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# Differences in the typology of dairy systems producing artisanal cheese and those producing only raw milk in Paraná State, Brazil

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**ABSTRACT** - We sought to develop a typology describing structural, production, and socioeconomic characteristics of dairy systems that produce artisanal cheese and compare it with that of systems that produce only raw milk. Data on 204 raw milk producers and 58 artisanal cheese producers in Paraná State, Brazil, were collected through on-site surveys and subjected to descriptive analysis, factor analysis, and means tests. Descriptive analyses were applied to characterize the sample and artisanal cheese production processes. Factor analysis identified the following three typological components: system production capacity, herd breed and milking characteristics, and farmer social characteristics. Farmers were divided into two groups, as follows: non-cheese producers (NCP) and artisanal cheese producers (ACP). Groups of farmers were compared in terms of typological components. It was found that ACP have smaller structure and production scale and focus less on herd breed and practices for improving milk quality than NCP. These results suggest that artisanal cheese production is a strategy to add value to milk that does not meet institutional or market requirements for transactions with the dairy industry, providing a foothold for producers to remain in the dairy business. Groups of farmers (ACP and NCP) do not differ in social indicators of typology.

**Keywords:** dairy farming, family production, informality, unlicensed

## 1. Introduction

Brazil is one of the world's major dairy producers, but the national milk production volume falls short of the country's potential (Bánkuti et al., 2020; FAO, 2020). Two major bottlenecks are the low production rates of dairy systems and a misalignment between the characteristics of milk produced in the country and market and institutional requirements for milk quality and volume (Bánkuti and Caldas, 2018; Defante et al., 2019). Faced with such difficulties, small-scale farmers have sought strategies to decrease costs and increase revenues, as exemplified by the use of bulk milk tanks, collective/cooperative arrangements for milk transactions, and artisanal cheese production (Brito et al., 2015; Martinelli et al., 2022).

In Brazil, artisanal cheese is usually produced from raw milk by using family labor and regional or local production techniques handed down over generations (Penna et al., 2021). However, despite the social, economic, and cultural importance of artisanal cheese production in Brazil, this activity is commonly carried out without regard for legal norms and, therefore, is considered part of the informal economy (Penna et al., 2021; Pineda et al., 2021). This situation has also been observed in other low- and middle-income countries (Alonso et al., 2018; Nyokabi et al., 2021).

Previous studies have sought to analyze artisanal cheese production in Brazil. However, most studies analyzed cheese parameters, microbiological indicators, production techniques, or the impact of institutional changes on the cheese sector (Penna et al., 2021; Pineda et al., 2021). We are unaware of any Brazilian study that has examined the typology of artisanal cheese production systems or compared their typology with that of dairy farms that produce only raw milk.

To address this knowledge gap, we aimed to develop a typology describing the structural and production characteristics of dairy systems and the socioeconomic characteristics of artisanal cheese producers and compare the findings with those from systems that produce only raw milk. Our results are expected to guide the development of public policies and private strategies for reducing problems associated with informality without disregarding the social, economic, and cultural importance of artisanal cheese in Brazil.

We hypothesized that non-cheese producers (NCP) have greater production capacity (number of lactating cows, milk production, milk production area, and total farm size) than artisanal cheese producers (ACP).

## 2. Material and Methods

Research procedures were approved by the local Human Research Ethics Committee (COPEP, protocol no. 2,396,173).

### 2.1. Sample and data collection

The study was conducted from January to May 2018. Data were collected through surveys administered on-site to 204 raw milk producers and 58 ACP in three mesoregions of Paraná State, namely Central-North (n = 98 dairy farms, 37.40% of the sample), West (n = 93 dairy farms, 35.50% of the sample), and Central-East (n = 71 dairy farms, 28.80% of the sample). These three mesoregions together account for about 25.40% of the milk production and 22.56% of the artisanal cheese production of the state (IBGE, 2018). Milk producers were identified from records of milk collection routes provided by members of cooperatives and dairy industries. Cheese producers were identified from information provided by technical assistance and agricultural extension agencies in Paraná. The only criterion used for sample selection was that dairy systems had to produce milk and/or artisanal cheese in Paraná. Within each mesoregion, producers were selected by convenience sampling, according to ease of access and farmers' consent to participate in the research.

Surveys contained questions on structural and production characteristics of dairy farms, technical variables related to animal management and milking hygiene, variables related to artisanal cheese production, and social characteristics of farm operators. A yes–no question was used to divide farms into two groups, NCP and ACP (Table 1).

