occurs in other countries (Murphy *et al.*, 2016; Bánkuti *et al.*, 2018). It is important to point out that criteria for determining milk price are not defined by-laws or contracts and appear to be unclear to farmers. As observed in previous studies, in Brazil, milk farmers usually do not receive clear information about how the industry determines the price of milk (Brito *et al.*, 2015a; Casali *et al.*, 2020; Rauta *et al.*, 2020). The main criterion that farmers know is the volume of milk transacted. However, other important criteria for price definition, such as the percentage of fat and protein, values of somatic cell count and others, are unknown to milk farmers. Such a situation can lead to asymmetry of information and, consequently, opportunistic actions (Williamson, 1985).

Changes in institutional and market environments have had important impacts on milk production in Brazil, especially for small-scale farms (Souza *et al.*, 2013; Bánkuti & Caldas, 2018). Inability to meet market demands may result in low milk prices and, consequently, financial difficulties, impairing the ability of dairy farms to remain in business in the long term.

Most studies on transactions between milk producers and processing companies focus on factors influencing price composition and variation or on the efforts producers would be willing to make to receive more for bulk milk (Stubley *et al.*, 2018; Edwards *et al.*, 2019; Klopčič *et al.*, 2019). Other authors examined the variability of prices offered to milk producers in a given period and region (Medeiros *et al.*, 2016; Ramos *et al.*, 2016). Studies assessing associations between the typology of the dairy farm and bulk milk price consider scarcely found. Given this scenario, we sought to analyze the relationship between dairy farm typology and the price of milk paid to farmers by the dairy industry.

METHODS

The sample included 143 dairy farms (35% of the registered dairies) located in six municipalities (Bastos, Tupã, Iacri, Rinópolis, Piacatu, and Herculância) in western São Paulo State (Figure 1), Brazil (IBGE, 2018). These municipalities were chosen because they experienced a marked decrease (45.5%) in milk production between 2001 and 2018. Of note, the six municipalities produced together 14.7 thousand liters of milk in 2018 (IBGE, 2018).

Dairy farms were selected from data on milk collection routes provided by representatives of cooperatives, dairy industries, and technical assistance and agricultural extension agencies operating in São Paulo State. Farmers were contacted and informed of the purposes of the study, methods of data collection, and type of information analyzed, following the protocol approved by the local Human Research Ethics Committee (COPEP protocol no. 2,396,173). All farmers who agreed to participate were included in the study and asked to indicate other farmers who they believed could collaborate with the research.

Data were collected on-site from January to March 2018 through semi-structured interviews. The questionnaire contained questions on structural, productive, and socioeconomic characteristics of farms and farm operators and one item regarding the price offered by the dairy industry per liter of bulk milk (independent variable). Part of the responses was recorded as numerical variables and the other part as ordinal variables, as shown in Table 1.

Ordinal variables were logically ordered, with the lowest score corresponding to the worst technical,

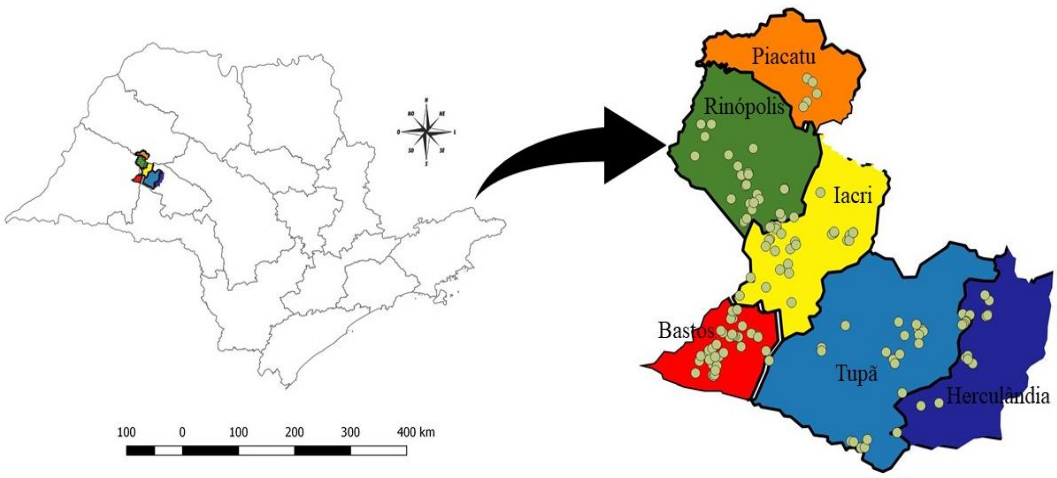

Figure 1. Map showing the location of the analyzed dairy farms in western São Paulo State, Brazil

