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Lipid profile of artisanal Minas cheese from certified regions in the state of Minas Gerais, Brazil

Abstract – The objective of this work was to determine the fatty acid profile of artisanal Minas cheese from seven certified regions in the state of Minas Gerais, Brazil. A total of 78 samples were collected in regions where the producers were registered by Instituto Mineiro de Agropecuária. For lipid profile determination, different cheese varieties from the following regions were analyzed: Canastra, Serro, Araxá, Serra do Salitre, Triângulo Mineiro, Campo das Vertentes, and Cerrado. The lipid profile of Serra do Salitre and Araxá cheeses was similar in caproic acid (C6:0), total polyunsaturated fatty acids, and ratio of polyunsaturated and saturated fatty acids. In the other regions, lipid profile differed due to associations with specific fatty acids, such as those of the cheeses from Triângulo Mineiro with C20:5n3, of Cerrado with C20:4n6, of Canastra with C8:0, of Serro with C22:2 and C22:6n3, and of Campo das Vertentes with C17:0, C18:0, and C20:0. The fatty acid profile and nutritional indices related to the lipid profile of artisanal Minas cheeses differ according to the region of origin. The content and profile of omega 3 fatty acids are significant parameters to differentiate artisanal Minas cheeses. Serro artisanal Minas cheese presents superior nutritional indices concerning fatty acid profile than the other studied cheeses.

Index terms: certification, fatty acids, regional characterization.

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Perfil lipídico de queijo minas artesanal de regiões certificadas no estado de Minas Gerais, Brasil

Resumo – O objetivo deste trabalho foi determinar o perfil de ácidos graxos em queijos minas artesanais provenientes de sete regiões certificadas no estado de Minas Gerais, Brasil. Um total de 78 amostras foram coletadas em regiões com produtores cadastrados pelo Instituto Mineiro de Agropecuária. Para determinar a composição lipídica, foram analisadas diferentes variedades de queijo das seguintes regiões: Canastra, Serro, Araxá, Serra do Salitre, Triângulo Mineiro, Campo das Vertentes e Cerrado. A composição lipídica dos queijos da Serra do Salitre e de Araxá foi similar em ácido caproico (C6:0), total de ácidos graxos poli-insaturados e razão entre ácidos poli-insaturados e saturados. Nas outras regiões, a composição lipídica diferiu devido a associações com ácidos graxos específicos, como as dos queijos das regiões do Triangulo Mineiro com C20:5n3, do Cerrado com C20:4n6, da Serra da Canastra com C8:0, do Serro com C22:2 e C22:6n3 e de Campo das Vertentes com C17:0, C18:0 e C20:0. O perfil de ácidos graxos e os índices nutricionais relacionados ao perfil lipídico dos queijos minas artesanais diferem de acordo com a região de origem. O teor e o perfil de ácidos graxos ômega 3 são parâmetros importantes para diferenciar os queijos minas artesanais. O

queijo minas artesanal do Serro apresenta melhores índices nutricionais quanto ao perfil de ácidos graxos que os demais queijos estudados.

Termos para indexação: certificação, ácidos graxos, caracterização regional.

Introduction

The characterization of the fatty acid profile of animal products, including those with Controlled Designation of Origin in Europe, has been studied and used to authenticate these products based on their composition and final characteristics (Vargas-Bello-Pérez et al., 2018; Danezis et al., 2020). In general, animal feed, production system, animal species, local conditions, time of the year, place of origin, and manufacturing technologies can provide a unique identity to dairy products (Segato et al., 2017; Vargas-Bello-Pérez et al., 2018).

In Brazil, artisanal Minas cheese is prepared from farm, raw, healthy, whole, and fresh milk, using only pure calf chymosin for mild coagulation. A manual process is used in pressing, which results in a final product with firm consistency, color, and flavor, providing uniform mass free from color additives and preservatives, according to the historical and cultural traditions of the region where it is produced (Minas Gerais, 2002). The artisanal cheeses from Minas Gerais are manufactured by small-scale productions, mostly family-based, with minimal technification, and handmade processes (Costa et al., 2022).

Currently, there are ten regions in the state of Minas Gerais that are recognized and certified by specific ordinances of Instituto Mineiro de Agropecuária for the production of artisanal Minas cheese (Kamimura et al., 2019; IMA, 2022). The final product varies according to the region due to several factors that confer specific characteristics to the cheese (Dores & Ferreira, 2012). Lipids are one of the main components of cheese, so the composition of fatty acids has been indicated as a factor, or marker, to determine the authenticity of products according to their origin (Capuano et al., 2015; Oliveira et al., 2015; Vargas-Bello-Pérez et al., 2018). Therefore, this parameter should be studied in the composition of artisanal Minas cheese and may be a tool for determining its authenticity once the change in the proportion of some fatty acids can be associated with the type and origin of dairy products (Danezis et al., 2020; Margalho et al., 2021).

