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Typology of dairy production systems that meet Brazilian standards for milk quality

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ABSTRACT - We aimed to compare the typology of dairy production systems (DPS) that meet Brazilian quality standards with that of non-compliant DPS. Semi-structured questionnaires were applied in 128 DPS located in Santa Izabel do Oeste, Paraná, Brazil (25°49'16" S and 53°29'04" W). In addition, milk quality reports of each DPS were analyzed. Dairy production systems were segregated into two groups: G1 – DPS that were in accordance with Brazilian regulations on milk quality, and G2 – DPS that did not comply with Brazilian regulations. Exploratory factor analysis was performed on structural, production, and technical variables. Two factors were defined: F1 – production scale and bargaining power, and F2 – autonomy and production control. Groups 1 and 2 were evaluated according to their structural, production, and technical characteristics as well as their F1 and F2 values. A small fraction (6.25%) of DPS met the minimum quality standards for milk. Dairy production systems that comply with quality regulations have larger production scale, higher productivity, and greater autonomy and control of milk production. Consequently, they have better bargaining power with the industry for the marketing of milk.

Keywords: agricultural systems, dairy cattle, milk composition, somatic cell count

Introduction

The state of Paraná contributes with 14% of the national milk production and is the second largest milk producer in Brazil (IBGE, 2016). Milk production in Paraná generates jobs and income for more than 114,000 families (Telles et al., 2008). Despite the critical role of dairy production in Paraná and in the country, milk produced in Brazil is considered of low quality (Souza et al., 2014; Sambuichi et al., 2012) and often fails to meet the minimum quality criteria of the Brazilian legislation (Silva et al., 2011; Fialho et al., 2012; Ribeiro Júnior et al., 2013; Vallin et al., 2009; Yamazi et al., 2010). Normative Instructions (NI) nos. 51 and 62 establish quality criteria regarding the physical, chemical, and microbiological characteristics of milk, including the maximum limits of somatic cell count (SCC) and standard plate count (SPC) (Brasil, 2002, 2011). Non-conformity with quality regulations prompts dairy producers to operate in the informal market or even abandon the activity (Bánkuti et al., 2009; Souza and Alves, 2010; Souza and Buainain, 2013). Milk quality is associated with technical and production characteristics of DPS, including production scale, system management and control practices, milk cooling processes, and hygiene of the milking process.

Therefore, improvement of milk quality demands advances in the entire production process. For the industry, an improved production process can result in higher yields and generate a product with enhanced sensory quality and longer shelf life. For rural producers, higher milk quality can lead to higher sales prices (Dürr, 2004; Fialho et al., 2012; Takahashi et al., 2012), more income, stimulus to production, and greater access to the external market (Oliveira and Silva, 2012; Taffarel et al., 2015). We aimed to analyze and compare the typology of DPS that meet Brazilian quality standards with that of non-compliant DPS.

Material and Methods

Semi-structured questionnaires were applied in 128 DPS located in Santa Izabel do Oeste, Paraná, Brazil (25°49'16" S and 53°29'04" W). The municipality was chosen because of its representativeness of milk production in Paraná and because of its easy access to the research team. In 2016, 31.2 million liters of milk was produced in Santa Izabel do Oeste, which generated R$ 38.6 million (IBGE, 2016). Dairy production systems were randomly selected from a list provided by DPS cooperatives and technical assistance agencies. Twenty variables were analyzed: 18 accounted for structural, production, and technical characteristics and two represented social characteristics (Table 1).

Table 1 - Description of categorical and numerical variables used to characterize dairy production systems