Table 1. Typological variables used to describe dairy farms and farm operators

Variables	Type	Statistical analysis
V1. Age of farm operator (years)	Numerical	Descriptive statistics
V2. Level of education of farm operator (years)	Numerical	Descriptive statistics
V3. Dairy farming experience (years)	Numerical	Descriptive statistics
V4. Milk yield per cow (L/cow/day)	Numerical	Descriptive statistics
V5. Milk yield per area (L/ha/day)	Numerical	Descriptive statistics
V6. Farm size (ha)	Numerical	Descriptive statistics
V7. Milk production area (ha)	Numerical	Descriptive statistics
V8. Daily milk yield (L/day/ per farm)	Numerical	Descriptive statistics/factor analysis
V9. Number of lactating cows (cows/per farm)	Numerical	Descriptive statistics/factor analysis
V10. Percentage of milk delivered to processing company	Numerical	Factor analysis
V11. Primary road conditions	Ordinal (0 to 10)	Factor analysis
V12. Secondary road conditions	Ordinal (0 to 10)	Factor analysis
V13. Milking method	Ordinal (0 to 10)	Factor analysis
V14. Cooling method	Ordinal (1 = manual, 2 = mechanical bucket-at-foot system, 3 = machine milking, 4 = machine milking and transfer system)	Factor analysis
V15. Milking management and hygiene	Ordinal (0 to 10)	Factor analysis
V16. Quality of milk transportation service	Ordinal (0 to 10)	Factor analysis
V17. Quality of milk transportation workforce	Ordinal (0 to 10)	Factor analysis
V18. Level of trust in the transportation service	Ordinal (0 to 10)	Factor analysis

productive, or structural condition and the highest score to the best condition (Table 1). Other typological studies used this method to categorize responses from rural farmers (Bánkuti *et al.*, 2020; Casali *et al.*, 2020).

Statistical Analysis

In the first step, productive, structural, and socioeconomic characteristics of dairy farms (V1–V9, Table 2) were analyzed using descriptive statistics (mean, maximum, minimum, and standard deviation).

In a second step, the average price paid by processing companies to local farmers for a liter of bulk milk was calculated from monthly data for the year 2017 provided by the Center for Advanced Studies on Applied Economics (CEPEA, 2017). This value was used to separate dairy farms into two groups: G1, comprising farms that were paid less than the regional average, and G2, comprising farms that secured a price above the regional average.

The third step consisted of the generation of typological indicators. For this, we defined a set of structural and productive variables possibly associated with milk price. These variables were defined from literature reviews (Parré *et al.*, 2011; Gazola *et al.*, 2018) and by consultation with specialists in milk production (researchers and technical assistance as well as agricultural extension agents). Variables were subjected to factor analysis, as carried out by several studies on animal production typologies (Riveiro *et al.*, 2013; Gelasakis *et al.*, 2017; Zimpel *et al.*, 2017; Ibidhi *et al.*, 2018).

The exploratory factor analysis model was applied as follows (Eq. 1):

$$X_1 = A_{11}F_1 + AF_2 + \ldots + A_{1m}F_m + E_1$$
$$X_2 = A_{21}F_1 + A_{21}F_2 + \ldots + A_{2m}F_m + E_2$$
$$\vdots$$
$$X_p = A_{p1}F_1 + A_{p1}F_2 + \ldots + A_{pm}F_m + E_p \quad (1)$$

where, X_p represents the p-th score of the standardized variable (p = 1, 2, …, m), F_m is the extracted factor, A_{pm} is the factor loading, and E_p is the error.