The objective of this work was to determine the fatty acid profile of artisanal Minas cheese from seven certified regions in the state of Minas Gerais, Brazil.

Materials and Methods

For the present study, 78 cheese samples were collected from producers in seven certified and recognized regions in the state of Minas Gerais for the production of artisanal Minas cheese (Kamimura et al., 2019). The samples were collected in properties located in the following regions: Araxá (19º00'S, 45º31'W to 20º05'S, 46º10'W), Campo das Vertentes (21º40'S, 44º77'W to 20º67'S, 44º02'W), Canastra (19º45'S, 47º30'W to 20º34'S, 45º30'W), Cerrado (18º87'S, 47º96'W to 18º87'S, 45º39'W), Serra do Salitre (19°06S, 46º41'W), Serro (18º37'S, 43º77'W to 19º00'S, 43º00'W), and Triângulo Mineiro (18°26'S, 47°22'W to 18°47'S, 49°00'W). The samples were collected from May to November 2019, through a partnership with Empresa de Assistência Técnica e Extensão Rural, from producers registered by Instituto Mineiro de Agropecuária, to ensure the current sanitary requirements and the minimum maturation time indicated for each producing region.

To carry out the lipid profile analysis, the cheese samples were collected, wrapped individually in nontoxic sterile polyethylene plastic packaging, identified by adhesive labels, and transported in an isothermal box with ice to the laboratory. The samples were collected per region in the following quantities: 4 samples in Araxá, 19 samples in Canastra, 10 samples in Cerrado, 3 samples in Vertentes, 25 samples in Serro, 6 samples in Salitre, and 11 samples in Triângulo Mineiro, representing a producer.

After collection, the samples were individually ground in a processor, homogenized, packed in nontoxic sterile polyethylene plastic containers, identified, and stored in a freezer at -18°C for the lipid profile to be analyzed.

The fatty acid profile was analyzed by extraction according to the methodology of Folch et al. (1957), followed by the preparation of methyl esters according to the method described by Hartman & Lago (1973). The methyl esters were analyzed according to the methodology of Melo et al. (2019), using the GC-2010

gas chromatograph (Shimadzu Corporation, Kyoto, Japan) equipped with the AOC-20 i automatic injector (Shimadzu Corporation, Kyoto, Japan), the GC-FID flame ionization detector (Shimadzu Corporation, Kyoto, Japan), and the SP-2560 Capillary GC Column (100 m x 0.25 mm x df 0.20 μm) (Merck KGaA, Darmstadt, Germany), using helium as the carrier gas (2 mL min^{-1}). The total running time was 60 min, with the column temperature starting and remaining at 140°C for 5 minutes. Subsequently, the temperature was increased in 4°C min^{-1}, reaching a final temperature of 240°C, which remained constant for 30 min.

The fatty acid profile was expressed in a chromatogram obtained from the GC solution software (Shimadzu Corporation, Kyoto, Japan), using as a reference the Fame Mix 37 standard composed of 37 fatty acids (Supelco, Sigma-Aldrich, St. Louis, MO, USA), to which the retention time of each peak in the samples was compared. The composition of the fatty acid profile in the analyzed cheese samples was expressed as a percentage of area, corresponding to the peaks identified in the chromatogram.

The atherogenic and thrombogenic indices were determined according to the methodology of Ulbricht & Southgate (1991). The ratio of hypocholesterolemic and hypercholesterolemic fatty acids, of polyunsaturated and saturated fatty acids, and of n6 and n3 were determined according to Melo et al. (2018) methodology.

For statistical analysis, analysis of variance was performed to determine possible differences in the composition of artisanal Minas cheeses among the studied regions using the Tukey's test, at 5% probability, and the SAS software (SAS Institute Inc., Cary, NC, USA). To evaluate the behavior of the variables in each region, the principal component analysis (PCA) was performed in the R environment (R Core Team, 2019) using the FactoMineR package (Lê et al., 2008).

Results and Discussion

The cheese samples analyzed in the present study revealed 21 different fatty acids out of the 32 identified ones and 11 parameters associated to lipid profile out of the 13 determined ones (Tables 1 and 2). A similar result was reported by Danezis et al. (2020), who found 29 different fatty acids out of the 37 identified ones for 11 types of Greek cheese with protected designation of origin. These results demonstrate that the fatty acid profile of cheeses from different origins vary, which highlights the importance of this parameter to determine the authenticity of these products (Danezis et al., 2020; Margalho et al., 2021).

Palmitic fatty acid (C16:0) had the highest percentage in all regions evaluated, followed by C14:0 and C18:0 in relation to the identified saturated fatty acids (Table 1). For C16:0, the highest percentage was found in Campo das Vertentes cheese, which had a content 16% higher than those from Serra do Salitre, while the other regions had similar results to each other. Capric acid (C10:0) showed higher rates in Canastra cheeses and lower rates in Campo das Vertentes cheeses. Canastra and Cerrado cheeses had the highest values for lauric acid (C12:0), as did Cerrado cheeses for myristic acid (C14:0). Campo das Vertentes cheeses had higher levels of stearic acid (C18:0), differing from those of Canastra, Cerrado, and Triângulo Mineiro.