### 2.2. Sample characterization

Descriptive analyses for sample characterization were performed in two stages, the first considering structural, productive, and socioeconomic variables of rural producers (V1 to V9, Table1) and the second considering variables related to artisanal cheese production (V13 to V19, Table 1).

### 2.3. Typological indicators

For typological analysis, 12 variables (V1 to V12, Table 1) were subjected to factor analysis, performed as follows (Eq. 1):

**Table 1 -** Characteristics of variables collected in dairy systems

| Variable | Level of measurement | Data type | Statistical analysis |
|---|---|---|---|
| V1. Age of farm operator | Numerical | Metric | DA and FA* |
| V2. Level of education of farm operator (years) | Numerical | Metric | DA and FA* |
| V3. Experience in the dairy business (years) | Numerical | Metric | DA and FA |
| V4. Total farm size (ha) | Numerical | Metric | DA and FA* |
| V5. Milk production area (ha) | Numerical | Metric | DA and FA* |
| V6. Number of workers for milk production | Numerical | Metric | DA and FA* |
| V7. Milk production (L/day) | Numerical | Metric | DA and FA* |
| V8. Milk yield per cow (L/cow) | Numerical | Metric | DA and FA |
| V9. Number of lactating cows | Numerical | Metric | DA and FA* |
| | 1 - Zebu crossbreeds | | |
| V10. Herd breed | 2 - Girolando | Ordinal | FA* |
| | 3 - Holstein, Jersey, Brown Swiss, Gir | | |
| | 1 - Immersion tank | | |
| V11. Cooling system | 2 - Bulk milk tank | Ordinal | FA* |
| | 3 - Individual tank | | |
| | 1 - Manual | | |
| V12. Milking system | 2 - Mechanical with foot bucket | Ordinal | FA* |
| | 3 - Mechanical with transfer line | | |
| | 4 - Pipeline | | |
| V13. Percentage of production sold as liquid milk | Numerical | Metric | DA |
| | 1 - Frescal | | |
| V14. Type of artisanal cheese produced | 2 - Colonial | Nominal | DA |
| | 3 - Other | | |
| | 1 - House kitchen | | |
| V15. Cheese production facility | 2 - Cheese room | Nominal | DA |
| | 3 - Other | | |
| V16. Milk used for cheese production | 1 - Raw milk | Nominal | DA |
| | 2 - Pasteurized milk | | |
| | 1 - Not inspected | | |
| V17. Sanitary inspection of cheese production | 2 - Municipal inspection | Nominal | DA |
| | 3 - State inspection | | |
| | 4 - Federal inspection | | |
| | 1 - Common refrigerator | | |
| V18. Cheese storage | 2 - Cold room | Nominal | DA |
| | 3 - Other | | |
| | 1 - Final consumers | | |
| V19. Main buyers | 2 - Markets, bakeries, street markets | Nominal | DA |
| | 3 - Other | | |
| V20. Artisanal cheese production? | 1 - No | Nominal | IV |
| | 2 - Yes | | |

DA - descriptive analysis; FA - factor analysis; IV - independent variable used for classification of farmers into two groups (artisanal cheese producers and non-producers).
* Variables retained in factor analysis.

$$X_1 = a_{11} \times F_1 + a_{12} \times F_2 + \cdots + a_{1m} \times F_m + e_p$$
$$X_2 = a_{21} \times F_1 + a_{22} \times F_2 + \cdots + a_{2m} \times F_m + e_p$$
$$\vdots$$
$$X_p = a_{p1} \times F_1 + a_{p2} \times F_2 + \cdots + a_{pm} \times F_m + e_p \quad (1)$$

in which $X_p$ 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 were estimated for each dairy farm by multiplying standardized variables by the coefficient of the corresponding factor score (Eq. 2):

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

in which $F_j$ is the $j$-th factor extracted, $d_{jp}$ is the factor score coefficient, and $p$ is the number of variables (Hair et al., 2009).

Principal component analysis with Varimax rotation was used as the extraction method. Kaiser–Meyer–Olkin (KMO) and Bartlett's sphericity tests were conducted (Hair et al., 2009). Variables with low to medium factor loadings ($<|0.5|$) were excluded, and factors with eigenvalues equal to or greater than 1.0 were retained, as defined by the Kaiser criterion (Hair et al., 2009). Factors were saved as regression measures, thereby allowing comparison of factor scores as mean values (Field, 2009). Variables V1 to V12 (Table 1) were used for typological analysis.

