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Artisanal Minas cheese parameters associated with regions of origin in Minas Gerais, Brazil

[*Determinação de parâmetros do queijo minas artesanal associados com as regiões de origem em Minas Gerais, Brasil*]

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ABSTRACT

Artisanal cheese production involves a centuries-old tradition in the state of Minas Gerais in Brazil, playing an important historical and social role. The aim of this study was to evaluate the characteristics of artisanal Minas cheeses from seven regions certified for their production in relation to their physical-chemical and centesimal composition to identify parameters that are useful to differentiate them. There were differences among the cheeses from different regions for the soluble nitrogen variables, extension and depth of ripening indexes, ash, oxidation, fat and pH. The highest values for the ripening length and depth index were observed in the Cerrado region. The cheeses from the Canastra region were different due to the higher moisture content, and the cheeses from Campo das Vertentes presented higher pH and nitrogen compound values. Despite the similarities among cheeses in each region, they had dispersed positions in the principal components analysis. There are differences in the physicochemical and centesimal composition among the artisanal Minas cheeses from the distinct regions in Minas Gerais, and the analyzed parameters can be used to differentiate them. The contents of ash, fat, oxidation index, soluble nitrogen and pH were the parameters that were associated with greater differences in cheeses.

Keywords: authenticity, certification; regional characterization, Canastra, Serro

RESUMO

A produção artesanal de queijos envolve uma tradição secular no estado de Minas Gerais, no Brasil, exercendo importante papel histórico e social. Objetivou-se, com este estudo, avaliar as características de queijos minas artesanal de sete regiões certificadas para sua produção em relação à sua composição físico-química e centesimal, a fim de se identificarem parâmetros que sejam úteis para diferenciá-los. A composição físico-química e centesimal revelou diferença entre os queijos das diferentes regiões para as variáveis nitrogênio solúvel, índices de extensão e profundidade de maturação, cinzas, oxidação, gordura e pH. Os maiores valores para os índices de extensão e profundidade de maturação foram observados na região do Cerrado. Os queijos da região da Canastra se mostraram diferentes daqueles das demais regiões em razão do maior teor de umidade, assim como os queijos de Campo das Vertentes, que apresentaram maiores valores de pH e compostos nitrogenados. Apesar das semelhanças entre os queijos em cada região, esses apresentaram posicionamentos dispersos na análise de componentes principais. Existem diferenças na composição físico-química e centesimal entre os queijos minas artesanais oriundos das distintas regiões em Minas Gerais, e os parâmetros analisados podem ser utilizados para diferenciá-los. Os teores de cinzas, gordura, índice de oxidação, teores de nitrogênio solúvel e pH foram os parâmetros que estiveram associados a maiores diferenças dos queijos conforme sua região de origem.

Palavras-chave: autenticidade, certificação, caracterização regional, Canastra, Serro

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INTRODUCTION

Artisanal cheese production involves a secular tradition with its manufacturing method passed on for generations, playing an important historical social and cultural role, in addition to supporting the survival of several families and fostering the economy of municipalities and regions in Brazil. Minas Gerais is the most traditional state in cheese production in Brazil, and currently, ten regions are recognized and certified by specific ordinances of the Instituto Mineiro de Agropecuária - IMA for the production of artisanal Minas cheese: Araxá, Campos das Vertentes, Canastra, Cerrado, Diamantina, Entre Serras da Piedade ao Caraça, Serra do Salitre, Serro, Triângulo Mineiro and Serras da Ibitipoca (Instituto…, 2006; Kamimura *et al*., 2019, Minas Gerais, 2022).

Artisanal Minas cheese is defined as cheese prepared from raw milk on the property where the milk comes from and according to the historical and cultural tradition of the region of the state where it is produced (Minas Gerais, 2020), which brings these and other guidelines regarding its production. Additionally, according to the document, the final product must have firm consistency, its own color and flavor, uniform mass, be free of dyes and preservatives, and there may or may not be the presence of mechanical bruises. Several conditions confer peculiar characteristics to each cheese, such as the type of feed and pasture available to the animals, composition of the "pingo" (milk-based serum-ferment), environmental conditions, regional microbiological diversity, form and ripening time, among others (Dores and Ferreira, 2012; Kamimura *et al*., 2019).