Cheeses from all studied regions presented high rates of capric acid (C10:0), lauric acid (C12:0), myristic acid (C14:0), palmitic acid (C16:0), and stearic acid (C18:0), which can be explained by the fact that saturated fatty acids represent the majority of the total fatty acids in ruminant milk and cheese fat, and, among these acids, the most abundant are palmitic, myristic, and stearic (German & Dillard, 2006; Capuano et al., 2015).

Regarding monounsaturated compounds, oleic acid (C18:1n9C) was the most representative, and its high percentage value significantly influenced the total of unsaturated fatty acids. There was a significant difference in this compound between Serro and Cerrado cheeses, which was similar to the others. In the group of polyunsaturated fatty acids, there was a difference in the composition of cheeses for linoleic acid (C18:2n6C): Serra do Salitre cheeses presented the highest rate, whereas Serro cheeses, the lowest, with no significant difference among the other regions. Lima et al. (2020), evaluating the influence of time of year and place of production on the fatty acid profile of Serra da Estrela cheeses, identified the same predominant fatty acid ratio, as did Danezis et al. (2020) for cheeses from different origins.

The behavior of the cheeses from all studied regions in relation to the fatty acid profile explained 67% of the total variation in the differences among the cheeses (Figure 1). It was verified that Canastra and Serro cheeses showed similar behavior on the

Dim1 axis. In the case of Canastra cheese, this result was linked with caprylic acid (C8:0), while Serro cheese was associated with docosadenoic (C22:2) and docosahexaenoic (C22:6n3) fatty acids. In the same way, butyric (C4:0), methyl nervonate (C24:1), eicosadienic (C20:2), myristolic (C14:1), palmitoleic (C16:1), and pentadecanoic (C15:0) fatty acids also contributed to distinguishing the cheese samples from these regions from others.

The cheese samples from the regions of Serra do Salitre, Araxá, and Cerrado showed similar behavior in the Dim1 axis in relation to the overall fatty acid profile (Figure 1). For Serra do Salitre cheeses, the result was related to caproic acid (C6:0); and those from Araxá and Cerrado were due to arachidonic (C20:4n6) and tridecanoic (C13:0) fatty acids, respectively. Additionally, the percentage of capric (C10:0), undecanoic (C11:0), lauric (C12:0), and myristic (C14:

Table 1. Fatty acid profile (%) of artisanal Minas cheese from seven certified regions in the state of Minas Gerais, Brazil, for production[1].

Fatty acid	Region[2]							SEM[3]	p-value
	ARA	CAN	CER	VER	SER	SAL	TMI		
C4:0	0.02b	0.13a	0.02b	0.01b	0.13a	0.03b	0.01b	0.038	<0.0001
C6:0	0.00b	0.13ab	0.00b	0.00b	0.02b	0.46a	0.10ab	0.133	0.024
C8:0	0.17ab	0.68a	0.10b	0.10ab	0.30ab	0.68a	0.48ab	0.213	0.003
C10:0	2.58abc	3.28a	2.19abc	0.75c	1.85bc	2.85ab	2.46abc	0.618	0.0001
C11:0	0.34ab	0.51a	0.31ab	0.09b	0.32b	0.43ab	0.35ab	0.103	0.002
C12:0	4.68ab	4.33a	4.67a	1.68c	3.38bc	4.23ab	3.45abc	0.553	<0.0001
C13:0	0.13ab	0.07bc	0.18a	0.07bc	0.06c	0.12ab	0.10abc	0.034	<0.0001
C14:0	13.81ab	13.01ab	14.11a	11.22b	12.42ab	12.81ab	12.05ab	0.970	0.042
C14:1	1.47ab	1.67ab	1.51ab	0.93b	1.79a	1.54ab	1.28b	0.244	0.006
C15:0	1.20	1.24	1.37	1.19	1.35	1.18	1.21	0.109	0.067
C16:0	35.53ab	33.56ab	35.78ab	38.04a	33.50ab	32.75b	35.98ab	1.533	0.006
C16:1	2.15	2.36	2.23	1.91	2.43	2.17	2.24	0.180	0.076
C17:0	0.62abc	0.63c	0.76ab	0.97a	0.68abc	0.68abc	0.66bc	0.075	0.004
C17:1	0.25b	0.26ab	0.25ab	0.27ab	0.33a	0.24ab	0.29ab	0.049	0.041
C18:0	11.61ab	11.11b	10.98b	15.09a	12.48ab	11.96ab	11.36b	1.051	0.009
C18:1n9T	0.46	0.43	0.43	0.49	0.49	0.56	0.47	0.070	0.772
C18:1n9C	21.86ab	23.05ab	21.75b	23.54ab	25.65a	23.72ab	24.10ab	1.651	0.010
C18:2n6C	2.18ab	2.25ab	2.36ab	2.24ab	1.56b	2.52a	2.39ab	0.595	<0.0001
C18:3n6	0.15	0.18	0.16	0.23	0.20	0.17	0.19	0.041	0.380
C20:0	0.02ab	0.02ab	0.03ab	0.06a	0.01b	0.02ab	0.02ab	0.010	0.004
C18:3n3	0.24c	0.48a	0.31bc	0.57a	0.38ab	0.34abc	0.25c	0.067	<0.0001
C21:0	0.01	0.01	0.02	0.03	0.07	0.02	0.03	0.049	0.310
C20:2	0.02	0.03	0.02	0.02	0.04	0.03	0.03	0.018	0.083
C22:0	0.05	0.05	0.05	0.10	0.09	0.06	0.07	0.047	0.603
C20:3n6	0.07	0.06	0.09	0.10	0.08	0.08	0.09	0.042	0.117
C20:4n6	0.14ab	0.17ab	0.19a	0.14ab	0.13b	0.17ab	0.18a	0.045	0.002
C23:0	0.14	0.17	0.19	0.14	0.13	0.17	0.18	0.045	0.084
C22:2	0.00b	0.01b	0.00b	0.00b	0.05a	0.00b	0.00b	0.022	<0.0001
C24:0	0.03abc	0.07ab	0.05abc	0.08a	0.03abc	0.05abc	0.01c	0.021	0.001
C20:5n3	0.02ab	0.04ab	0.02ab	0.05ab	0.01b	0.02ab	0.07a	0.019	<0.0001
C24:1	0.01	0.02	0.00	0.00	0.02	0.01	0.00	0.027	0.125
C22:6n3	0.02	0.02	0.00	0.00	0.07	0.02	0.00	0.063	0.206