### 2.4. Grouping and typological analysis of dairy systems

At this stage, dairy farms were separated into two groups, namely ACP and NCP. For typology determination, mean factor scores generated by factor analysis were compared between those two groups using means tests (Brito et al., 2015). This procedure allowed for objective analysis of the structural, production, and socioeconomic variables of groups. With this result, it was possible to characterize groups using a single value representing a set of characteristics. Of note, typological indicators generated by factor analysis do not have a unit of measurement, making it difficult to compare, for example, how much mean milk production volume (L/day) differs from one group to the other or assess differences in age or education level (years) between NCP and ACP groups. Given this limitation, we applied means tests for variables related to structural, production, and socioeconomic characteristics that were used as inputs for generation of typological indicators. This method has been used in previous studies (Bánkuti et al., 2020; de Oliveira Sidinei et al., 2021; Dias and Fischer, 2021). Prior to means tests, the data were assessed for normality by the Kolmogorov–Smirnov and Shapiro–Wilk tests and for homogeneity of variance by Levene's test. Given the non-normality of variables, we used the non-parametric Games–Howell test ($P<0.05$) (Field, 2009). Statistical analyses were conducted using Jamovi software version 2.2.

## 3. Results

### 3.1. General characteristics of dairy production systems and farmers

Farm managers had a mean age of 46.33±12.20 years, with a range of 18 to 84 years. As for formal education, farmers had a mean of 9.29±3.84 years of study, with a range of 0 to 17 years. The mean experience in the dairy activity was 19.99±12.17 years, ranging from 1.00 to 60.00 years. Analysis of production characteristics showed a mean farm size of 35.40±67.75 ha, with a range of 1.00 to

700.00 ha, and a mean milk production area of 18.79±28.38 ha, with minimum and maximum values of 0.50 and 250.00 ha, respectively. Dairy farms had on average 38.02±65.07 lactating cows, ranging from 2.00 to 600 lactating cows, which produced a mean of 882.00±2,319.08 L of milk per day, with a range of 6.00 to 24,000.00 L of milk daily. Farms had on average 3.05±2.37 individuals working in milk production, with the number of workers ranging from 1.00 to 24.00 individuals. Classification of farms according to type of product showed that 77.90% of dairy farms (n = 204) did not produce artisanal cheese (NCP). The remainder (n = 58, 22.10%) were classified as ACP.

Of the farmers who reported carrying out artisanal cheese production, 37.90% (n = 22) also sold raw milk. In this subgroup, raw milk sales accounted for only 23.02% of the total volume of milk produced, suggesting high economic dependence on cheese production. More than half of ACP (56.90%) produced frescal-type cheese, and the remaining 43.10% produced colonial-type cheese. The facility used for cheese production by 60.30% (n = 35) of ACP was the house kitchen, whereas 39.70% (n = 23) had a separate room designed specifically for cheese production. The majority of ACP (n = 51, 87.90%) produced cheese from raw milk, and only 12.10% (n = 7) reported using pasteurized milk.

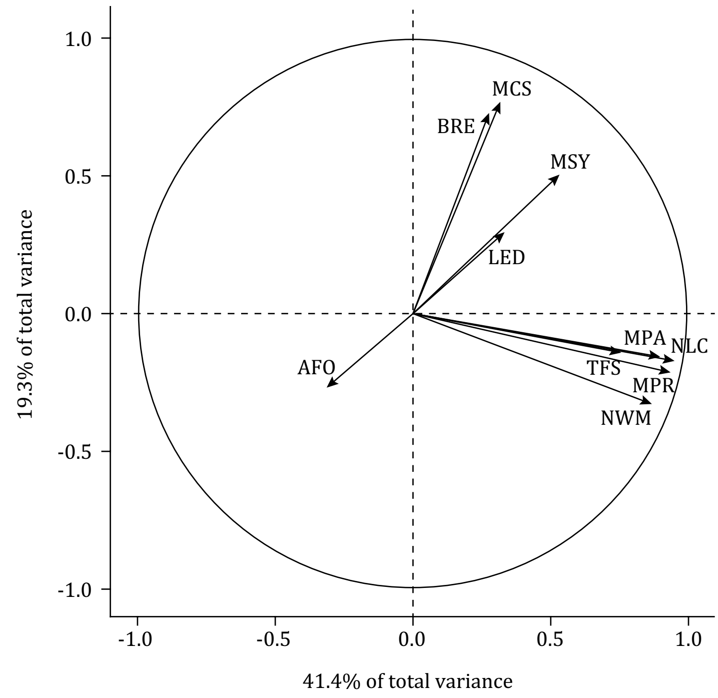
Most ACP (n = 39, 67.20%) were not licensed for this activity by sanitary inspection agencies and were, therefore, part of the informal economy. A lower proportion of ACP (n = 19, 32.80%) held a municipal license. Analysis of cheese storage facilities showed that 89.70% (n = 52) of ACP stored artisanal cheese in a common refrigerator at the farmer's house. A cold chamber was used by only 1.70% (n = 1) of ACP. About 8.60% (n = 5) used other forms of storage, such as isothermal containers. Analysis of marketing channel data revealed that most ACP (n = 48, 82.80%) sold their artisanal cheese to final consumers. About 13.80% (n = 8) sold their products mainly to small markets, bakeries, and street markets, and about 3.40% (n = 2) used other distribution channels, such as restaurants.

