



Effect of partial replacement of sodium chloride with potassium chloride on the characteristics of Minas Padrão cheese

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ABSTRACT

Partial replacement of NaCl by KCl (25% and 50%) in Minas Padrão cheese was investigated for the physicochemical characteristics, sensory evaluation, fatty acid profile, and texture parameters. Salt replacement did not affect the moisture content, protein, fat, ash, water activity, chloride, pH, and proteolysis. A significant reduction in sodium levels was observed, ranging from 369.12 mg 100 g⁻¹ to 210.05 mg 100 g⁻¹, while the control treatment (100% NaCl) presented 608.67 mg 100 g⁻¹. Proteolysis indexes increased throughout ripening. Hardness and chewiness increased, as a result of pH reduction and syneresis in cheese, which caused a decrease in moisture content. The fatty acid profile was affected by sodium reduction, with an increase in short chain, medium-chain, and polyunsaturated fatty acids. In relation to the acceptance test, no significant differences were observed for the cheese with a substitution of 25% sodium chloride with potassium chloride when compared with the control.

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1. Introduction

Sodium chloride in cheese plays important roles, such as improving taste, texture, and colour; inhibiting the growth of contaminating microorganisms that can cause defects; promoting syneresis of the curd; and assisting in the adjustment of final moisture content (McMahon, 2010). Sodium is also essential for the metabolic functions of the human body (Doyle & Glass, 2010). However, high sodium intake contributes to the development of hypertension (Cruz et al., 2011), renal diseases, stomach cancer, and renal calculus (Durack, Alonso-Gomez, & Wilkinson, 2008), in addition to increasing the excretion of calcium in the urine and favouring osteoporosis (Cruz et al., 2011). The World Health Organisation (WHO) recommends that daily sodium intake should not exceed 2000 mg, which corresponds to approximately five grams of

sodium chloride per person per day (WHO, 2011). However, sodium consumption in Brazil is estimated to be about 12 g of salt per person per day (IDEC, 2014).

The high sodium intake is due to the high sodium content of processed foods. In this context, cheeses are the fourth largest contributor to sodium intake in the Brazilian diet (IDEC, 2014). Minas Padrão cheese is a typical Brazilian ripened cheese, which has a brittle texture and a slightly acid and characteristic flavour. It is traditionally manufactured using a mesophilic starter composed of *Lactococcus lactis* ssp. *cremoris* and *L. lactis* ssp. *lactis*. Minas Padrão cheese is commonly consumed in Brazil at breakfast and also used to accompany desserts such as dulce de leche (Furtado, 2005). Felício et al. (2013) reported that 90% of Minas Padrão cheeses had a sodium content higher than 400 mg 100 g⁻¹, and one serving (30 g) contributes to 17.8% sodium in a 2000 mg Na per person per day diet (Felício et al., 2013). However, there are no studies on sodium reduction in Minas Padrão cheese. In cheeses, sodium can be replaced by substitute salts such as potassium,

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magnesium, and calcium to prevent changes in composition, enzymatic activity, sensory characteristics, and texture properties (Cruz et al., 2011). The objective of this study was to evaluate the effect of the partial replacement of NaCl by KCl on the physicochemical and sensory characteristics, fatty acid profile, and texture parameters of Minas Padrão cheese.

2. Materials and methods

2.1. Manufacture of Minas Padrão cheese

Minas Padrão cheese was manufactured at different days, with four replicates. Each batch of cheese was made in 300 L scale. Raw cows' milk was pasteurised at 65 °C for 30 min, standardised to 3.3–3.5% fat (w/v) and cooled to 32 °C. Then, calcium chloride (50%, w/v, 40 mL 100 L⁻¹) was added; freeze-dried culture directly, type O mesophilic (10 U 100 L⁻¹) consisting of *Lc. lactis* subsp. *lactis* and *Lc. lactis* subsp. *cremoris* (R704, Chr. Hansen, Valinhos, São Paulo, Brazil), was pre-ripened for 30 min at 32 °C. Coagulant 100% chymosin (Chy-Max M, 1000 IMCU/mL, Chr. Hansen, Valinhos, São Paulo, Brazil), as recommended by the producer (3 mL 100 L⁻¹), was added.