Artisanal cheeses in Minas Gerais have small-scale production, mostly family-based, and limited level of technification as common factors. Since it is a handmade product and is made according to historical tradition passed down through generations, variations in the production process are observed between each producer and region. The use of the "pingo" - natural culture obtained from the desorption of the cheeses produced the day before - transfers the local microbiota of the raw milk to the cheeses, as well others belong to environment where the cheeses are produced and that acting directly on the final attributes of flavor, aroma, and acidity (Santos *et al*., 2017). Therefore, the ripening process that, through various biochemical and microbiological changes, releases compounds such as short-chain fatty acids directly influences the flavor of artisanal cheeses (Bezerra *et al*., 2016). In addition, the edaphoclimatic factors of the production site (*terroir*) make the cheeses unique, and the process that it occurs has not yet been fully elucidated (Bezerra *et al*., 2016; Santos *et al*., 2017; Kamimura *et al*., 2019). All these factors confer identity to the cheese of each region, since they are closely linked to the characteristics of the place where they are produced, and they influence the sensory and physicochemical aspects of the final product (Kamimura *et al*., 2019).

However, there is a lack of effective knowledge about the composition of different artisanal Minas cheeses. The present study aimed to evaluate and compare to the physicochemical and centesimal composition of the products of each certified region to seek parameters that are useful to differentiate them and contribute to the determination of authenticity according to their region of origin.

MATERIAL AND METHODS

For the study, 78 cheese samples were collected from producers from seven regions certified and recognized for the production of artisanal Minas cheese (Fig. 1). The collection was obtained from May to November 2019 through a partnership with the Technical Assistance and Rural Extension Company of Minas Gerais (EMATER-MG). Samples were collected only from producers registered with the Instituto Mineiro de Agropecuária - IMA to ensure compliance with current sanitary requirements, as well as compliance with the minimum ripening time indicated for each producing region (Minas Gerais, 2020).

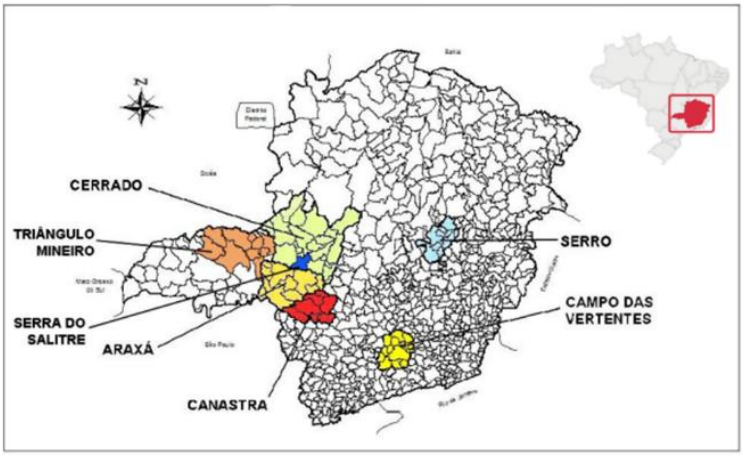


Figure 1. Map of the state of Minas Gerais highlighting the microregions producing artisanal Minas cheese used in the present study. Source: Adapted from EMATER-MG (Programa…, 2019).

The cheese samples were collected, individually packaged in nontoxic and sterile polyethylene plastic containers, externally identified with an adhesive label and transported in an isothermal box with ice to the laboratory for analysis. The number of samples collected by region and period were Araxá (04 samples in September 2019), Canastra (19 samples in May 2019), Cerrado (10 samples in September 2019), Campo das Vertentes (03 samples in November 2019), Serro (25 samples in May 2019), Serra do Salitre (06 samples in July 2019) and Triangulo Mineiro (11 samples in September 2019). Each sample represented a property/producer/farmer.

After collection, the samples were ground individually in a processor, homogenized, packaged in nontoxic and sterile polyethylene plastic containers, identified, and stored in a freezer at -18°C for analysis.

The centesimal composition was evaluated according to the methods of the Association of Official Analytical Chemists (Official…, 1997): moisture (926.08); ash (935.42); salt - %NaCl (935.43); nitrogen compounds (2001.14); fat (Determination…, 1989); fat in dry matter - FDM (Brasil, 2006); salt in moisture (Brasil, 2006); protein by the Kjeldahl method (991.36); and ripening extension and depth indexes according to Silva *et al.* (1997). The physicalchemical parameters analyzed were pH with digital pH meter, Brand Quimis, model Q400AS, according to the methodology described by AOAC (Official…, 1997); lipid oxidation by analysis of substances reactive to 2-thiobarbituric acid-TBARs according to Kang *et al*. (2001). All analyses of centesimal and physicochemical composition were performed in duplicate.