Factor scores for each dairy farm were estimated by multiplying the standardized variables by the coefficient of the corresponding factor score (Eq. 2):

$$F_1 = D_{11}X_1 + D_{12}X_2 + \ldots + D_{1j}X_p$$
$$F_2 = D_{21}X_1 + D_{21}X_2 + \ldots + D_{2j}X_p$$
$$\vdots$$
$$F_j = D_{j1}X_1 + D_{j1}X_2 + \ldots + D_{jp}X_{jp} \quad (2)$$

where F_j is the j-th factor extracted, D_{jp} is the factor score coefficient, and p is the number of variables (Hair *et al.*, 2009).

Factor analysis condenses correlated variables into factors (Hair *et al.*, 2009). Principal component analysis with Varimax rotation was used as the extraction method. Kaiser–Meyer–Olkin normalization and Bartlett's sphericity test were used to verify the adequacy of the dataset for factor analysis. Variables with low factor loadings (less than |0.5|) were removed from the analysis (Hair *et al.*, 2009).

The number of retained factors (Table 3) was determined using the Kaiser criterion. Factors with an eigenvalue greater than or equal to 1.0 and a cumulative variance of at least 60% should be retained (Hair *et al.*, 2009). Factor scores were then treated as regression variables, as applied in previous typological studies on agricultural systems (Brito *et al.*, 2015 b; Bánkuti *et al.*, 2020). Therefore, each dairy farm was assigned a score that represented its contribution to each factor (Hair *et al.*, 2009).

In regression analysis, factor loadings are adjusted from initial correlations between variables, eliminating differences between units of measurement and stabilizing variances. This procedure allows factor scores to be analyzed by tests of means (Field, 2020). The typological characteristics of dairy farm groups were assessed by tests of means using the mean factor scores of each group. Data were assessed for normality using Kolmogorov–Smirnov, Shapiro–Wilk, and Levene's tests. Given the non-normality of data, means were compared by the nonparametric Mann–Whitney *U*-test ($p<0.05$) (Field, 2020).

RESULTS

General Characteristics of the Sample

The evaluated farm operators had on average 51.62±13.97 years of age, 14.76±11.46 years of experience in dairy farming, and 7.12±4.08 years of formal education (Table 2). These findings show that the farm operators were middle-aged, with a good level of experience in dairy farming and a low level of education (incomplete primary education).

Dairy farms had a mean total size of 13.65±19.87 ha. An area of land on this farm destined for milk production of 6.38±6.83 ha (Table 2). Farms produced on average 132.59±115.07 L/day with 14.13±9.11 lactating cows. These values correspond to mean yields of 9.45±5.06/cow and 26.42±32.82 L/ha (Table 2).

Dairy farms were divided into groups according to the average price of bulk milk paid by dairy industries. In 2017 in the analyzed region, the average milk price was R$ 1.25/L (CEPEA, 2017). The vast majority (90.2%, n= 129) of farms were paid less than the regional average (R$ 1.05/L); these farms were classified as G1. The other farms (9.8%, n= 14) were paid more than the regional average (R$ 1.42/ L) and classified as G2.

Factor analysis was initially performed with 11 variables (Table 1), but 3 variables did not have a significant factor loading as determined by Kaiser (Hair *et al.*, 2009). The variables removed were "V16. Quality of milk transportation service", "V17. Quality of milk transportation workforce", and "V18. Level of trust in the transportation service". Therefore, only eight variables were subjected to the analysis (Table 4). For these eight variables, the Kaiser–Meyer–Olkin value was 0.614, and Bartlett's test was significant (p= 0.00), indicating that the sample was adequate for factor analysis (Hair *et al.*, 2009).

Eight factors were identified; however, only the first three (F1, F2, and F3) were retained, as their eigenvalues were greater than 1.0, and the total cumulative variance was 73.17% (Table 3).

Table 2. General characteristics of dairy farms in western São Paulo State, Brazil

Variables	Min	Max	Mean	SD
V1. Age of farm operator (years)	20.00	80.00	51.62	13.97
V2. Level of education of farm operator (years)	0.00	18.00	7.12	4.08
V3. Dairy farming experience (years)	1.00	60.00	14.76	11.46
V4. Milk yield per cow (L/cow/day)	1.90	26.90	9.45	5.06
V5. Milk yield per area (L/ha/day)	0.50	175.00	26.42	32.82
V6. Farm size (ha)	0.50	171.0	13.65	19.87
V7. Milk production area (ha)	0.50	60.00	6.38	6.83
V8. Daily milk yield (L/day/per farm)	8.00	700.00	132.59	115.07
V9. Number of lactating cows (cows/per farm)	2.00	80.00	14.13	9.11