[1]Means followed by equal letters, in the rows, do not differ from each other by Tukey's test, at 5% probability. [2]ARA, Araxá; CAN, Canastra; CER, Cerrado; VER, Campo das Vertentes; SER, Serro; SAL, Serra do Salitre; TMI, Triângulo Mineiro. [3]SEM, standard error of the mean.

0) fatty acids contributed to this behavior for cheeses from these regions in the principal component analysis (Table 1).

The lipid profiles of Triângulo Mineiro and Campo das Vertentes cheeses were negatively related to the composition of the other cheeses in the Dim1 axis (Serra do Salitre, Araxá, and Cerrado) and in the Dim2 axis (Canastra and Serro) (Figure 1). In addition, Campo das Vertentes and Triângulo Mineiro cheeses did not show similar behavior in the Dim2 axis. Triângulo Mineiro cheeses result was associated with eicosapentaenoic acid (C20:5n3), while for Campo das Vertentes cheeses, there was an influence of heptadecanoic (C17:0), stearic (C18:0), and arachidic (C20:0) fatty acids.

Some authors, analyzing specific fatty acids or groups of them, were able to establish a parameter for distinguishing different aspects, such as origin, scale, type, and production system. Danezis et al. (2020) reported that C18:2n6C fatty acids were associated with origin-based cheese samples, and C16:0 fatty acid was associated with type-based cheese samples. Therefore, these results demonstrate that the profile of fatty acids can be used to distinguish different factors associated with production.

Similarly, in the state of Minas Gerais, Margalho et al. (2021) found that cheese samples from Canastra, Campo das Vertentes, Araxá, and Cerrado were similar, and they could be distinguished from Serro ones by their fatty acid profiles. Therefore, although the fatty acid profile in cheese is directly related to milk composition, artisanal Minas cheese tends to have a specific terroir due to being handmade and using raw milk for their production, besides having a particular local method, microbiological culture, and ripening conditions that differ from region to region.

Different factors were determined for each region according to the fatty acid profile of the cheeses (Table 2). The atherogenic index (ATR) or the ratio of hypocholesterolemic and hypercholesterolemic compounds (HO/HE) was not affected by the region. On the other hand, the ratios of polyunsaturated and saturated fatty acids (PUFA/SFA; SFA/PUFA), omega 3 and 6 (n6/n3; n3/n6), and the thrombogenic index were significantly influenced by the region of origin. The highest PUFA/SFA ratio was observed in the

Table 2. Sum and parameters associated with the lipid profile of artisanal Minas cheese from seven certified regions in Minas Gerais state, Brazil, for production[1].