To determine possible differences in the composition of artisanal Minas cheeses between the regions studied, analysis of variance was performed using the Tukey test of means at the 5% significance level by using the SAS® computing package. All variables evaluated were tested for normality by the Shapiro-Wilk test before analysis, and any variable that did not follow the normal distribution was transformed using the RANK procedure of SAS. To verify the association of the parameters evaluated in relation to the regions of origin of the cheeses, principal component analysis (PCA) was performed in the R environment (R Core Team, 2013) using the FactoMineR package.

RESULTS

The analysis of variance revealed differences among the cheeses from different regions for the variables soluble nitrogen in trichloroacetic acid 12% (SNT), soluble nitrogen at pH 4.6 (SNP), ash, oxidation, fat, pH, and ripening extension index (RE) and ripening depth (RD) (Table 1). The highest contents of SNP and SNT were observed in the cheeses from the Campo das Vertentes region, and lower contents of SNP and SNT were observed for samples from Canastra, Serro and Serra do Salitre regions. The Cerrado region showed higher values for the ash content, while lower values were found for cheeses from

the Campo das Vertentes and Serro regions. Similar results of the ash content were observed in the other regions.

Cheeses from Serra do Salitre presented a higher oxidation index with similar results for the Campo das Vertentes and Triângulo Mineiro regions. The highest fat contents were found in cheeses from the Triângulo Mineiro region and the lowest in cheeses from the Campo das Vertentes region, while there was no difference among the fat contents in the other regions. There was no difference in fat in the dry matter (FDM) among the regions. Regarding pH, greater values were observed in the Campo das Vertentes region and the lowest for the cheeses from the Serra do Salitre region (Table 1).

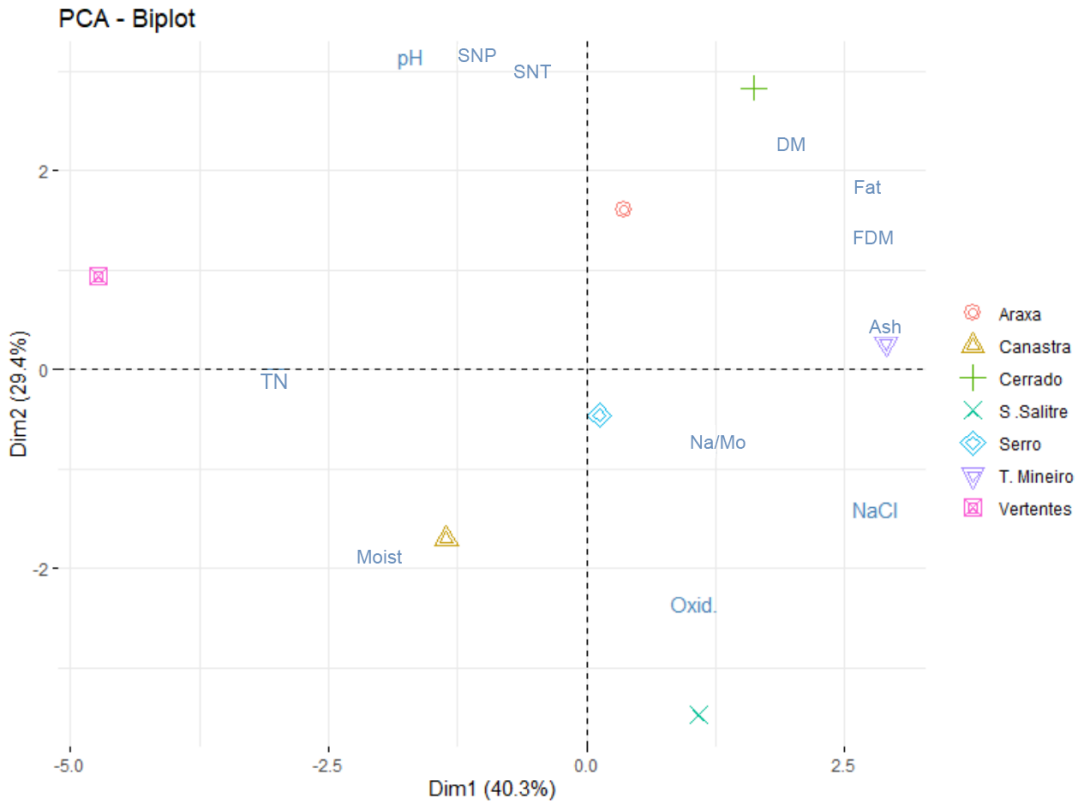
Table 1. Physicochemical parameters, ripening time and compositional constituents of artisanal Minas cheese from seven regions certified for its production