Coagulation occurred within 40 min. Curd was cut into cubes of approximately 1 cm per side, followed by slow stirring for 20 min. Heating was performed by indirect steam to raise the temperature by 1 °C every 2 min with continuous stirring up to 36–37 °C. After 40–50 min of stirring, the whey was drained and the curd was divided into three equal parts. Salting was carried out by the addition of salt in the curd (1.6%, w/w, in the final product). Three treatments were performed, with partial replacement of sodium chloride (Cisne, São Paulo, Brazil) by potassium chloride (Sigma, São Paulo, Brazil) in the following NaCl:KCl ratios: 100:0 (control); 75:25, and 50:50. Curd was placed into cylindrical moulds and pressed for 16 h (10 times the cheese weight). Cheeses (1 kg) were vacuum packed and stored at 10–12 °C for 60 days.

2.2. Physicochemical characterisation

The cheese was analysed on the 2nd day after manufacture for total solids, fat, protein, ash (Brasil, 2006) and chloride content (Volhard method; AOAC, 2012). Protein was calculated by determination of total nitrogen by Kjeldahl method, and it was converted to total crude protein using a nitrogen conversion factor of 6.38 for milk proteins.

Water activity (a_w) was measured by direct readings in Aqualab apparatus (Decagon, Washington, DC, USA). The sodium and potassium contents were determined by atomic absorption spectrophotometry, according to Moreno-Rojas, Pozo-Lara, Zurera, and Lopez (1993).

The pH, moisture and proteolysis were assessed at 2, 20, 40, and 60 days of ripening. The pH was determined by Brasil (2006). Total nitrogen (TN) was determined by the Kjeldahl method (AOAC, 1995); pH 4.6-soluble nitrogen (pH4.6-SN) and 12% trichloroacetic acid-soluble nitrogen (12% TCA-SN) were determined according to Barbano, Lynch, and Fleming (1991). Proteolysis was calculated as the extent and depth of proteolysis indices, according to the following equations:

$$\text{Extent of proteolysis index} = (\text{pH4.6-SN}/\text{TN}) \times 100.$$

$$\text{Depth of proteolysis index} = (12\% \text{ TCA-SN}/\text{TN}) \times 100.$$

2.3. Texture profile analysis

The texture profile analysis (TPA) was performed on the 2, 20, 40, and 60 days of ripening with a CT3 Texture Analyzer (Brookfield, Middleboro, MA, USA). Cheese cylinders 20 mm in diameter and

25 mm in height (TA4/1000) were sampled, which were later packed in plastic bags and stored at 10 °C for 1 h. A minimum of five measurements was performed for each cheese, in each replicate. The test parameters were: 40% compression; pre-test speed, 2 m s⁻¹; test speed, 1 mm s⁻¹; load cell, 4500 g; 38.1 mm diameter cylinder probe, 20 mm long.

2.4. Fatty acid profile

The fatty acid profile was quantified by gas chromatography with flame ionisation detection on the 20 days of ripening according to Felicio et al. (2016).

2.5. Sensory evaluation

The acceptance test was performed on the 20 days of ripening with 200 untrained assessors, consumers of Minas Padrão cheese, both gender, and age recruited among students, professors, and staff at EPAMIG. According to Brazilian legislation, Minas Padrão cheese must be ripened for 20 days, so the cheese was sensorially evaluated at that time. The samples were presented in cubes of 2.5 cm³, coded with 3 random digits. A 9-point hedonic scale (1 = extremely disliked to 9 = extremely liked; Meilgaard, Civille, & Carr, 2006) was used to evaluate appearance, aroma, flavour, texture, and overall impression.

2.6. Statistical analysis

A split-plot design was used, with the main factor represented by the treatments and the storage time as a subplot. A block design was used to analyse the physicochemical composition, fatty acid profile, and sensory evaluation in only one storage time. Statistical analyses were performed using Minitab 12.1 for Windows program (Minitab Inc., State College) for analysis of variance and Tukey's test at a significant level $P < 0.05$.