Variable[2]	Region[3]							SEM[4]	p-value
	ARA	CAN	CER	VER	SER	SAL	TMI		
Sum									
SFA	70.92a	68.90ab	70.66a	69.52ab	66.77b	68.41ab	68.40ab	1.935	0.049
UFA	29.07b	31.09ab	29.33b	30.48ab	33.22a	31.60ab	31.59ab	1.368	0.049
PUFA	2.85ab	3.28a	3.15a	3.34a	2.53b	3.34a	3.21a	0.676	0.001
MUFA	26.22b	27.81b	26.17b	27.14ab	30.69a	28.24ab	28.38ab	1.664	0.001
n6	2.55ab	2.67ab	2.80a	2.71ab	1.98b	2.93a	2.84a	0.629	<0.0001
n3	0.27c	0.55a	0.33bc	0.62a	0.47ab	0.38abc	0.33bc	0.088	<0.0001
Relations/Indices									
PUFA/SFA	0.040ab	0.048a	0.045ab	0.048a	0.038b	0.049a	0.047a	0.012	0.003
SFA/PUFA	24.88ab	21.01b	22.43ab	20.81b	26.39a	20.48b	21.31b	3.917	0.003
n6/n3	9.44a	4.85ab	8.48a	4.37bc	4.21c	7.71ab	8.61a	1.370	<0.0001
n3/n6	0.11c	0.21abc	0.12c	0.23ab	0.24a	0.13c	0.12c	0.039	<0.0001
ATR	1.22	1.18	1.25	1.14	1.20	1.17	1.18	0.046	0.094
TBO	4.08a	3.39ab	4.00a	3.81ab	3.28b	3.43ab	3.61ab	0.294	0.012
HO/HE	0.47	0.52	0.47	0.54	0.59	0.56	0.55	0.067	0.096

[1]Means followed by equal letters, in the rows, do not differ from each other by Tukey's test, at 5% probability. [2]SFA, saturated fatty acids; UFA, unsaturated fatty acids; PUFA, polyunsaturated fatty acids; MON, monounsaturated fatty acids; n6,n6 fatty acids; n3,n3 fatty acids; PUFA/SFA, polyunsaturated fatty acids/saturated fatty acids; SFA/PUFA, saturated/polyunsaturated fatty acids; n6/n3, n6/n3 fatty acids; n3/n6, n3/n6 fatty acids; ATR, atherogenic index; TBO, thrombogenic index; HO/HE, hypo/hypercholesterolemic fatty acids. [3]ARA, Araxá; CAN, Canastra; CER, Cerrado; VER, Campo das Vertentes; SER, Serro; SAL, Serra do Salitre; TMI, Triângulo Mineiro. [4]SEM, Standard error of the mean.

regions of Canastra, Campo das Vertentes, Triângulo Mineiro, and Serra do Salitre. The opposite can be observed in the ratio of saturated and polyunsaturated fatty acids for SFA/PUFA, in which Serro cheeses had the highest value.

Evaluating the ratios of omega 6 and omega 3 compounds (n6/n3; n3/n6), it is possible to verify that in Araxá, Cerrado, and Triângulo Mineiro cheeses there was a higher value in the n6/n3 ratio, mainly explained by the higher rates of linoleic acid (C18:2n6C) in the same regions. The opposite was observed in the n3/n6 ratio, being more significant in Serro region compared to the others, being alpha-linolenic acid (C18: 3n3) the compound that most contributed to the total of the omega 3 group. This is an important parameter found for Serro cheeses, since the recommended ratio for preventing a cardiovascular disease is 4:1 for n6/n3 (Simopoulos, 2002).

These groups of indexes associated with fatty acids composition, such as the n6/n3 or PUFA/SFA ratio,