Parameters	Regions							CV (%)	P Value
	Araxa	Canastra	Cerrado	Campo das Vertentes	Serro	Serra do Salitre	Triângulo Mineiro		
	(n=04)	(n=19)	(n=10)	(n=03)	(n=25)	(n=06)	(n=11)		
Physical									
Height (cm)	4.5±0.5	-*	4.7±1.2	4.0±0.5	-*	5.6±0.4	-*	-	-
Diameter (cm)	13.3±0.3	-*	13.5±1.0	14.5±1.0	-*	14.0±1.0	-*	-	-
Ripening (days)	14-22**	22-30	22	22	17-30	22-60***	22-30	-	-
Chemical composition									
Total Nitrogen (%)	3.14	3.22	3.02	3.27	3.16	3.06	3.10	6.54	0.231
Crude Protein (%)	20.05	20.54	19.28	20.84	20.13	19.51	19.80	6.54	0.231
SNT (%)	0.57^{ab}	0.37^{b}	0.59^{ab}	0.63^{a}	0.37^{b}	0.40^{ab}	0.55^{ab}	28.91	<0.0001
SNP (%)	0.40^{ab}	0.28^{b}	0.46^{ab}	0.49^{a}	0.31^{b}	0.28^{b}	0.38^{ab}	32.64	0.0001
Moisture (%)	33.56	37.43	33.92	36.50	33.29	36.59	33.49	16.61	0.167
Dry Extract (%)	66.44	62.57	66.08	63.50	66.71	63.41	66.51	8.84	0.167
Ash (%)	4.65^{ab}	4.41^{ab}	5.14^{a}	3.85^{b}	4.01^{b}	4.95^{ab}	4.90^{ab}	22.54	0.003
NaCl (%)	1.09	1.15	0.83	0.43	1.09	1.41	1.74	63.77	0.070
NaCl/Mo	3.46	3.17	2.58	1.20	3.50	3.95	5.46	71.27	0.204
Fat (%)	30.50^{ab}	29.06^{ab}	32.56^{ab}	23.47^{b}	29.28^{ab}	25.83^{ab}	33.09^{a}	18.57	0.023
FDM (%)	46.08	46.58	49.19	36.99	43.99	41.02	50.40	17.95	0.054
Physicochemical									
Oxidation (TBARs mg/100g)	2.68^{bc}	2.71^{bc}	2.49^{c}	2.99^{abc}	2.89^{bc}	3.72^{a}	3.39^{ab}	20.58	0.0001
pH	5.23^{abc}	5.09^{c}	5.26^{ab}	5.43^{a}	5.04^{c}	4.76^{d}	5.14^{bc}	3.79	<0.0001
RE (%)	12.58^{abc}	8.85^{c}	15.24^{a}	15.09^{ab}	9.96^{bc}	9.17^{bc}	12.16^{ab}	33.76	<0.0001
RD (%)	18.30^{abc}	11.59^{c}	19.51^{a}	19.40^{ab}	11.88^{c}	13.14^{bc}	17.72^{ab}	30.06	<0.0001

Values followed by the same letter in the row do not differ by the Tukey test (α=0.05). SNT - Soluble Nitrogen in trichloroacetic acid 12%; SNP - Soluble Nitrogen in pH 4.6; NaCl - Sodium Chloride; NaCl/Mo - NaCl and Moisture ratio; FDM - Fat in the Dry Matter; RE - ripening extension index; RD - ripening depth index; *Regions whose samples were collected in regional competition and it was not possible to measure the variables; **Only one sample presented 14 days of ripening; ***Only one sample presented 60 days of ripening. CV – Coefficient of variation

The total nitrogen (TN) and crude protein (CP) contents were similar ($p>0.05$) for cheeses from different regions in the present study. Regarding the RE, higher values were verified for cheeses from the Cerrado region and lower for cheeses from the Canastra and Serro regions. Cheeses from the Araxá region showed similar results for these parameters for all the regions evaluated. The results found for the RD were similar to those for RE, and cheese from the Serro region showed lower values for RD.