3. Results and discussion

3.1. Physicochemical characterisation

The composition of Minas Padrão cheeses concerning moisture content, protein, fat, ash, and chloride level was not affected by the substitution of sodium for potassium chloride ($P > 0.05$) (Table 1). Similar results have been reported for other salt-reduced cheeses (Ayyash & Shah, 2011a; Ayyash, Sherkat, & Shah, 2012; Thibaudeau, Roy, & St-Gelais, 2015).

The water activity of the cheeses was not affected by the sodium reduction ($P > 0.05$), probably due to the concentration of solutes and the moisture content that influence the water activity (Guinee & Fox, 2004).

The sodium and potassium levels differed among treatments ($P < 0.05$). The sodium content decreased with an increase in potassium concentration. Similar results were found by Ayyash and Shah (2011a,b), Ayyash et al. (2012), and Felicio et al. (2016). Felicio et al. (2013) studied 30 Minas Padrão cheese samples from the market, and found sodium content between 150 and 967 mg 100 g⁻¹, with an average of 594 mg 100 g⁻¹. This value is close to the content found in this study for the treatment with no sodium replacement (100% NaCl).

According to the Brazilian legislation (Brasil, 2012), the cheeses of the treatments (KCl:NaCl) 25:75 and 50:50 can be considered light, because at least a reduction of 25% of the sodium occurred when compared to the control treatment (100% NaCl). This is beneficial because of the potential health risks of excessive sodium consumption, since the ingestion of two slices of 30 g each of Minas

Table 1
Physicochemical composition of Minas Padrão cheese manufactured with NaCl and mixtures of NaCl and KCl after two days of refrigerated storage.^a

Composition	Treatment (KCl:NaCl)		
	0:100	25:75	50:50
Moisture (% w/w)	48.46 ± 0.37 ^a	49.23 ± 0.96 ^a	47.83 ± 0.44 ^a
Fat (% w/w)	28.2 ± 0.25 ^a	28.5 ± 0.50 ^a	28.25 ± 0.25 ^a
Protein (% w/w)	19.47 ± 0.49 ^a	18.88 ± 0.83 ^a	19.73 ± 0.59 ^a
Ash (% w/w)	3.67 ± 0.14 ^a	3.46 ± 0.19 ^a	3.14 ± 0.12 ^a
Chloride (% w/w)	1.54 ± 0.12 ^a	1.58 ± 0.11 ^a	1.46 ± 0.11 ^a
Fat in dry matter (% w/w)	54.82 ± 0.49 ^a	56.14 ± 0.51 ^a	54.15 ± 0.37 ^a
^a _w	0.964 ± 0.005 ^a	0.963 ± 0.005 ^a	0.967 ± 0.005 ^a
Na (mg 100 g ⁻¹)	608.67 ± 41.09 ^a	396.12 ± 47.42 ^b	210.05 ± 50.43 ^c
K (mg 100 g ⁻¹)	101.75 ± 16.37 ^c	324.37 ± 40.33 ^b	523.08 ± 51.20 ^a

^a Data are means ± SEM; means within a row with different superscript letters differ significantly ($P < 0.05$).

Padrão cheese contributes to 17.8% of the amount of sodium consumed by one person daily (2000 mg day⁻¹) (Felicio et al., 2016).

3.2. pH, moisture and proteolysis

The pH was not affected by the sodium reduction ($P > 0.05$). The mean pH values for the treatments (KCl:NaCl) 0:100, 25:75, and 50:50 at all times evaluated were, respectively, 4.90, 4.91, and 4.91, probably due to the similar moisture content among the treatments. Costa et al. (2018b), Gomes et al. (2011) and Ruyssen et al. (2013) reported that the partial replacement of NaCl by KCl did not affect the pH of Prato cheese, Minas Frescal cheese and Gouda cheese, respectively. However, some studies have found a lower pH in cheeses salted with NaCl and KCl blends, possibly due to the distinct inhibitory effect of KCl on lactic acid bacteria when compared with NaCl (Fitzgerald & Buckley, 1985; Grummer, Karalus, Zhang, Vickers, & Schoenfuss, 2012). In the present study, there was no difference in the water activity of the cheeses, which may not have affected the activity of the lactic bacteria and, consequently, the pH of the cheeses. Reddy and Marth (1995) found that sodium reduction with the use of KCl in Cheddar cheese had no influence on the predominant lactic acid bacteria.