### 3.2. Typology of ACP and NCP systems

Typological indicators were obtained by factor analysis. KMO (0.80) and Bartlett's sphericity (0.00) tests indicated that the variables were suitable for analysis by the selected method (Hair et al., 2009). Analysis of variance showed that two or three factors could be retained, given that the first two factors had eigenvalues equal to or greater than 1.0 and cumulative variance greater than 60% (Hair et al., 2009). Three factors were retained because of the greater accumulation of variance and the importance of variables defining the third factor. Analysis of orthogonal plans derived from factor analysis revealed a positive relationship among almost all variables that defined the three factors. An exception was the variable age of farm operator, which showed an inverse relation to level of education of farm operator (Figure 1).

The first factor (F1) was defined by variables related to structural and production characteristics of dairy systems, representing their production scale (Table 2). Given this, F1 is referred to as system production capacity (SPC). The production scale of dairy systems is indicative of their ability to meet market demands related to the minimum volume of milk traded with the industry (Simões et al., 2021). The second factor (F2) was defined by variables related to herd breed, milking hygiene, and cooling procedures (Table 2). These variables are directly associated with raw milk quality and production volume, which are critical aspects in artisanal cheese production (Pineda et al., 2021). Therefore, F2 was named herd breed and milking characteristics (HBMC). The third factor (F3) was formed by the variables age and years of study of the farm operator. Thus, F3 was named farmer social characteristics (FSC).

Variances explained by typology components revealed that dairy farm systems differed mainly in production capacity (SPC, 41.40% of variance explained), followed by milk quality (HBMC, 19.30% of variance explained) and social characteristics (FSC, 14.50% of variance explained) (Table 2).




System production capacity: NLC - number of lactating cows, MPR - milk production, NWM - number of workers for milk production, MPA - milk production area, TFS - total farm size. Herd breed and milking characteristics: BRE - herd breed, MCS - milk cooling system, MSY - milk system. Farmer social characteristics: LED - level of education of farm operator, AFO - age of farm operator.

**Figure 1 -** Orthogonal plan with principal factors for variables related to system production capacity, herd breed and milking characteristics, and farmer social characteristics.

**Table 2 -** Variables retained in each factor (in brackets) and factor's explained variance

| Variable | F1 | F2 | F3 |
|---|---|---|---|
| Number of lactating cows (head) | (0.948) | 0.172 | 0.102 |
| Milk production (L/day) | (0.946) | 0.116 | 0.095 |
| Number of workers for milk production | (0.918) | 0.014 | 0.074 |
| Milk production area (ha) | (0.892) | 0.184 | 0.084 |
| Total farm size (ha) | (0.748) | 0.110 | 0.136 |
| Herd breed | 0.031 | (0.841) | −0.029 |
| Milk cooling system | 0.012 | (0.871) | 0.126 |
| Milking system | 0.298 | (0.777) | 0.067 |
| Level of education of farm operator (years) | 0.118 | 0.095 | (0.829) |
| Age of farm operator (years) | −0.101 | −0.086 | (−0.828) |
| Eigenvalue | 4.140 | 1.930 | 1.450 |
| Variance (%) | 41.400 | 19.300 | 14.500 |
| Cumulative variance (%) | 41.400 | 60.700 | 75.200 |

F1 - system production capacity (SPC); F2 - herd breed and milking characteristics (HBMC); F3 - farmer social characteristics (FSC).

Analysis of typological components by groups of farmers indicated that NCP scored higher on SPC and HBMC than ACP (P<0.05). No differences in FSC scores were observed between groups (P>0.05) (Table 3).

In addition to typological indicators, we compared structural, production, and socioeconomic variables between NCP and ACP systems, allowing for a more detailed assessment. Analysis of production and structural characteristics showed significant differences between groups in all variables (P<0.05). There were no differences in socioeconomic characteristics (P>0.05) (Table 4).