Principal component analysis (PCA) represented 69.7% of the total information of the differences obtained for physicochemical and centesimal composition of artisanal Minas cheeses and their regions of origin (Fig. 2).



TN - Total Nitrogen; CP – Crude Protein; SNT - Soluble Nitrogen in trichloroacetic acid 12%; SNP - Soluble Nitrogen in pH 4.6; DE - Dry Extract; NaCl - Sodium Chloride; NaCl/Mo - NaCl and Moisture ratio; FDM - Fat in the Dry Matter.

Figure 2. Principal component analysis of physicochemical characterization and centesimal composition of artisanal Minas cheese from seven regions certified for its production.

The variables ash, fat, fat in FDM and salt (NaCl) were those that most influenced the behavior of cheese results from regions according to the Dim1 axis. The cheeses from the Cerrado, Araxá and Triângulo Mineiro regions revealed similar characteristics in relation to the ash, fat, FDM and dry extract (DE) parameters. The cheeses from the Triangulo Mineiro and Cerrado regions revealed a similar behavior to ash and DE. The cheeses from the Araxá region, despite showing a relationship with the variables mentioned above, had behavior influenced by pH, SNP and SNT.

The cheeses from the Canastra region were different from those from all the other regions, standing out with respect to moisture. Similarly, cheeses from the Campo das Vertentes region were different from the others, which was due to pH, SNP and SNT parameters. Moreover, its positioning is also related to ash, fat, FDM and NaCl content because cheeses from Campo das Vertentes presented the lowest values for these parameters. They are the most influenced in the Dim1 axis, explaining their positioning in the left quadrant of the same axis, Fig. 2.

Cheeses from the Serro and Serra do Salitre regions showed similar results. The behavior of the two regions was influenced by the salt to moisture index as well as NaCl content. Furthermore, the positioning of the Serra do Salitre region in the graph is related to the higher oxidation index presented by the cheeses from this region compared to the others.

DISCUSSION

The differences observed for the contents of soluble nitrogen, ripening extension and depth indexes among the cheeses of regions evaluated could be related to the different concentrations of casein, in addition to the amount and

concentration of the coagulant agent used in the manufacturing, microbiological composition of the "pingo", and time and conditions of ripening cheeses (McSweeney, 2004; Pereira, 2019). The SNP is derived mainly from the action of enzymes of the coagulant agent, which degrades casein into high molecular weight peptides. SNT parameter is a result of the degradation of high molecular weight peptides into short chain peptides and amino acids by the action of microbial enzymes and aminopeptidases originating from the milk, as well as microbial enzymes present in the "pingo". These parameters are related to primary and secondary proteolysis and consequently represent the extension and depth index of the cheese ripening process (Fox and McSweeney, 1998; McSweeney, 2004; Pereira, 2019).

The higher results of SNP and SNT observed in the cheese from the Campo das Vertentes region are related to the higher concentration of crude protein. On the other hand, cheese from the Canastra and Serro regions showed higher protein content despite having the lowest SNP and SNT values. This result may be due to the use of smaller quantities and/or concentrations of the coagulating agent and "pingo" during the manufacturing process of these cheeses. Furthermore, the lower SNP, SNT, RE and RD contents observed for Serro's cheeses may be due to the shorter ripening time recommended for this region, which is 17 days, since the values of these parameters tend to increase with ripening time (Pereira, 2019). Although the cheeses from the Araxá region presented the shortest ripening time established in the legislation (Minas Gerais, 2020), they did not have lower values for SNP, SNT, RE and RD, as expected. This result suggests that there was a larger use of rennet and "pingo" during the production of these cheeses. This could be the same reason for the higher values of RE and RD identified in the Cerrado cheeses, as well as the differences in the microbiological composition in the "pingo". Another factor that influences the development of proteolytic bacteria and the action of their enzymes is the lower temperatures in the ripening environment of cheese (Fox and McSweeney, 1998; Sousa *et al*., 2001; Dores *et al*., 2013). However, it could not be related because the average annual temperature and its variation in the Campo das Vertentes, Canastra, Cerrado and Serro regions are similar (Kamimura *et al*., 2019).