Significant differences in pH were observed over time ($P < 0.05$) (Table 2); however, there was no difference in treatment versus time interaction ($P > 0.05$). The pH reduction during ripening may be due to the fermentation of residual lactose with the production of organic acids, caused by microorganisms present in cheeses (Ayyash & Shah, 2011a). Buriti, Rocha, and Saad (2005) found a

reduction in pH during storage of Minas Frescal cheeses manufactured with type O mesophilic lactic acid bacteria, which reduces casein-bound calcium and causes a more brittle texture in cheese. A similar lactic acid bacteria culture was used in the manufacture of Minas Padrão cheese in the present study, which led to the formation of a slightly acidic flavour and a more brittle texture, characteristic of this type of cheese.

None of the sodium reduction treatments affected the moisture content of the cheeses ($P > 0.05$) at all ripening times evaluated. The moisture content of the treatments (KCl:NaCl) 0:100, 25:75, and 50:50 were 47.18%; 46.66% and 47.86%, respectively. However, during ripening, there was variation in the moisture content ($P < 0.05$), from 48.50% (w/w) to 46.10% (w/w) between 2 and 60 days of ripening (Fig. 1). The partial replacement of NaCl by KCl was not the cause of this decrease in moisture content in time, since there was no difference between the treatments, but it was possibly due to the reduction of pH ($P < 0.05$), caused by fermentation by lactic acid bacteria, leading to casein demineralisation and increased syneresis; an increase in whey in the packaging, which was impermeable, was noticed during ripening. Other authors verified that the use of type O mesophilic lactic acid bacteria causes a greater acidification, with an increase in syneresis and consequent reduction of the moisture content of the cheeses (Buriti et al., 2005; Oliveira, Garcia, Queiroga, & Souza, 2012). The interaction between treatments and time was not significant ($P > 0.05$).

The extent of proteolysis and depth of proteolysis indices (EPI and DPI, respectively) have been used to evaluate proteolysis in cheese. The former measures the primary proteolysis with the formation of high molecular weight peptides generated by the

Table 2
Evolution of pH and proteolysis index of Minas Padrão cheese manufactured with NaCl and mixtures of NaCl and KCl over 60 days of refrigerated storage.^a

Ripening time (days)	Treatment (KCl:NaCl)		
	0:100	25:75	50:50
pH			
2	5.06 ± 0.03 ^a	5.03 ± 0.04 ^a	5.02 ± 0.04 ^a
20	4.85 ± 0.02 ^b	4.90 ± 0.01 ^b	4.89 ± 0.02 ^b
40	4.86 ± 0.01 ^b	4.86 ± 0.01 ^b	4.87 ± 0.01 ^b
60	4.83 ± 0.02 ^b	4.86 ± 0.01 ^b	4.88 ± 0.02 ^{ab}
Extent of proteolysis index (%)			
2	3.19 ± 0.25 ^b	3.52 ± 0.21 ^b	2.99 ± 0.14 ^b
20	4.58 ± 0.80 ^{ab}	4.71 ± 0.54 ^{ab}	5.16 ± 0.65 ^a
40	4.68 ± 0.47 ^a	5.50 ± 1.05 ^a	4.89 ± 0.35 ^a
60	5.91 ± 0.41 ^a	5.48 ± 0.61 ^a	6.14 ± 0.65 ^a
Depth of proteolysis index (%)			
2	5.35 ± 0.22 ^b	4.97 ± 0.32 ^a	5.03 ± 0.14 ^b
20	6.62 ± 0.22 ^{ab}	6.62 ± 0.46 ^{ab}	6.60 ± 0.46 ^{ab}
40	6.51 ± 0.57 ^{ab}	6.94 ± 0.98 ^a	6.85 ± 0.39 ^a
60	7.68 ± 0.22 ^a	7.52 ± 0.21 ^a	7.97 ± 0.48 ^a

^a Data are means ± SEM; means within a column (among different days of storage) with different superscript letters differ significantly ($P < 0.05$).

