

Use of quali-quantitative feeding practices criteria in typology of smallholders' dairy production systems

Angelica Petersen Dias¹ , Vivian Fischer* 

¹ Universidade Federal do Rio Grande do Sul, Departamento de Zootecnia, Porto Alegre, RS, Brasil.

*Corresponding author:
vivinha.fischer@hotmail.com

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ABSTRACT - This study aimed to typify smallholders' dairy systems using quali-quantitative measures of feeding practices and detect the main discriminatory elements identifying the systems. We collected data from 30 farms distributed in 10 municipalities in the eastern region of Rio Grande do Sul, Brazil, using a survey with semi-structured questions, in addition to bimonthly observations of milking and feeding practices. Multivariate analysis based on principal factors and cluster analysis were performed. Multiple linear regressions were made between the principal factors scores and variables of milk production and composition. Three principal factors with eigenvalues ≥ 1.0 explained 58.9% of the total variance. The original variables with the highest factor loading values were production scale and feeding practices involving greater quantities of byproducts; use of corn silage and sugarcane; and commercial and farm-made concentrate for principal factor 1, principal factor 2, and principal factor 3, respectively. Milk yield and concentrations of lactose and solids non-fat increased linearly with principal factor 1 and principal factor 3 but decreased linearly with principal factor 2. Observations were grouped into three clusters. Farm area and quantity of corn silage and byproducts were the most important variables to set the clusters. The use of quali-quantitative feeding practices criteria to characterize dairy systems is effective to identify the opportunities for improving milk production and composition. Whereas high inclusion of sugarcane as roughage was detrimental for milk production, moderate supply of concentrate and byproducts enhanced milk yield without compromising milk composition.

Keywords: dairy production systems, feeding practices, milk composition, milk yield, multivariate analysis

1. Introduction

Smallholders' dairy systems (SDS) are defined as owner-managed production unit ranging from 5 to 110 ha with family labor and account for approximately 97.5% of milk produced in Rio Grande do Sul (RS) (EMATER, 2019). In Brazil, SDS present a wide diversity in terms of production scale, herd size, and feeding and milking practices (Bodenmüller Filho et al., 2010; Gabbi et al., 2013; Balcão et al., 2017). Characterization of these production systems is important to identify their weak and strong points that might be used in strategic planning (Madry et al., 2013; Costa et al., 2013).

Dairy production contributes to nearly 70% of the total income on dairy farms in southern Brazil (Costa et al., 2013), demonstrating the importance of accurate decisions to minimize high production costs. Feeding costs contribute with approximately 60% of the total variable costs for pasture-based farming system (Ruviano et al., 2020). As a result, it is crucial to characterize better strategies, especially

with regards to feeding practices, identifying the main points that might enhance the competitiveness of small dairy farms in RS and in Brazil.

Milk production and composition result from multiple factors such as genetic, nutrition, management, and environment. Therefore, it is difficult to measure the impact of each single characteristic of system on milk production and composition. The use of multivariate analysis may help to highlight the association between several production system characteristics with milk production and composition (Williams, 1994). Principal factor analysis (PFA) has been used to characterize SDS based on socioeconomic characteristics (Castel et al., 2003; López-i-Gelats et al., 2011), farm structure, production and management (Milán et al., 2011), milk production (Acosta-Alba et al., 2012), feed supply and production level (Gelasakis et al., 2012), main management practices, milk production and quality (Bodenmüller Filho et al., 2010; Costa et al., 2013; Gabbi et al., 2013; Balcão et al., 2017), forage production area, concentrate supply, and workforce (Koerich et al., 2019).

However, few studies have been undertaken using quantitative variables, such as mechanization, farm structure (Todde et al., 2016), and quantity of feed offered (Werncke et al., 2016) to characterize SDS. Koerich et al. (2019) quantified the amount of concentrate offered and reported its important role in increasing milk production, but these authors did not explore the effect of feeding practices on milk composition neither quantified the amount of other feeds except the concentrate. We hypothesize that the lack of feed planning with the use of pastures, conserved forages, and byproducts is likely to lead producers to rely on the purchase of large quantities of concentrate ingredients to compensate the deficiencies of roughage. Thus, in turn, this may keep milk production but in an unsustainable way.