**Table 3** - Factor scores for non-cheese producers (NCP) and artisanal cheese producers (ACP)

| Factor | Group | N | Mean±SD | P-value |
|---|---|---|---|---|
| SPC | NCP | 204 | 0.039±1.126a | 0.036 |
| | ACP | 58 | −0.136±0.205b | |
| HBMC | NCP | 204 | 0.428±0.393a | 0.000 |
| | ACP | 58 | −1.507±1.028b | |
| FSC | NCP | 204 | 0.0150±0.928a | 0.698 |
| | ACP | 58 | −0.052±1.229a | |

SPC - system production capacity; HBMC - herd breed and milking characteristics; FSC - farmer social characteristics; SD - standard deviation.
Means followed by the same letters in the column do not differ by the Games-Howell-test at a significance level of 5%.

**Table 4** - Structural, productive, and socioeconomic characteristics for non-cheese producers (NCP) and artisanal cheese producers (ACP)

| Variable | Group | N | Mean±SD |
|---|---|---|---|
| Number of lactating cows (head) | NCP | 204 | 45.710±71.788a |
| | ACP | 58 | 10.970±9.061b |
| Milk production (L/day) | NCP | 204 | 1126.700±2577.387a |
| | ACP | 58 | 21.340±12.983b |
| Number of workers for milk production | NCP | 204 | 3.070±2.637a |
| | ACP | 58 | 2.980±1.068b |
| Milk production area (ha) | NCP | 204 | 21.900±31.303a |
| | ACP | 58 | 7.870±6.522b |
| Total farm size (ha) | NCP | 204 | 41.050±75.679a |
| | ACP | 58 | 15.550±10.320b |
| Herd breed[1] | NCP | 204 | 3.990±0.140a |
| | ACP | 58 | 2.790±0.894b |
| Milk cooling system[2] | NCP | 204 | 2.960±0.240a |
| | ACP | 58 | 1.910±0.960b |
| Milking system[3] | NCP | 204 | 3.090±1.018a |
| | ACP | 58 | 1.880±0.595b |
| Level of education of farm operator (years) | NCP | 204 | 9.700±3.743a |
| | ACP | 58 | 8.470±5.696a |
| Age of farm operator (years) | NCP | 204 | 45.750±11.878a |
| | ACP | 58 | 48.360±13.192a |

[1] 1 - Zebu crossbreeds; 2 - Girolando; 3 - Holstein, Jersey, Brown Swiss, Gir.
[2] 1 - immersion tank; 2 - bulk milk tank; 3 - individual tank.
[3] 1 - manual; 2 - mechanical with foot bucket; 3 - mechanical with transfer line; 4 - pipeline.
Means followed by the same letters in the column do not differ by the Games-Howell test at a significance level of 5%.

It was found that NCP had a greater number of lactating cows (45.71±71.78 cows) than ACP (10.97±9.07 cows). The number of lactating cows varied from 3.00 to 600.00 for NCP and from 2.00 to 40.00 for ACP. The mean milk production was also higher in the NCP group, 1126.70±2577.38 L/day. ACP had a mean milk production volume of only 21.34±12.98 L/day. This variable ranged from 40.00 to 24,000.00 L/day for NCP and from 3.00 to 60.00 L/day for ACP. The number of workers was also higher in NCP (3.07±2.63 individuals) than in ACP systems (2.98±1.06 individuals). In NCP systems, the workforce ranged from 1.00 to 24.00 workers, whereas, in ACP systems, the range was 2.00 to 6.00 workers. Milk production per area was higher in the NCP group than in the ACP group (21.90±31.30 *vs.* 7.87±6.52 L/ha). This variable ranged from 1.00 to 250.00 L/ha in NCP systems and from 0.50 to 24.20 L/ha in ACP systems. Non-cheese producers also had a higher farm size than ACP, 41.05±75.67 and 15.55±10.32 ha, respectively. Farm size ranged from 1.00 to 700.00 ha for NCP and 1.30 to 48.40 ha for ACP. Herd breed also differed significantly between groups; NCP had a mean herd breed score of 3.99±0.14, whereas ACP had a mean score of 2.79±0.89. Herd breed scores had the same range in both groups (2.00 to 4.00).

Non-cheese producers had higher mean scores on milk cooling variables than ACP (2.96±0.24 *vs.* 1.91±0.96). Milk cooling score ranges did not differ between groups (1.00 to 3.00). Differences in milking hygiene scores were significant: NCP and ACP had mean milking hygiene scores of 3.09±1.01 and 1.88±0.59, respectively, with a range of 1.00 to 4.00 for both groups.