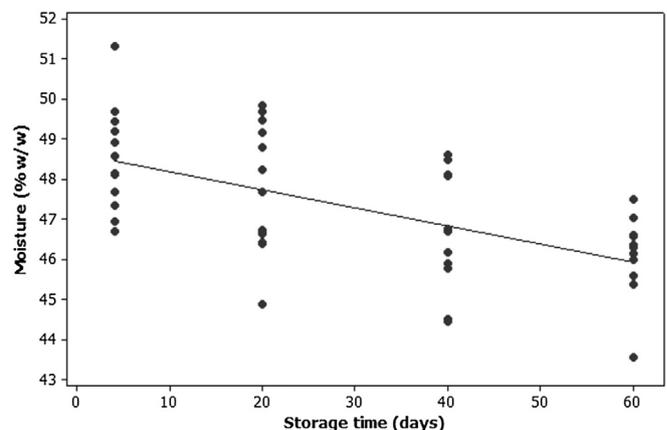


Fig. 1. Moisture content during ripening of Minas Padrão cheese manufactured with NaCl and mixtures of NaCl and KCl during ripening.

hydrolysis of casein by chymosin and plasmin, the latter measures low molecular weight peptides and amino acids generated mainly by the action of lactic acid bacterial peptidases.

The EPI and DPI were not significantly different ($P > 0.05$) among the treatments (Table 2), probably because all the cheeses were manufactured in a single batch, with the same proportions of coagulant and lactic acid bacteria that cause proteolysis. Moisture and chloride contents, and pH, which affect proteolysis, were not significantly different among the treatments ($P > 0.05$). McMahon et al. (2014) found no difference in the percentage of water-soluble nitrogen (WST) and degradation of β -CN and α_{S1} -CN in reduced sodium Cheddar cheeses when sodium was replaced by other cations, including potassium. Water activity also influences the proteolysis of cheeses by controlling microorganisms and enzyme activity (Choisy, Desmazeaud, Gripon, Lamberet, & Lenoir, 2000). In the present study, sodium reduction did not affect the proteolysis of cheeses, since similar water activity values were observed for all treatments.

Both EPI and DPI increased significantly ($P < 0.05$) during the ripening (Table 2). These results are in agreement with other authors, who found an increase in the nitrogen fractions in Kefalograviera (Katsiari, Voutsinas, Alichanidis, & Roussis, 2001), Haloumi (Ayyash & Shah, 2011b), Mozzarella (Thibaudeau et al., 2015), Prato cheese (Costa et al., 2018b) and Coalho cheese (Costa et al., 2018a) with replacement of NaCl by KCl. The greater proteolysis during cheese ripening is expected, with the formation of alkaline nitrogenous compounds that cause a decrease in acidity (Al-attar, Abou-ghorrah, & Haddad, 2015) and consequently an increase in pH, which can be observed in cheeses with longer ripening periods.

Proteolysis is influenced by the moisture content, since it is a hydrolysis reaction. In this work, a reduction of the moisture content of cheese was observed throughout the ripening, which may have caused a deceleration of the proteolysis. The formulas for calculating the proteolysis indexes (EPI and DPI) do not take into account the moisture content, which could help to verify the impact of moisture content on proteolysis. Nevertheless, the average salt-to-moisture ratio of the treatments ($P > 0.05$) was 2.91%, which allows the proteolysis in the cheese. However, proteolysis did not cause an increase in pH during ripening, as the pH of the cheese is determined by the lactic acid content and the buffering capacity of the curd, which has a strong buffering capacity at pH 4.8 (Lucey & Fox, 1993), close to that found in the Minas Padrão cheese. Possibly, this increase in pH would be observed if the cheese was analysed for longer. Nepomuceno, Costa Junior, and Costa (2016) verified an increase in pH of Prato cheese after 90 days of ripening caused by proteolysis. There was no significant difference in the interaction between treatment and time for EPI and DPI indexes ($P > 0.05$).