This study aimed to typify SDS using quali-quantitative measures of feeding practices and detect the main discriminatory variables for different types of SDS. The differences identified may provide the information needed to better understand and diagnose problems and identify opportunities for improvement regarding milk production and composition.

2. Material and Methods

The study was conducted between June 2016 and July 2017 in 30 SDS distributed in 10 municipalities in eastern RS, Brazil. The technical department of the dairy processor invited the dairy farmers by convenience, varying farm area, herd size, monthly milk production, and feeding and milking management. The SDS were visited by the same member of the research team and, before starting the interview, farmers were informed about the objective of the study and that participation was voluntary with the confidentiality guaranteed. All SDS included in the study were pasture-based milk production.

Visits were made bimonthly with application of semi-structured questionnaires, in addition to direct observation of milking and feeding practices. The semi-structured questionnaire comprised five class of indicators related to herd structure: breed and number of lactating cows; social conditions of dairy farmers: educational level and use of family labor; farm production level: total area (in ha), milk yield per month (MYm), and milk yield per cow per day (MYd); type and quantity (as fed) offered per cow of corn silage, sugarcane, concentrate (farm-made or commercial), and byproducts [wet brewers' grain (WBG), and centrifuged soybean (CSB)], and use of winter cultivated pasture (WCP); and milking practices and hygiene: milking equipment and parlor, use of pre-dipping and post-dipping, subclinical mastitis test [e.g. California Mastitis Test (CMT), clinical mastitis test (e.g. fore-stripping)], and the use of alkaline-based and acid-based dairy detergents to clean the milking equipment. During the visit, a milk sample was collected from each farm's bulk tank to assess milk composition (lactose, protein, fat, and total solids), somatic cell count (SCC), and total bacterial count (TBC). Forage mass and animal stocking rate were not evaluated in this study. The database was composed by 555 observations.

The methodology for typification was based on a two-step multivariate analysis with PFA and cluster analysis (CA) (Hair et al., 1998; Madry et al., 2013). Principal factor analysis aims to reduce the numbers of variables that explain most of the variance observed when there are many variables involved

and can also be used to search variables for subsequent analysis, such as linear regression analysis (Lesschen et al., 2005; Bodenmüller Filho et al., 2010). In PFA, any variable with little contribution in explaining total variance (<10%) is removed (Escobar and Berdegué, 1990; Gabbi et al., 2013). We performed PFA with the FACTOR procedure (data = scats method = prin nfactors = 5 maxiter = 30 msa r = varimax) using SAS® software (Statistical Analysis System, version 9.4); principal factors (PF) were considered significant when eigenvalues were equal or higher than 1 (Comrey and Lee, 1992). Principal factor analysis was used to explore the relationship between indicators of productive systems related to type and quantity of feed offered to cows. To ensure the orthogonality of principal factor, the rotated factor matrix was used. The relative weight of each original variable on each PF is then termed the loading value and the value for each SDS at each month (referred as an observation) is termed score. Variables with loading value less than 60% were not considered in the results due to low discriminatory capacity (Hair et al., 1998).

To estimate the coefficient of a linear equation involving one or more independent variables that better predict the value of the dependent variable, linear regression analysis was performed. It was possible to test whether the variables are linearly related and calculate the strength of the relationship between variables using the multiple regression equation:

$$Y = \alpha + \beta_1X_1 + \beta_2X_2 + \dots + \beta_kX_k,$$

in which k is the number of independent variables (X), which values are used to predict the dependent variable (Y) (Lesschen et al., 2005). In the present study, score values were calculated with the SCORE procedure and were further used as the independent variables in a multiple linear regression model to analyze the effects of production scale and feeding practices on milk production and composition. Score values of the significant PF as well as SCC (covariate) were included as independent variables, according to the following model:

$$Y = \beta_0 + \beta_1PF_1 + \beta_2PF_2 + \beta_3PF_3 + SCC + \varepsilon,$$

in which Y is a dependent variable; β_0 is the intercept; β_1PF_1 , β_2PF_2 , and β_3PF_3 are linear regression coefficients for $PF_{1 \text{ to } 3}$; SCC was used as covariate; and ε is the error term of the model. The t test was used to test the regression coefficients.