## 4. Discussion

### 4.1. General sample characterization

The study sample comprised relatively young farmers with a low level of education and substantial experience in the dairy activity, as already observed in other studies analyzing milk farmers in Paraná (Brito et al., 2015; Bánkuti et al., 2020). Hyland et al. (2018) reported that younger farm operators tend to respond more favorably to institutional and market requirements than older operators. Low level of education, however, may hinder farmers' compliance with institutional and market demands.

The evaluated dairy systems were characterized as having small and medium production scales, typical of dairy production systems in Paraná and Brazil (IBGE, 2018). However, total farm size and average milk production were higher than the mean observed in the state. In Paraná, 76% of dairy systems have a total farm area of less than 20 ha, 33% of which have a total size of 6–10 ha and an average milk production of 37.43 L/day (IBGE, 2018). The great heterogeneity observed in the sample represents the reality of milk production systems in Paraná (Yabe et al., 2015; Defante et al., 2019; Bánkuti et al., 2020).

The good performance of farms evaluated in this study can be explained by the characteristics of dairy systems located in Western and Central-Eastern Paraná, which comprised about 63% of the study sample. Dairy farms in these regions are characterized by high production capacity, high productivity, and use of more advanced production technologies compared with farms in other regions (Bánkuti and Caldas, 2018).

### 4.2. Characteristics of artisanal cheese production

Of the 262 dairy farms analyzed, 22.10% produced artisanal cheese. This proportion is higher than that estimated for Paraná (11.22%) and Brazil (14.89%) (IBGE, 2018). Half of the cheese-producing farmers stored milk in immersion coolers, 41.10% stored milk in individual cooling tanks, and 8.60% stored milk in community cooling tanks. In analyzing legal aspects of cheese production, we found that 67.2% of farms did not have sanitary permits for artisanal cheese production, characterizing an informal activity. The other farms had authorization from municipal inspection bodies.

In general, informal activities do not comply with part or all of the rules defined by the institutional environment, being guided by informal norms, values, and behaviors. Therefore, such activities are limited in terms of development, given that informal systems cannot participate in the most demanding markets and are subject to legal penalties (Pinto-Correia et al., 2021). In most cases, artisanal cheese was produced in home kitchens from raw milk stored in common refrigerators, following production, hygiene, and quality criteria determined by the farmers themselves. Such criteria derived from farmers' interpretation of current sanitary legislation or from personal knowledge, generally passed from generation to generation. These conditions demonstrate the inadequacy of these practices, which may cause public health problems. Liguori et al. (2022) argued that most of the diseases caused by food contamination in low- and middle-income countries stem from unsafe production practices.

Brazilian legislation states that artisanal cheese production facilities must be adequate to ensure product quality and safety. Maturation periods shorter than 60 days are allowed, provided that the quality and harmlessness of the resulting cheese have been proven scientifically. Furthermore, legislation states that artisanal cheese production must be carried out in cheese dairies located in regions with registered or traditionally recognized geographical identification, in properties certified to be free of or controlled for tuberculosis and brucellosis. Rural properties with cheese dairies must implement a program to control clinical and subclinical mastitis and adopt good milking and manufacturing practices, including operator control, pest control, and adequate transport to warehouses, as well as chlorination and control of the potability of water used for production. Milk used for artisanal cheese production must comply with microbiological and physicochemical standards determined by the legislation in force (Brasil, 2013, 2019).

Failure to comply with sanitary legislation can cause public health problems of various kinds, because raw materials used in cheese production are a source of contamination by zoonotic pathogens. For instance, *Brucella* spp. are the causative agents of brucellosis, a disease that can cause abortion and various reproductive problems in cattle, thereby generating economic losses to farmers. In humans, brucellosis can cause generalized infection. Another frequent pathogen found in dairy products made from unpasteurized milk is *Mycobacterium bovis*, one of the causative agents of tuberculosis. In animals, tuberculosis causes nodular lesions on the skin and other organs, which may lead to abortion and reduced milk production, ultimately requiring euthanasia. In humans, tuberculosis results in several health problems, especially in the lungs. Other pathogens, such as *Staphylococcus aureus*, *Salmonella* spp., *Listeria monocytogenes*, *Campylobacter* spp., and *Escherichia coli* can cause health problems in both cattle and humans (Penna et al., 2021; Pineda et al., 2021). The presence of such pathogens in raw milk and dairy products is common in other areas of the world (Alonso et al., 2018; Lemma et al., 2018; Nyokabi et al., 2021).

In agreement with the findings of Pineda et al. (2021), we found here that compliance with legislation seems to be difficult and costly for dairy farmers, especially those with a small production scale. Furthermore, many farm managers claimed that the process of obtaining sanitary permits for artisanal cheese production incurs high costs, making the activity unfeasible. Of note, several studies reported problems associated with contamination of Brazilian artisanal cheeses (Penna et al., 2021; Pineda et al., 2021).