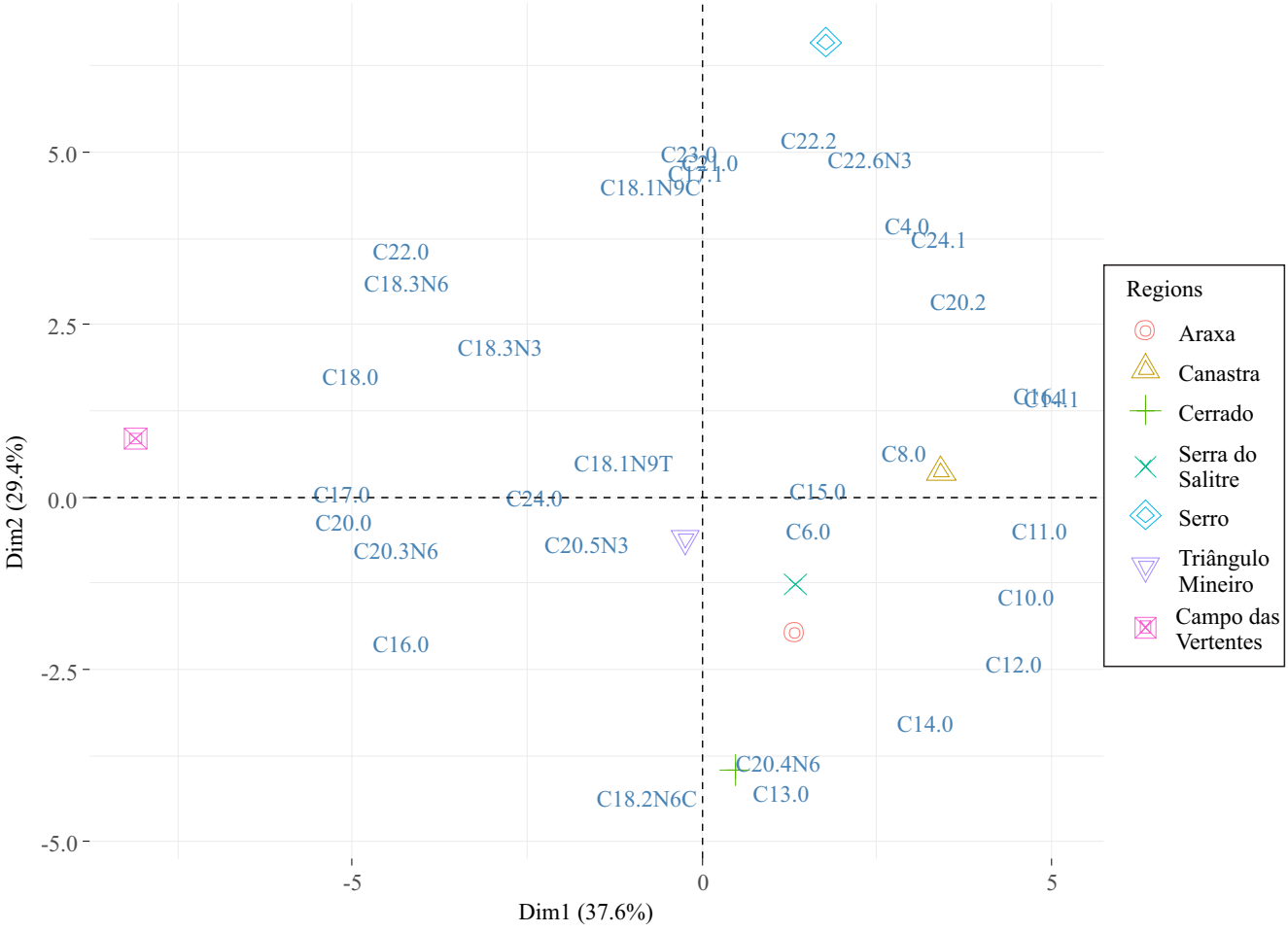

Figure 1. The principal components analysis (PCA) of the fatty acid profile of artisanal Minas cheese from seven regions in the state of Minas Gerais, Brazil. C4:0, butyric acid; C6:0, caproic acid; C8:0, caprylic acid; C10:0, capric acid; C11:0, undecanoic acid; C12:0, lauric acid; C13:0, tridecanoic acid; C14:0, myristic acid; C14:1, myristoleic acid; C15:0, pentadecanoic acid; C15:1, pentadecenoic acid; C16:0, palmitic acid; C16:1, palmitoleic acid; C17:0, marginal acid; C17:1, margaroleic acid; C18:0, stearic acid; C18:1N9T, oleic acid; C18:1N9C, elaidic acid; C18:2N6T, linolelaidic acid; C18:2N6C, linoleic acid; C20:0, arachidic acid; C18:3N6, linolenic acid; C20:1, gadoleic acid; C18:3N3, alpha-linolenic acid; C21:0, heicosanoic acid; C20:2, eicosadienic acid; C22:0, behenic acid; C20:3N6, dihomo-gamma-linolenic; C22:1N9, erucic acid; C20:3N3, dihomo-alpha-linolenic; C20:4N6, arachidonic acid; C23:0, tricosanoic acid; C22:2, docosadienic acid; C20:5N3, eicosapentaenoic acid; C24:0, lignoceric acid; C24:1, methyl nervonate; C22:6N3, docosahexaenoic acid.

may bring health benefits, considering that omega-3 fatty acids prevent chronic diseases and decrease the risk of thrombosis and other blood disorders (Djuricic & Calder, 2021). Besides having a higher saturated fat content, some cheeses, such as those from Serro region, have a nutritionally desirable lipid profile.

There was a significant difference in the thrombogenic index (TBO) with higher values for Araxá and Cerrado cheeses and lower ones for Serro cheeses (Table 2). Margalho et al. (2021) also reported a difference in thrombogenic rates for artisanal Minas cheese associated with higher concentration of saturated fatty acids (C16:0 and C18:0) for Araxá, Canastra, and Cerrado samples compared with Campo das Vertentes and Serro ones, and higher monounsaturated fatty acids (MUFA) rates for Araxá, Campo das Vertentes, and Serro cheeses. In the present study, this lower TBO value in Serro cheese is due to a higher level of MUFA and unsaturated fatty acids (UFAs), as well as a lower n6 percentage. The thrombogenic index is determined by the ratio of the pro-thrombogenic (C12:0, C14:0, and C18:0) and the anti-thrombogenic (MUFA, n3, and n6), the lower a parameter for a certain type of food, the healthier it is (Chen & Liu, 2020; Lima et al., 2020; Paszczyk & Łuczyńska, 2020). Omega 3 fatty acids, especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are the most effective in anti-thrombogenic effects (Chen & Liu, 2020).