To study the effect of using qualitative and quantitative feeding practices characteristics on the typification of SDS, we used the information about type and quantity of each feed offered to cows in the CA. Therefore, the CA was employed to group observations with similar feeding practices using the FASTCLUS procedure (the number of clusters was set using κ -means CA, partitioning the observations into clusters, and minimizing the sum of distance from each object to its cluster centroid); differences in all variables between groups were tested using GLM procedure and LSmeans, pdiff option. Significant differences were declared when $P < 0.05$, and a trend considered to exist if $0.05 < P < 0.10$.

3. Results

Overall means were 19 ± 17 ha, 22 ± 18 cows, and 13.3 ± 4.5 L/cow for total surface area, herd size, and daily average milk yield, respectively; all SDS employed family labor. Approximately 77% of the herds consisted of Holstein cows, 3.6% of Holstein-Jersey crossbred, and 19.1% of Zebu crossbred. Farmers used mechanical milking into buckets (65.4%) and pipeline systems (34.6%). Feeding practices were highly diversified between and within the SDS visited. On all SDS, cows received supplementation of concentrate in a pasture-based system with natural range pastures during the warm season. In 71.1% of the SDS, the concentrate was bought (commercial formulation) and offered at 4.5 ± 1.6 kg per cow/per day, while on 28% of farms, the concentrate was prepared in the SDS (farm-made) without balance or technical guidance—it was composed of simple high-energy ingredients (e.g., corn or sorghum grains, wheat bran, or rice bran) and was offered at 4.8 ± 1.5 kg per cow/per day. Details of forages used and the quantities offered of sugarcane, corn silage, WBG, and CSB are shown in Table 1.

The PFA evidenced three PF with eigenvalues ≥ 1.0 , which explained 58.9% of the accumulated variance. The PFA originated the rotated component matrix showing the vector loads of the original variables (Table 2). The PF1 explained 26.6% of the total variance and original variables with greatest loading values were those related to production scale (farm area and number of cows) and to the quantity of WBG offered. The PF2 explained 17.2% of the total variance, and the original variables with greatest loading factors were quantity of corn silage and sugarcane offered, while PF3 explained 15.2% of the total variance, and the quantity offered of commercial and farm-made concentrates were the most representative original variables. The positive association between production scale, feeding practices such as higher quantities of CSB, WBG, commercial concentrate, and corn silage is shown in Figure 1. There was a close association between the use of crossbred cows and greater quantity of sugarcane and farm-made concentrate.

The dependent variables MYd, MYm, milk yield per area (MYha), milk fat percentage (Fat%), milk lactose percentage (Lact%), and milk solids non-fat percentage (SNF%) were linearly related ($P < 0.05$) with the three PF and SCC (Table 3). Somatic cell count was included in the model because, despite feed management, SCC is well known to affect milk yield and composition (Auld et al., 1995; Zanela et al., 2006; Forsbäck et al., 2009). Variables MYd, MYm, MYha, Lact%, and SNF% increased linearly, while Fat% decreased linearly with PF1 (farm area, number of cows, and of WBG and CSB). Variables MYd,

Table 1 - Type and quantity of feeds (as fed) effectively offered in dairy farms during the year

Feed	Frequency (%) ¹	Mean±SD (kg as fed/cow/day)
Chopped sugarcane	48.3	10.8±3.0
Corn silage	38.7	20.0±5.2
Wet brewers' grain	37.7	12.7±3.3
Centrifuged soybean	20.5	10.0±0
Winter cultivated pasture	32.0	*

SD - standard deviation.

¹ Relative frequency of feed offered to animals considering all observations (n = 555, resulting from farms × bimonthly observations).

* The allowance of forage, pasture mass, and animal stocking rate were not evaluated in this study.