The cheeses from the Campo das Vertentes, Araxá and Cerrado regions showed opposite behavior to those from Canastra and Serro due to the influence of the SNP and SNT parameters. Dores *et al*. (2013) reported variations between 0.6 and 5% for SNP values and between 0.42 and 0.45% for SNT values at 22 days of ripening for artisanal Minas cheese from Canastra in different seasons of the year. According to these authors, the variation observed was due to the temperature variation in the ripening environment, associated with different protein contents. Silva *et al*. (2011) compared the variation in physicochemical parameters of Canastra cheese in two seasons of the year and observed lower values for RE and RD in the winter, which represents the dry season in Brazil. Thus, this difference between samples from different regions that was found in the present study could also be associated with the period that the samples were collected, according to these authors due to an effect of lower temperatures in disturbing the action of the rennet enzymes and the microbiota activity of the "pingo". The samples of cheese from Canastra and Serro were collected in May, which represents the beginning of the dry season where the humidity and temperature in the environment start to decrease in comparison to the samples that were collected in September and November (Araxá, Cerrado and Campo das Vertentes).

For artisanal Minas cheese from the Serro region, Machado *et al*. (2004) reported lower values of SNT (0.27%) and RD (9.18%) than those observed in the present study for this region. This difference occurred because the samples collected and analyzed by these researchers had three to six days of ripening, which is a reduced time for the development of secondary proteolytic activity in cheeses. On the other hand, for samples of cheese from the Serro region, Vale *et al*. (2018) reported ripening times between 3 and 31 days between 10.19% and 22.68% for RD, and Chaves *et al*. (2016) observed SNT values between 0.188% and 0.611%. According to these authors, the variation observed demonstrates that these indexes tend to increase over ripening time and that secondary proteolysis occurs gradually (Law and Tamime, 2010; Dores *et al*., 2013).

The variation in the ash content of cheeses could be related to the amount of salt added to the products, as well as the type of salting used (Costa Júnior *et al*., 2014; Pereira, 2019). However, although there was variation from 0.43 to 1.74% for NaCl, there was no difference between the regions (P>0.05). Thus, the difference observed in the ash content for the cheeses of the Cerrado, Campo das Vertentes and Serro regions may be related to the other variables, such as composition of the herd diet and mineral supplementation, stage of lactation of the cow and seasons of the year, which directly influence the composition of the milk. In addition to other factors, such as ripening time, reduction of moisture content and an increase in the total dry extract, with a consequent increase in the ash content (Sobral *et al*., 2013; Costa Júnior *et al*., 2014).

In the PCA, the samples of cheeses from the Triângulo Mineiro region showed a strong relationship with the ash parameter. Likewise, they also had the behavior influenced by fat, FDM and NaCl parameters, although there were no differences for FDM and NaCl among regions. They did not present a higher value for the contents of ash in the analysis of variance (Table 01). The behavior of the Campo das Vertentes region can also be explained by these variables since the cheeses from this region presented the lowest contents of fat. It also may be influenced by the period of collection of these samples (in November) represents that the rainy season has started and the fiber level in grass decreases according to improvement in nutritional quality, having increase of protein level and digestibility with decreasing of the fat level in the milk (Kammes and Allen, 2012). Furthermore, the similarity between the Triângulo Mineiro, Araxá and Cerrado regions was related to the high contents of ash, FDM and DE presented for these regions. These results may be influenced by nutritional factors related to the manager of the animals in the farmer (considering the results of ash and fat) as well as the decrease in moisture content during ripening (considering the results of FDM and DE).

In a study about artisanal Minas cheeses from the Campo das Vertentes region, Costa Júnior *et al*. (2019) found an ash content of approximately 3.98% at 20 days of ripening, which was similar to that observed in the present study for this region. However, Costa Júnior *et al*. (2014) reported the influence of the weather in cheese samples from the Campo das Vertentes region with higher values of ash during the dry period than the rainy period, and this variation was attributed by the authors to a greater mineral supplementation provided to dairy cows in the period.

Regarding lipid oxidation, malonaldehyde (MDA) is the main product of secondary oxidation resulting from the decomposition of peroxides, which react with thiobarbituric acid, and its determination is performed by spectrophotometry (Lima and Abdalla, 2001; Kubo *et al*., 2013; Taticchi *et al*., 2017). The main factors that influence lipid oxidation include the lipid composition of the product and the exposure time to temperature, light and oxygen. During ripening and storage, artisanal cheese is kept without packaging, which may contribute to increasing the occurrence of the oxidation process (Velasco *et al*., 2010; Buccioni *et al*., 2012).