Variable[1]	Category	Type
1. Total farm area (ha)	Absolute value	Numerical
2. Production area (ha)	Absolute value	Numerical
3. Individual animal records	1 - Not used; 2 - Only for lactating cows; 3 - All animals have individual records	Categorical
4. Management of milk productivity per cow	1 - Not performed; 2 - Monthly control; 3 - Daily control	Categorical
5. Dairy cows (n)	Absolute value	Numerical
6. Lactating cows (n)	Absolute value	Numerical
7. Milk productivity (L day^{-1})	Absolute value	Numerical
8. Milk productivity per cow (L day^{-1} cow^{-1})	Absolute value	Numerical
9. Pre-and post-milking teat disinfection	1 - Not performed; 2 - Pre-milking disinfection only; 3 - Post-milking disinfection only; 4 - Pre- and post-milking teat disinfection is performed	Categorical
10. Frequency of milk quality testing	1 - Milk quality is not tested; 2 - Milk quality is tested a few times a year; 3 - Milk quality is tested monthly	Categorical
11. Milk supply agreements	1 - No; 2 - Yes, we have signed an agreement to improve milk quality and productivity	Categorical
12. Management of revenues and expenses	1 - Not performed; 2 - Revenue management only; 3 - Expense management only; 4 - We manage both revenues and expenses	Categorical
13. Financial incentives to increase milk productivity and quality	1 - No; 2 - Yes	Categorical
14. Other incentives to improve milk quality	1 - No; 2 - Yes	Categorical
15. Facilities for worker welfare	1 - No; 2 - Inadequate facilities; 3- Adequate facilities	Categorical
16. Facilities for animal welfare	1 - No; 2 - Yes	Categorical
17. Access of animals to shade	1 - No; 2 - Some plots offer shade; 3 - All plots offer shade	Categorical
18. Milking room and milk cooler	1 - No; 2 - Yes, but cold water is used for cooling milk; 3 - Yes, a milk cooler is used	Categorical
19. Years in the dairy business	Absolute value	Numerical
20. Age of the business proprietor	Absolute value	Numerical

[1] 1 to 18 - Structural, technical, and production variables of dairy production systems; 19 and 20 - social variables of rural producers.

Variables were of two types, numerical or categorical. A classification score was adopted for categorical variables (Hair et al., 2009). The lowest score corresponded to the least adequate technical, production, or structural situation, whereas the highest score was attributed to the most adequate technical, production, or structural situation (Table 1).

Descriptive statistics (mean and standard deviation) were calculated for each variable to characterize DPS.

We assessed milk quality by analyzing SCC and SPC in milk over 36 consecutive months. Milk quality variables were provided by industries that bought milk from DPS. Quality analyses were conducted by an accredited institution.

The maximum limits for SCC and SPC according to Brazilian NI no. 62 (Brasil, 2011) are 500,000 somatic cells/mL and 300,000 colony forming units (cfu)/mL, respectively. Dairy production systems were segregated into two groups. The first group (G1) comprised the eight DPS that were in accordance with NI no. 62 and the second group (G) comprised the 120 DPS that did not meet NI no. 62 SCC and SPC standards (Table 2).

Groups 1 and 2 were analyzed according to the following production and productivity variables: total farm area (ha), production area (ha), dairy cows (n), lactating cows (n), milk productivity (L day^{-1}), and milk productivity per cow (L day^{-1} cow^{-1}). We performed Kolmogorov-Smirnov and Shapiro-Wilk tests for normality and Levene's test for homogeneity of variance (Field, 2009). In case of non-normality, residuals were analyzed using generalized linear models with gamma distribution and Wald chi-square test. With this procedure, it was possible to identify the typology of compliant and non-compliant DPS according to the quality standards of Brazilian regulations.

Exploratory factor analysis (EFA) was applied to the structural, production, and technical variables. Principal component analysis was used as the extraction method and was followed by varimax rotation with Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity (Barroso and Artes, 2003; Brito et al., 2015; Smith et al., 2002). We retained factors defined by one or more explanatory variables that had a significant (>0.5) factor loading (Fávero et al., 2009; Yabe et al., 2015). Factor scores were saved as regression variables; thus, each DPS received a contribution score for each factor. In the regression method, factor loadings are adjusted from the initial correlation between variables, eliminating possible differences between units of measure and stabilizing variances. This procedure allows factor scores to be analyzed in several manners, including in mean tests (Field, 2009).

Groups 1 and 2 were analyzed according to factor loadings (Brito et al., 2015; Zimpel et al., 2017) to determine which factor most distinguishes compliant DPS from non-compliant DPS.

Results

The mean total farm area of the 128 DPS was 11.21±10.18 ha, and the mean production area was 7.83±6.21 ha. The mean numbers of cows and lactating cows were 21.47±12.36 and 11.88±6.35, respectively. Mean milk productivity was 147.70±154.09 L day^{-1}. The mean age of farmers (i.e., decision makers) was relatively high (49.18±11.51 years old), and most farmers had ample experience with dairy production (25±13.29 years).

Compliant and non-compliant DPS did not differ significantly (P>0.10) (Table 3) in terms of total farm area and production area. However, compliant DPS had more dairy cows (P<0.06), more lactating

Table 2 - Milk quality in dairy production systems classified as compliant or non-compliant with Brazilian standards

Group	N	%	SCC	SPC
G1 (compliant)	8	6.25	367.66	176.79
G2 (non-compliant)	120	93.75	652.57	2,515.08

SCC - somatic cell count (somatic cells/mL); SPC - standard plate count (cfu/mL).
Note: Brazilian legislation on milk quality establishes an SCC limit of 500,000 somatic cells/mL and an SPC limit of 300,000 cfu/mL (Brasil, 2011).

cows (P<0.05), higher milk productivity (P<0.07), and higher milk productivity per cow (P<0.07) than non-compliant DPS (Table 3).