Table 3. Eigenvalues and total variance explained by factors

Factor	Eigenvalue	% of variance	Cumulative %
1	**2.532**	**31.65**	**31.65**
2	**1.735**	**21.69**	**53.34**
3	**1.586**	**19.83**	**73.17**
4	0.777	9.71	82.88
5	0.440	5.51	88.39
6	0.411	5.14	93.53
7	0.179	3.49	97.02
8	0.238	2.98	100.00

Note: Significant factors are highlighted in bold. Factor 1= Milk volume and quality; Factor 2= Road conditions; Factor 3= Production area.

Table 4. Rotated factor matrix of variables

Variables	Factor		
	1	2	3
V13. Milking method	**0.849**	0.048	−0.059
V15. Milking management and hygiene	**0.839**	0.032	−0.138
V8. Daily milk yield (L/day)	**0.812**	0.020	0.059
V14. Cooling method	**0.655**	−0.119	0.240
V11. Primary road conditions	0.003	**0.926**	−0.003
V12. Secondary road conditions	−0.007	**0.925**	0.024
V6. Farm size (ha)	−0.054	−0.029	0.869
V7. Milk production area (ha)	0.094	0.054	0.868

The retained factors, defined by a set of correlated variables and their respective factor loadings, are presented in Table 4.

F1, named Milk volume and quality, was formed by four variables (V13, V15, V8, and V14) (Table 4). Milking technique and management, as well as refrigeration practices, directly influence milk quality (Connell *et al.*, 2016; Silva *et al.*, 2016). F1 explained the highest amount of variance (Table 4). Therefore, factors associated with milk quality and volume were the most responsible for differences between dairy farms. Milk quality and production volume are important variables in determining bulk milk price. The results indicate that the milking method, milking management and hygiene, daily milk yield, and cooling method are highly correlated, as they composed the same factor (Table 4).

F2 was represented by V11 and V12 and was, therefore, called Road conditions (Table 4). Access road conditions can be an important factor in determining the price of milk and may even be used as a criterion by processing companies to decide whether to buy milk from certain suppliers. Transport distance and road conditions are related to freight costs charged from the farmer's earnings. Therefore, the higher the freight cost, the lower the amount paid per liter of milk (Vilela *et al.*, 2017; Bánkuti & Caldas, 2018). F2 was found to be an important indicator of bulk milk price. We highlight the correlation between variables that compose F2 (Table 4).

F3, defined by V6 and V7, was named Production area (Table 4). Both variables correlated highly with each other. The milk production area is indicative of the possibility of increasing production scales, as, for instance, it implies a greater capacity to house a larger number of animals. With larger production scales, farms are better equipped to negotiate better prices in transactions with the industry. Although production area is directly associated with production scale, farm productivity should also be considered. Farms with intensive production and greater use of technologies can achieve high yields in smaller areas.

Table 5. Mean factor scores of dairy farm groups

Factor	G1	G2	p-value
F1. Milk quality and volume	−0.071	0.658	0.016
F2. Road conditions	−0.029	0.27	0.216
F3. Production area	−0.023	0.213	0.903

Note: G1= dairy farms paid below the regional average per liter of bulk milk, G2= dairy farms paid above the regional average per liter of bulk milk. Means were compared by the Mann–Whitney U-test ($p<0.05$).

Comparison of typological variables showed that G2 had a better performance ($p<0.05$) in F1 (Milk volume and quality) than G1 (Table 5). No differences ($p>0.05$) in F2 (Road conditions) or F3 (Production area) were found between groups (Table 5).

DISCUSSION

The analyzed farm operators were middle-aged and had a low level of formal education. This is the reality of rural farmers in São Paulo State and much of the country. According to official data, 51% of rural farmers in São Paulo State are 45 to 65 years old. Furthermore, official data also reveals that 27% are in the age group 55–65 years and 30% of farmers completed elementary school and 12% completed middle school (IBGE, 2018).