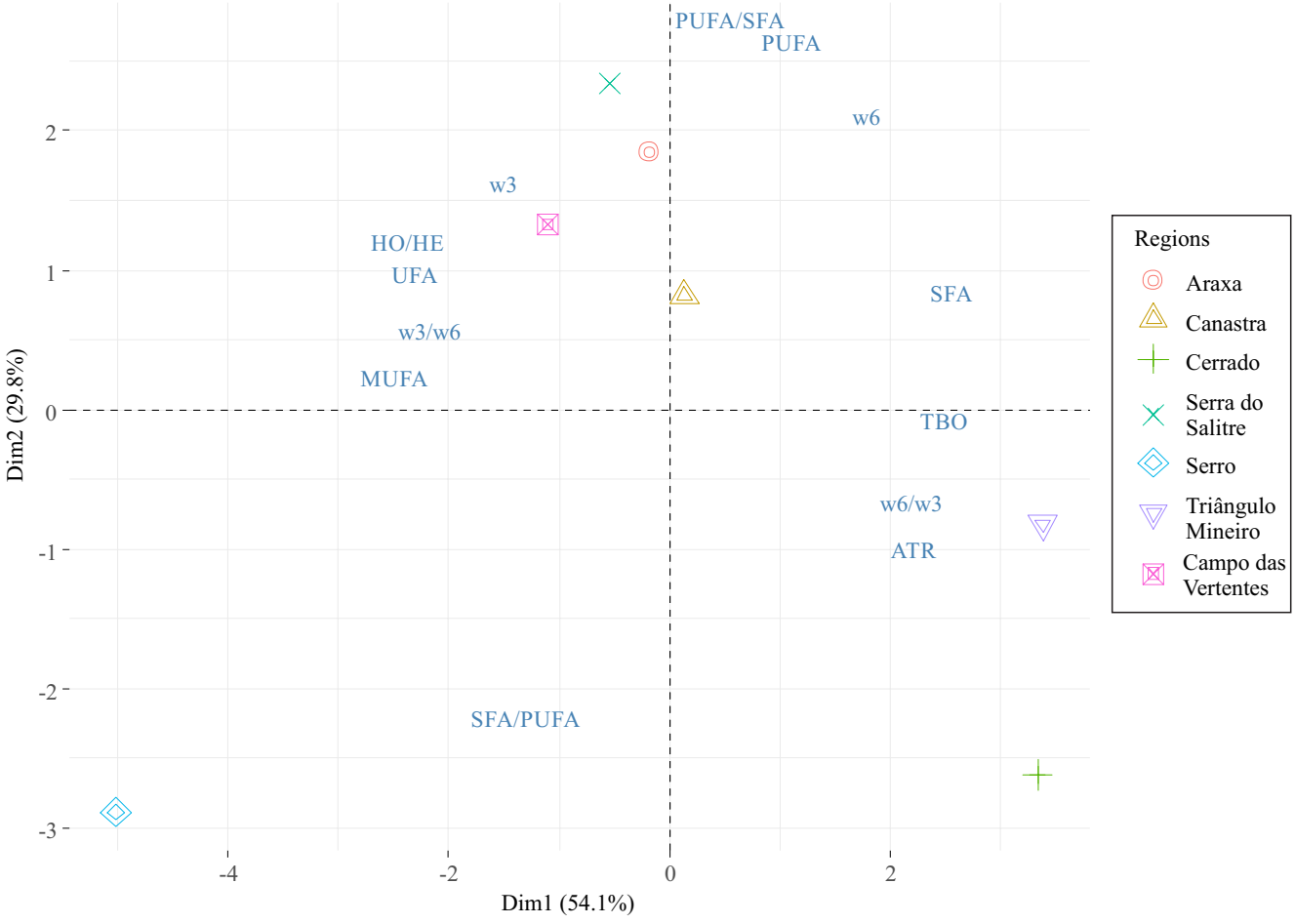

Figure 2. The principal components analysis (PCA) of the fatty acid profile grouped by chemical classification of artisanal Minas cheese from seven certified regions in Minas Gerais state, Brazil, for production. SFA, saturated; UFA, unsaturated; MUFA, monounsaturated; PUFA, polyunsaturated; w6, sum of n6 fatty acids; w3, sum of n3 fatty acids; PUFA/SFA, polyunsaturated fatty acids/saturated fatty acids; SFA/PUFA, saturated/polyunsaturated fatty acids; w6/w3, n6/n3; w3/w6, n3/n6; ATR, atherogenic index; TBO, thrombogenic index; HO/HE, hypo/hypercholesterolemic.