The KMO test (0.845) and Bartlett's test of sphericity (0.000) applied to the 18 variables revealed good factorability of data (Fávero et al., 2009; Hair et al., 2009). The first two factors in EFA (factor 1, F1; factor 2, F2) explained 52% of the total variance, satisfying the requirements for factor extraction (Fávero et al., 2009; Hair et al., 2009) (Table 4).

Factor 1 explained the most variance (36.97%) among DPS (Table 4). It was composed of the following variables: dairy cows (n), lactating cows (n), milk productivity (L day^{-1}), milk productivity per cow (L day^{-1} cow^{-1}), frequency of milk quality testing, milk supply agreements, financial incentives to increase milk productivity and quality, and other incentives to improve milk quality (Table 5). The variables that compose F1 are indicative of the scale of production and bargaining power of rural producers in transactions with the industry. Given these characteristics, F1 was labeled as "production scale and bargaining power."

The fact that F1 explained most of the variance among DPS suggests that scale of production and bargaining power are the main characteristics that distinguish DPS of G1 from those of G2.

Factor 2 was composed of the variables total farm area (ha), production area (ha), individual animal records, pre- and post-milking teat disinfection, management of revenues and expenses, facilities for worker welfare, facilities for animal welfare, access of animals to shade, milking room, and milk cooler (Table 5). These variables can provide information on the autonomy of farms in feed production, production control, working conditions, and system management as well as on variables that are strongly linked to the quality of milk, such as milking hygiene practices, and conditions of milk storage in the rural property (Almeida et al., 2015; Santana et al., 2004; Vallin et al., 2009). Thus, F2 was considered to represent the "autonomy and production control" of DPS (Table 5).

Table 3 - Typology of groups

Variable	Group[1]	Mean	SD
Total farm area (ha)	G1	10.062	5.882
	G2	11.286	10.415
Production area (ha)	G1	7.812	4.628
	G2	7.831	6.317
Dairy cows (n)[2]	G1	29.000a	18.024
	G2	20.980b	11.827
Lactating cows (n)[3]	G1	17.500a	11.551
	G2	11.510b	5.748
Milk productivity (L day^{-1})[4]	G1	298.000a	311.216
	G2	137.680b	134.255
Milk productivity per cow (L day^{-1} cow^{-1})[4]	G1	13.750a	6.719
	G2	10.620b	4.191

SD - standard deviation.
[1] G1: compliant dairy production systems; G2: non-compliant dairy production systems.
[2] Means followed by different letters differ significantly at P<0.06.
[3] Means followed by different letters differ significantly at P<0.05.
[4] Means within a variable followed by different letters differ significantly at P<0.07.

Table 4 - Total variance explained by factors 1 and 2

Factor[1]	Total	% of variance	Cumulative %
F1	8.134	36.971	36.971
F2	3.319	15.085	52.056

[1] F1: production scale and bargaining power; F2: autonomy and production control.

Table 5 - Factor loadings

Variable	Factor[1]	
	F1	F2
1. Total farm area (ha)	0.305	0.617*
2. Production area (ha)	0.433	0.598*
3. Individual animal records	0.355	0.574*
4. Management of milk productivity per cow	0.579*	0.346
5. Dairy cows (n)	0.667*	0.388
6. Lactating cows (n)	0.730*	0.498
7. Milk productivity (L day^{-1})	0.910*	0.308
8. Milk productivity per cow (L day^{-1} cow^{-1})	0.779*	0.348
9. Pre- and post-milking teat disinfection	0.268	0.599*
10. Frequency of milk quality testing	0.785*	0.038
11. Milk supply agreements	0.589*	0.141
12. Management of revenues and expenses	0.219	0.640*
13. Financial incentives to increase milk productivity and quality	0.851*	0.152
14. Other incentives to improve milk quality	0.748*	0.042
15. Facilities for worker welfare	0.326	0.655*
16. Facilities for animal welfare	0.009	0.613*
17. Access of animals to shade	−0.015	0.577*
18. Milking room and milk cooler	0.101	0.649*

[1] F1: production scale and bargaining power; F2: autonomy and production control.
[*] Factor loadings >0.5.