Table 2 - Rotated factor loadings of feeding practices and farm characteristics of dairy farms in the eastern region of Rio Grande do Sul, Brazil (significant original values = loading values ≥ 0.60) with eigenvalues and percentage of total variance explained

Variable	PF1	PF2	PF3
Numbers of cows	0.84	-0.10	0.13
Herd breed	-0.44	0.57	0.00
Area	0.61	0.44	0.18
Corn silage ¹	0.15	-0.65	0.08
Sugar cane ¹	-0.29	0.74	0.14
Wet brewers grain ¹	0.84	-0.06	-0.08
Commercial concentrate ¹	0.12	0.08	0.92
Farm-made concentrate	-0.13	0.26	-0.90
Centrifuged soybean ¹	0.59	-0.15	0.11
Winter cultivated pasture ²	-0.20	-0.41	0.25
Eigenvalue	2.91	1.89	1.67
Variance (%)	26.5	17.2	15.2
Cumulative variance (%)	26.6	43.7	58.9

PF - principal factor.

¹ Daily quantity of the feed offered per cow.

² Use of winter cultivated pasture (yes = 1; no = 0).

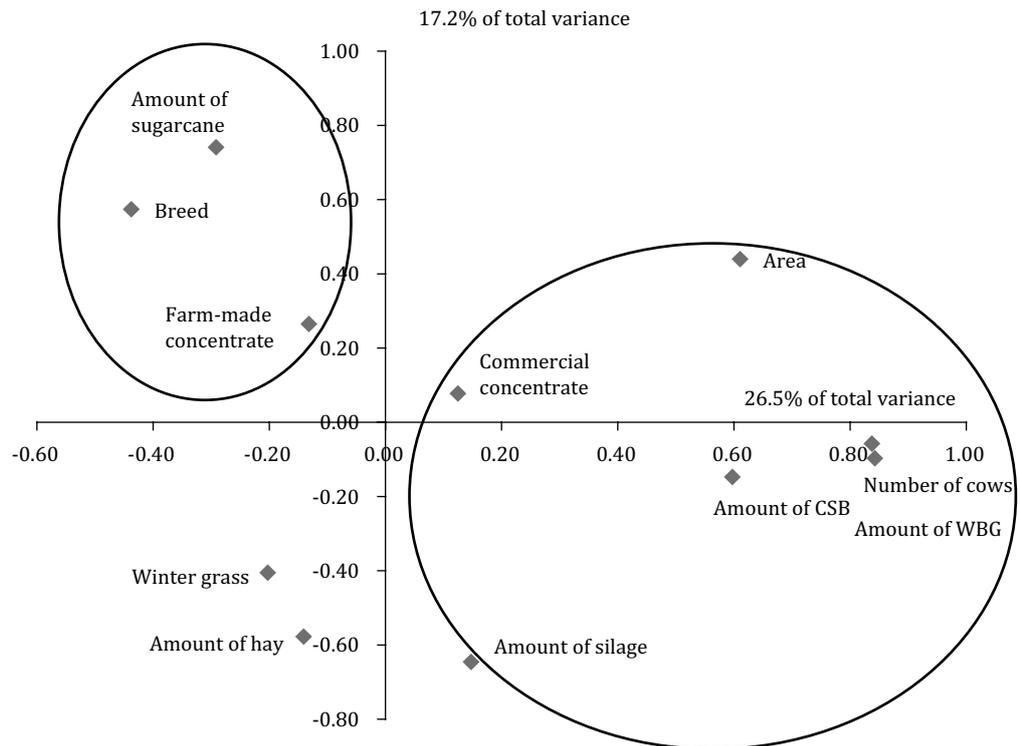


Figure 1 - Orthogonal plan with principal factors for variables related to production scale: farm area, number of cows, breed of cows, and feeding practices (use of winter grass pastures, quantities offered of hay, sugarcane, farm-made concentrate, commercial concentrate, wet brewers grain (WBG), and centrifuged soybean (CSB).