In the present study, there was a higher oxidation content for cheese samples from Serra do Salitre and it may be influenced by the longer maturation time of one sample obtained in this region (60-day-ripening period). However, for cheese produced in this region, the common ripening period recommended is 22 days (Kamimura *et al*., 2019; Minas Gerais, 2020). Cheese samples from the Araxá and Serro regions showed reduced values for oxidation, which might be associated with the shortest ripening period (14-day to 17-day respectively). On the other hand, cheese samples from the Cerrado region showed a lower oxidation index despite having a similar condition of ripening compared to others (minimum 22-day-ripening period), which indicates that other factors, such as storage condition or lipid composition, might have been different and influenced this result. The reduced variation in oxidation content from the beginning to the end of ripening in cheese may be associated with the low concentration of oxygen in the cheese matrix, reflecting the low oxidative activity of unsaturated fatty acids (Buccioni *et al*., 2012).

The fat content was different according to the region of origin, with higher values for cheeses from Triângulo Mineiro and lower values in

cheeses from Campo das Vertentes. Similar values to the present study for fat content for cheeses from the Canastra region (27.59% to 28.51%) and Serro region (28.00% to 30.67%) were found by Silva *et al*. (2011) and Oliveira *et al*. (2018). On the other hand, Costa Júnior *et al*. (2019) reported for cheeses from the Campo das Vertentes region greater fat content (32.45% to 40.27%) than found in the present study for cheese over 60 days of ripening, and this variation was associated with the gradual increase in fat percentages to the loss of moisture and consequent concentration of total solids. The fat percentage of cheeses from the Cerrado region in the present study was higher than those reported by Oliveira *et al*. (2017), and this difference may be related to the higher moisture contents found by these authors, justifying this variation in cheeses from the same region (Figueiredo *et al*., 2015; Pereira, 2019).

Therefore, differences in fat content in cheese can be associated with several factors in the farmer that influence the percentage of milk fat, such as type of feeding and herd breed, stage of lactation and health of the animals. Other factors involved in cheese ripening can influence moisture loss (Dores and Ferreira, 2012; Dores *et al*., 2013; Pereira, 2019). In general, the milk composition has a direct influence on the physicochemical characteristics of the cheese, in addition to variations in the conditions and cheese techniques of manufacturing from different regions or among cheeses from the same region due to management adopted on each farm (Costa Júnior *et al*., 2019; Pereira, 2019).

Although there was no difference in the fat content in the dry matter between the cheeses from the regions evaluated, according to Ordinance N^{o}. 146 of the Ministry of Agriculture, Livestock and Supply - MAPA (Brasil, 1996), cheeses samples analyzed from Araxá, Canastra, Cerrado and Triângulo Mineiro regions would fit into the "fatty" classification, since they presented values between 45.0% and 59.9% for FDM. The cheeses from the Campo das Vertentes, Serro and Serra do Salitre regions, according to the same normative, would be classified as "semifat", according to the values observed in this study.

In the present study, a higher pH value was identified in the cheeses from the Campo das Vertentes region, while samples from Serra do Salitre showed a lower pH value. In general, the reduction will occur throughout the ripening process in cheese because of the action of lactic acid bacteria into lactose content (Costa Júnior *et al*., 2019). However, the pH values in cheese can be influenced by the manufacturing process with respect to the pressing of the cheese paste; if there is higher initial moisture and lactose content, the conversion rate into lactic acid will increase, and more intense pH reduction will occur at the early stage of ripening (Costa Júnior *et al*., 2014). The other important factor besides the pH value is the variation in the microbiological composition of the "pingo" used by producers that have different amounts of lactic acid bacteria according to the season. Castro *et al*. (2016) reported for Campo das Vertentes cheese that it had a higher concentration of lactic acid bacteria in the dry season cheese samples and that could represent a better characteristic quality of the cheese in this period due to the inhibition of undesirable microbiota even if there was no difference in the pH value of the products. Also, the increase of pH during the ripening process would be associate to the proteases present in the milk and the "pingo" that degrades proteins into alkaline nitrogen compounds (Büchl and Seiler, 2011; Dores *et al*., 2013; Figueiredo *et al*., 2015; Pereira, 2019). As shown in Table 1, the highest pH value, and the highest values of proteolysis parameters (SNP and SNT) were found in samples from Campo das Vertentes cheese.