Table 6 - Mean factor loadings of dairy production systems classified as compliant or non-compliant with Brazilian legislation on milk quality

Group	Mean factor loading[1]	
	F1	F2
G1 (Compliant)	0.8745	0.1652
G2 (Non-compliant)	−0.0583	−0.0110

[1] F1: Production scale and bargaining power; F2: autonomy and production control.

Group 1 (compliant) DPS had higher mean factor loadings for production scale and bargaining power (F1) and autonomy and production control (F2) than G2 (non-compliant) DPS (Table 6). This result indicates that DPS that meet the quality standards defined by Brazilian legislation have, in general, larger scale of production, greater bargaining power, greater autonomy, and better control of production than non-compliant DPS.

Discussion

Most of the analyzed DPS did not comply with all legal requirements for milk quality defined by NI no. 62 (Brasil, 2011). Results of SPC exceeding the regulatory limit indicate either ineffective cleaning and disinfection procedures for milking equipment, cooling systems, and cow teats or the occurrence of mastitis (Elmoslemany et al., 2009; Marion Filho and Oliveira, 2011; Taffarel et al., 2013). Somatic cell count is indicative of udder health, milk quality, and cow welfare. High SCC values also indicate the presence of mastitis (Rysanek et al., 2007; Cicconi-Hogan et al., 2013).

High SCC milk is a cause for concern for industries, as it can affect fermentation and coagulation processes, decreasing the yield of dairy products, such as cheese and butter (Coelho et al., 2014).

Furthermore, high SCC milk can result in products with reduced shelf life (Barbano et al., 2006). Values of SCC and SPC can be influenced by the season of the year, environmental variables, lactation, and volume of milk produced per cow (Takahashi et al., 2012).

We found that compliant DPS had higher milk productivity, greater bargaining power with the dairy industry, greater autonomy, and greater control of milk production than non-compliant DPS. The vast majority (93.75%) of the analyzed DPS did not comply with quality standards and had fewer dairy cows, fewer lactating cows, lower productivity, lower productivity per cow, and fewer management and control procedures than compliant DPS.

Proper milking hygiene, milk cooling methods, and mastitis control were more frequent in larger DPS, as these practices require investment in employee training, equipment, and production techniques (Ingham et al., 2011). Milk losses associated with quality problems have a lower economic impact on large-scale DPS compared with small-scale DPS (Ingham et al., 2011). Nevertheless, large-scale DPS have better control of milk quality and sanitary standards than small-scale DPS (Dong et al., 2012).

Compliant DPS had adequate facilities for worker and animal welfare and used more specialized breeds for milk production. Compared with non-compliant DPS, compliant DPS performed more efficiently and had better management and production practices, controlling revenues, expenses, and milk productivity per cow.

Compliant DPS also had positive relationships with the industry. Technical assistance and subsidies were provided more frequently to compliant DPS than to non-compliant DPS, as the former met quality and volume criteria more often. Financial incentives represent an important strategy for improving the quality of milk (Ribeiro Júnior et al., 2014).

The volume of milk sold by the rural producer to the industry affects the price of milk; producers are paid better prices for larger volumes of milk (Magalhães, 2007; Bánkuti et al., 2008). For the industry, the higher price is compensated by a reduced freight cost. In addition, knowledge on milk composition increases the bargaining power of the farmer in transactions with the industry and reduces asymmetries of information and possible opportunistic actions by the buyer (Magalhães, 2007; Fernandez-Stark et al., 2012; Brito et al., 2015).

Success in the dairy activity is associated with the ability to control animal performance parameters and manage the system as a whole (IPARDES, 2009). Simple management and control practices, such as monitoring production and economic indicators, are able to help rural producers in making safe decisions (Atzori et al., 2013; Zimpel et al., 2017).

Small-scale DPS have more difficulty in meeting milk quality standards. Low milk productivity and poor hygiene conditions are more common in small-scale DPS (Pedrico et al., 2009). Analysis of structural, technical, and production characteristics of DPS compliant with NI no. 62 revealed that these farms had higher productivity and produced milk of higher quality. These results indicate that, compared with non-compliant DPS, compliant DPS have higher chances of remaining competitive in the medium and long term.

Conclusions

A small fraction of dairy production systems comply with milk quality requirements of the Brazilian legislation. Dairy production systems that meet quality standards have larger scale of production, higher productivity, greater autonomy, and better control of milk production. Consequently, compliant DPS have greater bargaining power with the industry for the marketing of milk.

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