As observed in previous studies (Zimpel *et al.,* 2017; Muller *et al.,* 2019), age is associated with level of education among farm operators. Older farmers tend to have lower education levels, implying a lower possibility of adopting management practices or technologies to meet current market demands. Sauer & Latacz-lohmann (2015) and Zimpel *et al*. (2017) argued that farm operators with a higher level of education are more likely to adopt management practices and production technologies, which might positively influence dairy farms performance.

The mean daily production of dairy farms (132 L/day) was lower than the threshold for volume bonuses. As reported by farmers during on-site interviews, volume bonuses are granted progressively, starting from 200 L/day.

The number of lactating cows was higher than the national average but lower than the average of São Paulo State. The state is among the largest milk producers in the country (IBGE, 2018). In some regions, such as the Paraíba Valley region, dairy farms are characterized by high yields and technological levels (IBGE, 2018).

Census data showed that the number of dairy farms has decreased over the years (IBGE, 2018), attributed to increased agricultural activities, such as sugarcane production. Most of the remaining farms are small-scale and aimed almost exclusively at family subsistence.

The majority (90.2%) of dairy farms were paid R$ 1.05 per liter of bulk milk, which is lower than the regional average (R$ 1.25/L). This result indicates that most farmers are not adequately meeting the demands of local processing companies; these demands involve criteria related to volume and quality. The difficulty in responding to the demands of industries, especially regarding milk quality and volume, implies low prices to dairy farmers in milk transactions. The low remuneration does not cause dairy farmers incentives to continue in milk production, as already observed in other Brazilian regions (Souza *et al.,* 2013; Brito *et al.,* 2015 b; Neumann *et al.,* 2016).

Analysis of typological indicators revealed that G2 farms scored higher on Milk volume and quality (F1) than G1 farms (Table 5), indicating that milk quality and production volume are decisive for bargaining a better price in transactions with the industry. Higher production volumes imply reduced freight costs, negotiation costs, and transaction monitoring and control. Therefore, the industry benefits from large scales of production (Paixão *et al.,* 2017).

Milk quality is mainly assessed by somatic cell and standard plate counts (Brasil, 2018). These parameters depend on milking management and hygiene practices, as well as on cooling methods (Gonçalves *et al.,* 2014; Motta *et al.,* 2015). In the current study, milking management and hygiene practices were grouped into the same indicator as to the production scale, indicating a correlation between variables. Large-scale dairy farms generally have good hygiene practices and better cooling methods, given that such practices require financial investments in equipment and employee training (Ingham *et al.,* 2011; Defante *et al.,* 2019).

The lack of differences in F2 between groups can be attributed to similarities in road conditions. Therefore, differences in milk prices are not influenced by this factor. According to the reports of farm operators and on-site observations, the roads that give access to dairy farms are under relatively good conditions and receive constant maintenance. As a result, bulk milk trucks have easy access to most analyzed dairy farms.

Dairy farm location, transportation distance, and road conditions are important parameters influencing freight costs. It is estimated that costs associated with milk collection and transportation account for 30% of total processing costs (FAO, 2021). Therefore, farms located far from processing companies or whose access roads are under poor conditions may get lower prices per liter of milk.

Lahrichi *et al*. (2015) found that the costs of collecting and transporting milk have an important impact on the profitability of dairy companies. Caria *et al*. (2018) argued that sharing milk transportation costs between small-scale farmers is essential, particularly for geographically dispersed farms with poor access routes.

G1 and G2 scored similarly on F3, indicating that the factor (comprising the variables farm size and milk production area) had no relationship with the differences in prices received by dairy farm groups. This result may be due not only to the homogeneity in production areas between farms (Table 2) but also to the fact that this parameter is not evaluated by such a result to determine milk price. This result is confirmed by the low contribution of variables to F3 compared with other factors (Table 3). A lower contribution indicates a low power of discrimination between analyzed cases (Hair *et al.,* 2009).

CONCLUSION

Dairy farms that produced higher milk volumes, adopted better management and milking hygiene practices, and stored bulk milk under adequate conditions were paid more in transactions with the dairy industry. By contrast, primary and secondary road conditions, farm size, and milk production area were not important in determining bulk milk price. Based on these findings, it is concluded that farm operators aim primarily at increasing production scale and improving milk quality to remain competitive in business. Such factors are internal to the dairy farm and therefore easier to control than external factors.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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