Table 3 - Coefficient of regression (β) between dependent variables and scores of principal factors (PF) and somatic cell count (SCC)

Dependent variable ¹	Intercept (β_0)	β_{1PF1}	β_{2PF2}	β_{3PF3}	SCC	R ²
MYd	14.1*	+1.4*	-2.4*	+0.6*	-0.14	0.41
MYm	5184*	+7177*	-2522*	+1542*	+827*	0.67
MYha	26.5*	+182.8*	-372.1*	+75.9*	+108.7*	0.36
Prot%	2.98*	+0.01	-0.00	+0.04*	+0.028	0.07
Fat%	3.2*	-0.08*	+0.02	+0.04*	+0.04*	0.08
Lact%	4.6*	+0.05*	-0.03*	+0.01	-0.05*	0.35
SNF%	8.6*	+0.07*	-0.03*	+0.03*	-0.02*	0.12

MYd - milk yield per cow per day; MYm - milk yield per month; MYha - milk yield per area; Prot% = milk crude protein; Fat% - milk fat percentage; SNF% - milk solids non-fat percentage.

* Significant ($P < 0.05$).

MYm, MYha, Lact%, and SNF%, but not Fat%, decreased linearly with PF2 (quantity of sugarcane and corn silage offered). Variables MYd, MYm, MYha, Prot%, Fat%, SNF%, but not Lact%, increased linearly with PF3 (use of commercial concentrate and farm-made concentrate).

Based on feeding practices, observations were grouped into three clusters (Table 4). Cluster 2 ($n = 141$) presented in-between characteristics, with the highest number of cows between cluster 1 ($n = 196$, more intensified) and cluster 3 ($n = 218$, less intensified). The most significant variables that determined the groups are described below. Variable MYd was highest in cluster 1, followed by cluster 2 and cluster 3 ($P < 0.05$). Cluster 1 presented the farmers with higher level of education than in clusters 2 and 3 ($P < 0.05$). Regarding feed management, in cluster 1, farmers offered the

Table 4 - Means and standard deviation of structural, productive, and milk composition variables surveyed from dairy farms in the eastern region of Rio Grande do Sul, Brazil

Attribute	Cluster 1 (n = 196)	Cluster 2 (n = 141)	Cluster 3 (n = 218)
Numbers of cows	19.6±11.5b	44.5±22.4a	11.0±4.5c
Breed ¹	1.0±0.0b	1.0±0b	1.5±0.5a
Area (ha)	11.8±4.7c	33.5±22.4a	18.0±14.9b
Milk yield (L/cow/day)	15.8±5.2a	14.4±3.0b	10.3±2.4c
Total milk production (L/month)	9,878±7,699b	19,605±11,108a	3,522±2,047c
Milk production per area (L/ha)	893±704a	889±875a	254±129b
Corn silage ²	14.2±11.6a	8.6±8.3b	1.4±4.9c
Sugarcane ²	0.7±2.3c	3.2±4.4b	10.5±4.3a
Commercial concentrate ²	3.4±1.4a	3.4±2.2a	2.9±3.1b
Farm-made concentrate ²	0.3±1.1c	1.3±2.5b	2.3±2.5a
Wet brewers grain ²	3.1±4.8b	13.7±3.2a	0.4±2.0c
Centrifuged soybean ²	2.3±4.2b	4.8±5.0a	0±0c
Pre-dipping use ³	0.27±0.44a	0.09±0.28c	0.18±0.39b
Post-dipping use ³	0.60±0.49a	0.29±0.46b	0.22±0.42b
Forestrip/Clinic mastitis test ³	0.94±0.23a	0.74±0.44c	0.85±0.36b
California Mastitis Test ³	0.71±0.45a	0.44±0.49b	0.31±0.46b
Acid detergent use ³	0.71±0.46a	0.48±0.50b	0.45±0.50b
Alkaline detergent use ³	0.86±0.35a	0.72±0.45b	0.67±0.47b
Farmer education ⁴	3.3±1.2a	2.7±1.4b	1.4±0.6c
Milk fat (%)	3.44±0.3a	3.38±0.4a	3.54±0.4b
Milk protein (%)	3.09±0.2a	3.14±0.15b	3.09±0.2a
Lactose (%)	4.37±0.1a	4.39±0.1a	4.29±0.2b
Total solids (%)	11.9±0.5a	11.9±0.4a	11.93±0.5a
Solids non-fat (%)	8.5±0.2a	8.6±0.2b	8.38±0.3c
Somatic cell count (×1000)	613±382a	1022±625c	894±675b
Total bacterial count (×1000)	810±1170a	1445±2059b	1419±1761b

¹ Holstein, Holstein-Jersey crossbreeds = 1, Zebu crossbreeds = 2.