Similar pH results to those found in the present study for cheeses from the Campo das Vertentes region were observed by Costa Júnior *et al*. (2014); in the Cerrado region by Oliveira *et al*. (2017); and in the Campo das Vertentes and Serro regions by Machado *et al*. (2004). According to Monteiro and Da Matta (2018), artisanal Minas cheeses are classified as slightly acidic, and thus, the pH values between 4.76 and 5.43 observed in the present study would be in accordance with this classification.

Regarding the total nitrogen and crude protein contents, there were no differences between the samples of cheeses from the regions analyzed that showed average between 3.02 and 3.22% for TN and 19.28 and 20.84% for CP. Silva *et al*. (2012) evaluated artisanal Minas cheeses from the Triângulo Mineiro region and observed

values of 3.73% for TN and 26.09% for CP, while in artisanal cheeses from the Campo das Vertentes region, Costa Júnior *et al*. (2019) reported values between 19.70% and 27.26% for CP. These observed variations in TN and CP content in artisanal Minas cheese may be related to the influence of milk composition and other factors involved in the manufacturing process, such as the microbiological culture present and the environmental conditions of each farmer and region (Montel *et al*., 2014; Kamimura *et al*., 2019). As the ripening time increases and moisture is consequently lost, there is a concentration of total solids, including the contents of CP and nitrogenous compounds (Silva *et al*., 2012; Costa Júnior *et al*., 2019).

Although there were no differences between the moisture contents of cheeses from different regions in the present study, with a variation of 33.29% and 37.43%, all samples of cheese complied with Decree No. 44.864 (Minas Gerais, 2008), which established a maximum moisture content of 45.9%. Moisture in cheese can be influenced by factors such as ripening time, temperature and humidity of the environment, method of production, cutting size of the grains, stirring, syneresis and pressing of the cheese mass (Silva *et al*., 2011; Oliveira *et al*., 2018). In addition, the reduction of moisture content in cheeses during ripening will promote the decrease of water activity available in the cheese matrix, limiting the growth and development of pathogenic microorganisms (Pereira, 2019).

In the PCA, cheeses from the Canastra region showed a strong relationship with the moisture content, and there were no differences in these parameters compared to others in the variance analysis (P>0.05). This behavior would be associated with the highest numerical value for moisture content and the opposite position on the graphic because of the lowest result for SNT, SNP, pH, RE and RD compared to cheese samples from other regions.

The NaCl as well as the salt to moisture ratio (NaCl/Moisture), did not differ between cheeses from the different regions studied. In the present study, NaCl values ranging from 0.43 to 1.74% were observed in the cheese samples. The addition of salt, in addition to contributing to the taste of cheeses, is important for preventing the development of pathogenic microorganisms (Guinee and Sutherland, 2011). Additionally, salt reduces the water activity in the cheese matrix and consequently influences the control over enzymatic activities, microbial growth, and biochemical events during ripening (Guinee and Sutherland, 2011; Pereira, 2019). In general, the amount of salt used in the salting process varies between producers and regions, as does the salting time, which contributes to final variations in these parameters and moisture in artisanal Minas cheeses independent of origin (Costa Júnior *et al*., 2014; Pereira, 2019).

In general, samples cheeses from the Cerrado, Araxá and Triangulo Mineiro regions were similar according to their composition, and they were differentiated by higher ash contents for those from the Cerrado and fat content for those from Triangulo Mineiro. Similarly, the cheeses from Serra do Salitre and Serro were similar and differentiated by the higher oxidation index for the Serra do Salitre cheeses. On the other hand, the cheeses from Campo das Vertentes, with higher levels of soluble nitrogen and pH, and from Canastra, with lower values of soluble nitrogen, pH, and length of ripening, were different from those from other regions.

Considering the universe of samples used in the present study, it was possible to verify the occurrence of differences in the cheeses according to the region of origin in function of the physical-chemical composition analyzed. However, further studies are recommended in order to identify the parameters that can be used to determine the authenticity according to the origin of these products, once there are multiple factors that can influence the composition of artisanal Minas cheese. It is also recommended that a better standardization of sample collection be found, considering that variations due to the season of the year and the ripening period can promote changes in the composition of the cheese and influence the parameters evaluated.

CONCLUSION

There are differences in physicochemical and centesimal composition between artisanal Minas cheeses from different regions in Minas Gerais, and the parameters analyzed can be used to differentiate them. The contents of ashes, fat, oxidation index, soluble nitrogen and pH were the parameters that were associated with greater

differences in the cheeses according to their region of origin.

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