For many farmers, producing and selling artisanal cheese seems to represent a way to add value to milk, maintain cultural traditions, and remain in rural areas. Artisanal cheese is well accepted by society and, in some cases, may contribute to the development of the local economy. In recent years, some artisanal cheese producers in Brazil have stood out for representing tradition, innovation, and product quality (Penna et al., 2021). However, there are many artisanal cheese production systems that require adaptations.

Of the dairy systems producing cheese, 56.90% (n = 33) produced Minas frescal cheese and 43.10% (n = 25) produced colonial cheese. Frescal cheese is among the most produced types of cheese in Brazil (Penna et al., 2021). It has a soft texture and is usually produced from raw milk in rural areas, although it can be produced from pasteurized milk, as commonly occurs in dairy industries. Colonial cheese has a yellowish hard or semi-hard shell with a soft and creamy mass. This artisanal cheese is also produced from raw milk and is among the most produced and consumed in Southern Brazil (Kamimura et al., 2019). Artisanal cheese is mainly sold directly, from producers to consumers, or in small retail outlets, street markets, and bakeries. Marketing channels like these have also been reported in informal dairy trade in other countries (Alonso et al., 2018).

In the majority of cases (82.8%), cheese was sold directly to consumers. In these transactions, relationships of trust and convenience, such as home delivery and the possibility of paying every 15 or 30 days, are perceived by consumers as differential factors. Many farmers have their own stalls in street markets, whereas others sell their cheese to third-party stalls, small markets, or bakeries, almost always located in non-central regions of Brazilian cities (Pineda et al., 2021). For many farmers, there is the understanding that greater profit can be reached by selling artisanal cheese, as it represents an increase in the price of milk per liter. However, this perception is questionable, given that some farm managers do not control the costs of milk or cheese production.

### 4.3. Analysis of typology

Typological analysis of dairy systems and their managers revealed that NCP exhibited greater production capacity (e.g., number of lactating cows, milk production, milk production area, and total farm size). This finding allows us to accept the hypothesis of this study. Furthermore, NCP had superior herd breed and milk quality indicators than ACP (Table 3). Structural and production characteristics are crucial for discriminating groups of dairy producers in Paraná. Several studies analyzing aspects related to sustainability, competitiveness, and compliance with milk quality standards, among others, showed that dairy farms with a larger production scale tend to have better results than those with smaller production scales (Brito et al., 2015; Balcão et al., 2017; Defante et al., 2019; Dias and Fischer, 2021).

Milk production volume is indicative of the production capacity of dairy systems. As a rule, producers who trade higher volumes receive a higher value per liter of milk, given the reduction of costs associated with bulk milk transportation (Bánkuti et al., 2020). By contrast, farmers who trade small volumes of milk tend to be paid less per liter of milk and have greater difficulty finding buyers. The results of the current study show that NCP had higher total farm and milk production areas, number of workers, number of lactating cows, and milk production per cow than ACP. Therefore, the greater production structure and better adaptation to market demands of NCP suggest that these systems are more likely to remain competitive in the medium and long terms. Previous studies demonstrated that production scale is related to increased investment in production technologies, use of cost management and control systems, and qualified labor (Zimpel et al., 2017; Gargiulo et al., 2018), characteristics that may be more frequent for NCP.

Analysis of bulk milk quality indicated that NCP used more specialized herd breeds and better milking and milk cooling technologies than ACP. Breeds specialized in milk production tend to produce higher milk volumes. Milking and cooling processes are crucial for raw milk quality and, consequently, artisanal cheese quality (Defante et al., 2019; Pineda et al., 2021). Furthermore, increased milk quality results in better remuneration in transactions with the industry (Simões et al., 2021).

Given these results, it is believed that ACP encounter greater difficulty and may be discouraged from selling raw milk to the industry. In extreme cases, low milk quality combined with low production volume, as observed among ACP, may even lead farmers to exit the dairy activity, a trend that has been observed not only in Brazil but also in several other countries, as previously reported (Gargiulo et al., 2018; IBGE, 2018). These results reinforced the perception we had during questionnaire application. Some ACP mentioned that cheese production represented an option for adding value to milk, a product for which farmers have received low remuneration in transactions with the industry. They also claimed that the industry has become more demanding, especially in relation to the minimum volume of milk sold per producer.