² Daily feed offered per cow (kg) as-fed basis.

³ Use of pre- and post-dipping, CMT, forestrip, acid, or alkaline detergent (0 = no use, 1 = use).

⁴ Education (1 = incomplete basic education; 2 = complete basic education, 8 years; 3 = high school; 4 = graduation).

a,b,c - Means in the same row followed by distinct letters are significantly different (P<0.05).

highest quantity of corn silage than in clusters 2 and 3 (P<0.05). Regarding supplementation with commercial concentrate, both clusters 1 and 2 offered greater quantities compared with cluster 3 (P<0.05). In cluster 2, farmers used larger quantities of byproducts (CSB and WBG) compared with cluster 1 (P<0.05) and cluster 3 (P<0.05). Finally, in cluster 3, the SDS had the lowest production of milk/cow/day, albeit these farms have intermediate farm area and used the highest quantity of farm-made concentrate compared with clusters 1 and 2 (P<0.05).

Regarding milking management, farms in cluster 1 adopted appropriate milking practices more often, such as pre- and post-dipping, fore-stripping plus visual inspection of milk, and CMT for clinic and subclinic mastitis tests, respectively, and the use of acid and alkaline detergents to clean the milking equipment compared with clusters 2 and 3 (P<0.05). Regarding milk composition, farms in clusters 1 and 2 produced milk with higher concentrations of lactose and SNF but with lower concentration of fat than farms in cluster 3 (P<0.05). In Cluster 1, cows produced milk with the lowest SCC and TBC values (P<0.05) compared with clusters 2 and 3 (Table 4).

4. Discussion

Indicators that generated PF1, PF2, and PF3 are in line with previous studies that have shown that farm surface area, herd size, and feed management are important variables in the characterization of dairy systems. The importance of production scale (area and herd size) and feeding practices to explain the diversity observed in dairy systems in Brazil was already reported by Bodenmüller Filho et al. (2010), Gabbi et al. (2013), Werncke et al. (2016), and Balcão et al. (2017). Likewise, García et al. (2012), when characterizing 115 dairy farms in Central Mexico, reported that five PF explained 70.4% of the variance of data and that the first two PF included feeding strategies, such as forage and concentrate.

Farm area enables to gain scale in pasture-based milk production (Ferrari et al., 2005), and larger areas are positively associated with larger herd size and total milk production (Costa et al., 2013; Gabbi et al., 2013; Werncke et al., 2016). The use of byproducts is a relevant resource in ruminant diets to support lactation, maintaining milk yield and milk solids similar to those obtained with conventional ingredients, in addition to reducing feeding cost because of their competitive prices relative to other commodities (Ertl et al., 2015). Wet brewers grain has been used successfully in dairy farms because it does not affect dry matter intake and milk production (Imaizumi et al., 2015), increasing fat and milk protein contents (West et al., 1994) and, consequently, SNF. As we could notice, one unit of variable PF1 represents an increase of 0.05% in lactose and 0.07% in overall SNF, with a decrease of 0.08% in milk fat.