The samples of cheeses from all studied regions did not present differences in the ATR, and the results varied between 1.14 and 1.25, despite the differences in fatty acids associated with atherogenic effect (C12:0, C14:0, C16:0 unsaturated fatty acids) (Table 2). Danezis et al. (2020), determining the ATR, also found that this parameter did not differ in samples from different origins. This means that cheeses from different origins and regions can have similar nutritional parameters, alike to the findings in the present study.

Therefore, variations in fatty acids composition in cheeses are important both in health aspects (Alothman et al., 2019) and in determining the type and the region of origin of cheeses (Kamimura et al., 2019; Danezis et al., 2020; Margalho et al., 2021).

The principal component analysis represents 83.9% of the data variation and is explained by the graphical representation of the totals, ratios and indices calculated according to the fatty acid profile of the cheeses from the different regions studied (Figure 2). The Dim1 axis was mainly represented by saturated compounds (SFA), thrombogenicity index (TBO), unsaturated fatty acids (UFA) and by the ratio between hypo- and hypercholesterolemic compounds (HO/HE). The most important variables that represented the positioning of the regions in relation to the Dim2 axis were the ratios of polyunsaturated and saturated compounds (PUFA/SFA; SFA/PUFA) and the group of polyunsaturated fatty acids (PUFA). Although these parameters are not considered a specific way to determine cheese origin and authentication (Vargas-Bello-Pérez et al., 2018; Danezis et al., 2020; Margalho et al., 2021), they can be a useful criterion for consumers to select cheeses according to health aspects (Alothman et al., 2019; Djuricic & Calder, 2021).

The Serra do Salitre, Araxá, and Campo das Vertentes cheeses showed similar behavior in function of PUFA and the PUFA/SFA ratio (Figure 2). Although these variables of the cheeses from all studied regions show statistical similarity, the highest rates were observed in Serra do Salitre cheeses. Furthermore, the Campo das Vertentes cheeses were influenced by the n3 group, similarly to Serra do Salitre ones. The UFAs and MUFAs, as well as the n3/n6 ratio, contributed to the behavior of the cheeses from these three regions. The HO/HE ratio, in turn, had higher values in the Campo das Vertentes and Serra do Salitre cheeses compared with Araxá ones, although this parameter did not show a significant difference among regions. The lipid profile of Serro cheese was negatively related to that of the other studied regions. This behavior is associated with the SFA/PUFA ratio and is justified by the higher value of this parameter as well as a lower PUFA and n6 total. Similar to Serro cheese, Canastra one differs from those of other regions due to the higher PUFA and PUFA/SFA ratio and intermediate results for n6 and SFA total.

In the present study, Serro cheese presented the highest percentage of MUFA, while Araxá, Canastra and Cerrado cheeses, the lowest. On the other hand, Canastra, Cerrado, Serra do Salite, Campo das Vertentes, and Triângulo Mineiro cheeses presented the highest values for PUFA, and those from Serro presented the lowest. Margalho et al. (2021) found similar results for MUFA in cheese from these regions, with lower values for Cerrado and Canastra cheeses compared with Araxá, Serro, and Campo das Vertentes ones; however, for Araxa cheese, the PUFA value was lower than those from the Serro, Cerrado, Canastra, and Campo das Vertentes. Therefore, this difference according to the total SFAs, MUFAs and PUFAs for each region is variable and can help to distinguishing the cheese composition.

For the principal component analysis plot for the grouped fatty acids, it was observed that Triângulo Mineiro and Cerrado cheeses were similar and associated with the thrombogenic index, atherogenic index, and n6/n3 ratio (Figure 2). Higher rates of these indices mean that there are higher rates of saturated fatty acids compared to unsaturated and omega 6 and 3 compounds, which is not beneficial to human health because they increase blood cholesterol levels (Alothman et al., 2019; Djuricic & Calder, 2021).

It is important to note that the cheese production process influences the characteristics of the final product, especially with regard to the biochemical changes that occur during maturation, as well as the edaphoclimatic conditions of the terroir in which the cheeses are produced (McSweeney & Sousa, 2000; Silva et al., 2011). Considering the limited samples used in the present study and that there are multiple factors that can influence the lipid profile of artisanal Minas cheese, further studies are recommended to understand the fatty acid profile variation observed for cheeses from these regions.

Conclusions

1. The fatty acid profile and nutritional indices related to lipid profile of artisanal Minas cheeses differ according to the region of origin.

2. The content and profile of omega 3 fatty acids are significant parameters to differentiate artisanal Minas cheeses.

3. Serro artisanal Minas cheese presents superior nutritional indices concerning fatty acid profile than the other studied cheeses.

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