The qualitative information obtained during survey application further corroborates that low production scale and low milk quality are factors that stimulate artisanal cheese production, also influenced by the growing demand for artisanal cheese and the perception that cheese production adds value to raw milk, as also reported by Pineda et al. (2021). Another contributing factor is the low supervisory power of competent bodies in reprimanding artisanal cheese production systems that do not meet regulatory criteria.

The results for bulk milk quality allow us to suggest that ACP have a higher risk of leaving the activity in the medium and long terms or of remaining in adverse conditions compared with NCP.

Greater risk of leaving the activity is mainly associated with non-compliance with sanitary legislation for artisanal cheese production and type of milk storage. Half of the ACP stored milk in immersion tanks. According to Brazilian legislation, milk must be cooled in cooling tanks.

This situation underscores the need for public policies and private strategies aimed at increasing production scale and improving milk production practices. An example is the inclusion of dairy farmers in horizontal arrangements, such as cooperatives and production associations, which may facilitate access to information, economies of scale, training, and acquisition of technologies and equipment shared with other members (Martinelli et al., 2022).

Groups did not differ in FSC scores. This result indicates that, for the analyzed cases, there is no relationship between the decision to produce artisanal cheese and farmers' age or education level and that there is an inverse relationship between farmers' age and years of education; that is, younger farmers tend to have more years of formal education than older farmers (Table 2).

Individualized analysis of structural, productive, and socioeconomic variables confirmed the results of typological indicators for the analyzed groups, demonstrating that NCP have a greater production capacity and productivity than ACP. Socioeconomic variables, however, did not differ between groups.

This research has a set of limitations, including the impossibility of extrapolating the results. We believe that our results represent well the analyzed sample, demonstrating the reality of milk and cheese production in the study regions. Another limitation is related to possible problems of interpretation and errors in data collection. Although the research team was trained for this task, we cannot rule out the possibility of mistakes. Furthermore, farmers might have provided incorrect or inaccurate data. Another limitation is that data were not collected as a time series, which would have allowed for better representation of the reality of the study sample.

We suggest future studies to address the gaps identified here. Farmers' perception of the sanitary adequacy of artisanal cheese production should be evaluated. For this, it is suggested that theories related to decision-making be used as theoretical framework, such as the theory of planned behavior.

## 5. Conclusions

Artisanal cheese producers have smaller farm structure and production scale than non-cheese producers. Furthermore, artisanal cheese producers focus less on the use of specialized breeds for milk production and on practices to improve milk quality. The better results of non-cheese producers indicate a greater degree of adequacy to institutional and market demands related to the minimum volume of milk traded with the industry and compliance with criteria that interfere with milk quality. Therefore, in the study sample, farmers who only produce milk tend to have a greater chance of remaining in the dairy business in the medium and long terms compared with artisanal cheese producers. The small milk production scale, use of less specialized breeds, and use of less adequate milking and milk storage techniques by artisanal cheese producers may contribute to their non-conformity with institutional and market demands, generating incentives for artisanal cheese production as an alternative for utilizing milk that would have low acceptance and low valuation in transactions with the industry. This situation underscores the need for public policies and private strategies aimed at increasing production scale and improving milk production practices in systems of artisanal cheese producers. An example is the inclusion of dairy farmers in horizontal arrangements, such as cooperatives and production associations, which may facilitate access to information, economies of scale, training, and acquisition of technologies and equipment shared with other members. Another possibility is the provision of technical assistance by public or private entities for legalization of artisanal cheese production, for instance, to qualify for the ARTE label. Such assistance would need to be adapted to the specific characteristics of each production system. Furthermore, it is suggested that licensed farmers sell artisanal cheese to markets that value family production and cultural, local, and human aspects of artisanal cheesemaking.

## Conflict of Interest

The authors declare no conflict of interest.

## Author Contributions

Conceptualization: F.I. Bánkuti, G. Oliveira and J.C. Damasceno. Data curation: F.I. Bánkuti, G. Oliveira, P.G.L. Lima and M.A. Zambom. Formal analysis: F.I. Bánkuti, J.C. Damasceno and P.G.L. Lima. Funding acquisition: G. Oliveira. Investigation: F.I. Bánkuti, J.C. Damasceno, P.G.L. Lima, M.A. Zambom and M.D.M. Bouroullec. Methodology: F.I. Bánkuti, J.C. Damasceno and P.G.L. Lima. Project administration: F.I. Bánkuti and M.D.M. Bouroullec. Software: F.I. Bánkuti. Supervision: F.I. Bánkuti. Validation: F.I. Bánkuti. Visualization: F.I. Bánkuti. Writing – original draft: F.I. Bánkuti and M.D.M. Bouroullec. Writing – review & editing: F.I. Bánkuti.

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