Wet brewers' grain has been reported as a good source of protein with 25 to 34% crude protein (CP), of which 35% is rumen degradable protein, which means that the remainder is bypass protein or rumen undegradable protein. It is also considered a great source of digestible fiber with 42 to 55% neutral detergent fiber, due to the removal of starches and sugars during the process, leaving mainly the structural cell wall carbohydrates, such as cellulose and hemicellulose (Meneghetti and Domingues, 2008). Centrifuged soybean meal is a byproduct of soybean meal, obtained by chemical processes, in which an important fraction of the protein is extracted for making food products for human consumption, constituting an alternative for the replacement of soybean meal in cattle diets, with average values of 33% CP and 71% of total digestible nutrients (Neumann et al., 2006). Farms that offered WBG also offered corn silage and commercial concentrate (Figure 1, Table 4). Altogether, these feeding practices increased nutrient supply, resulting in higher milk production and lactose content (Oliveira et al., 2011; Gabbi et al., 2018).

The negative linear relation observed between PF2 and milk yield and SNF% and Lact% is explained by the use of high quantities of sugarcane in detriment of corn silage in the less intensified SDS (Figure 1, Table 4), decreasing nutrient supply and thus milk yield and SNF% (Oliveira et al., 2011). The lower nutrient supply and highest SCC lowered Lact% in the milk (França et al., 2017). In the present study, 38.7% of SDS provided corn silage and 48.3% sugarcane as a source of roughage, while 13% relied on pasture. The greater use of sugarcane and low adoption of corn silage in cluster 3 may be due to the low investment capacity of these farmers, in agreement with the results of Martínez-García et al. (2020), who pointed out that factors such as land, financial resources, and machinery availability, as well as knowledge about silage making, affect silage adoption by farmers. Replacement of corn silage by sugarcane up to 50% of the diet (in dry matter basis) can lower feed cost without compromising milk production (Magalhães et al., 2004; Costa et al., 2005). Nevertheless, the inclusion of 33.3% sugarcane as roughage was economically viable, while higher levels (66.6 and 100%) were not. In the present study, sugarcane was supplied on average above 50% of total diet dry matter (Table 4), and there was no correction with urea and ammonium sulfate to improve nutritional quality.

Regarding PF3, the inverse association between commercial and farm-made concentrate between SDS was explained by the fact that less intensified SDS used larger quantities of farm-made concentrate together with commercial concentrate, while more intensified SDS used less total concentrate, much less farm-made concentrate and used more silage. It is worth pointing out that the farm-made concentrate was made by the producer without technical recommendation of ingredients or proper formulation.

Most of them used only energy ingredients such as ground corn grain, wheat, or rice bran not only due to the ease of acquisition but also due to the lack of guidance on the need to balance the sources of carbohydrates and nitrogen in the rumen. As β 3PF3 was positively related to all variables of milk yield and SNF%, we can infer that the supply of commercial concentrate contributed to the increase in milk production and improved milk composition.

According to Moran (2009), excessive levels of concentrate are used in SDS because most small dairy farmers keep more cows than they can handle, which means that they must purchase feed outside the farm, although frequently cows are underfed, making this the most expensive way to produce milk, which is in line with Balcão et al. (2017). On the same line, Sbrissia et al. (2017) stated that milk production is reduced when dairy farms do not have strategic forage reserves as silage or hay and adequate provision of concentrate throughout the year to meet the nutrient requirements when quantity and quality of pasture are insufficient.

These findings support our hypothesis that the lack of feed planning with pastures, conserved forages, or purchase of byproducts is likely to lead producers to buy and offer large quantities of concentrate ingredients in an attempt to compensate the deficiencies of quantity and quality of the roughage. These practices may contribute to increase or keep milk production, but at high and frequently non economical cost. Given that, our findings are based on a limited feed analysis; the results from such analysis should, therefore, be treated with considerable caution.

The SCC coefficients confirmed the negative influence on SNF% and Lact% in line with the literature (França et al., 2017). Regarding milk fat concentration, the positive values of the PF3 and negative values of the PF1 imply that the supply of larger quantities of farm-made concentrate with the low supply of byproducts and corn silage and predominance of crossbred cows (Figure 1) are associated with a higher milk fat concentration. Farm-made concentrates are produced without adequate nutrient balance or technical guidance and are mostly composed of simple high-energy ingredients (e.g., corn or sorghum grains, wheat bran, or rice bran) and when offered in large quantities, may reduce milk fat concentration due to fat synthesis depression (Bauman and Griinari, 2001). However, most of these farms also offer large quantities of sugarcane, probably indicating that the effective fiber was adequate to maintain normal rumen function and prevent low-fat milk syndrome.

Moreover, animals with low milk production usually present higher protein and fat concentration in their milk compared with more productive animals, as these milk components concentrate within a smaller milk volume in their mammary gland. It is also reasonable to consider the role of breed in fat and protein concentrations in milk, as Zebu crossbred cows produce milk with higher fat and protein contents than Holstein cows (Bovenhuis et al., 1992; Barbosa et al., 2008; Brasil et al., 2015).

Low coefficients of determination were found for Prot%, Fat%, and SNF%, implying that other factors have affected milk composition besides those enrolled in PFA (production scale and breed and feeding practices) or that there is weak linear relationship between PF and milk components. Nevertheless, even with a low R^2 value, the independent variables were statistically significant, which allows us to address the former considerations about relationships among PF, original variables, and milk components.

To assist in the discussion on the guidance of technical assistance, aiming at specific advice based on a set of similar characteristics for decision making, we classified our initial observations in three groups (Table 4). The results generated corroborate the idea that both feeding and milking management affect productive results. Among the dairy systems studied, cluster 2 combines farms with larger area and herd size and use of Holstein cows, leading to the highest yield per month. When other traits related to intensification of production were considered (e.g., milk yield per cow or milk yield per unit of area), cluster 2 showed intermediary values between clusters 1 and 3, indicating less intensification than SDS in cluster 1, what was also followed by intermediary values for farm-made concentrate and corn silage, producer's education level, and less efficient adoption of sanitary measures in the milking management, resulting in higher values for TBC and SCC compared with cluster 1. It is worth noting that cluster 2 offered the highest quantities of grain byproducts (WBG and CSB). Lower nutrient intake and high SCC may lead to more pronounced decrease in the amount of milk produced than in the synthesis of fat,

which in turn, may keep fat concentration similar to cows in cluster 1, with lower SCC and fed higher input of nutrients.

On the other side, SDS in cluster 3 may be classified as low intensified as they combine lack of production scale, e.g., small farm and herd size, use of crossbred cows, largest quantities of sugarcane, and farm-made concentrate, resulting in lower milk yield per cow, per area, and per farm. Due to less capacity of investment and probably due to lower education level, these SDS offered less corn silage and adopted less sanitary and hygienic measures during milking, resulting in higher SCC and TBC than those in cluster 1.

Despite the best feeding and milking practices observed in cluster 1, values of SCC and TBC are still beneath those recommended by Normative Instructions no. 76 and 77 (Brasil, 2018a,b), less than 500,000 cells/mL and 300,000 cfu/mL, respectively. All SDS, irrespective of their classification into the clusters, can be defined as smallholders' systems. Defante et al. (2019) observed that only 6.3% of dairy systems in Paraná, Brazil, reached the minimum quality standards for milk traits and pointed out that smallholders face expressive difficulty in meeting the milk quality normatives.

5. Conclusions

Our findings evidenced that the approach of using the quali-quantitative criteria of feed management to characterize smallholders' dairy systems is useful for better understanding the opportunities for improving milk production and composition. Increased supply of sugarcane beyond 50% of diet as the main source of roughage instead of corn silage negatively affects milk production, whereas moderate use of commercial concentrate as well use of byproducts increase milk yield without compromising milk solids content, especially when combined with adequate hygienic milking. Farmers relying on concentrate use, but without expressive quantities of good quality forages such as corn silage, produce less milk and may have their economical sustainability compromised.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: A.P. Dias and V. Fischer. Formal analysis: V. Fischer. Funding acquisition: V. Fischer. Investigation: A.P. Dias and V. Fischer. Methodology: A.P. Dias and V. Fischer. Project administration: A.P. Dias and V. Fischer. Resources: A.P. Dias and V. Fischer. Supervision: V. Fischer. Visualization: A.P. Dias and V. Fischer. Writing-original draft: A.P. Dias and V. Fischer. Writing-review & editing: A.P. Dias and V. Fischer.

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