3.3. Texture profile

The sodium reduction in Minas Padrão cheese did not affect hardness, adhesiveness, cohesiveness, and springiness ($P > 0.05$). Other researchers also found no differences in hardness of cheeses produced with NaCl/KCl blends in Feta (Katsiari, Voutsinas, Alichanidis, & Roussis, 1997) and Mozzarella cheese (Thibaudeau et al., 2015). Hardness increased for all treatments over time ($P < 0.05$) (Fig. 2). Although proteolysis leads to a reduction in

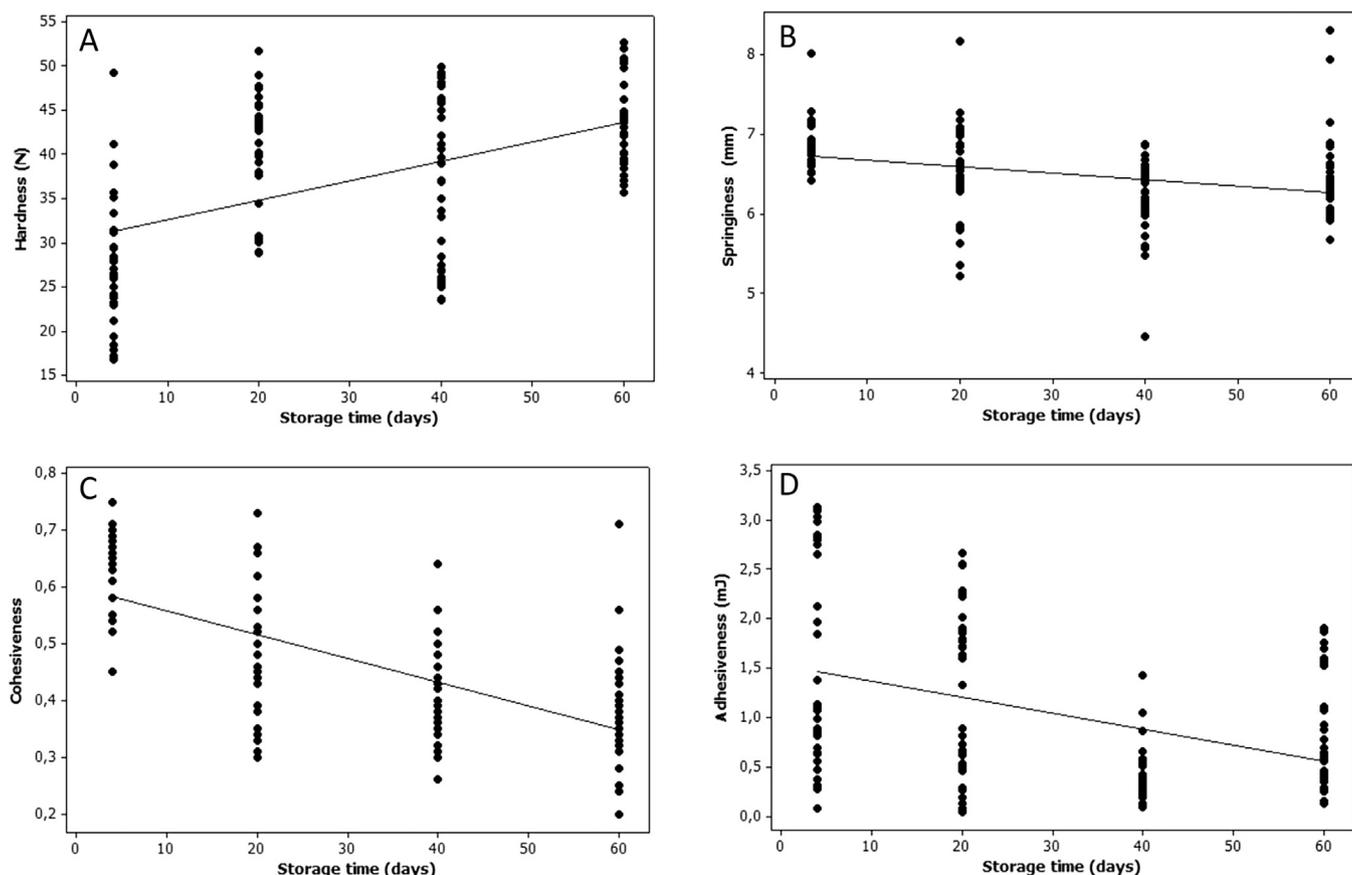


Fig. 2. Evolution during ripening of texture profile of Minas Padrão cheese manufactured with NaCl and mixtures of NaCl and KCl; A, hardness; B, springiness; C, cohesiveness; D, adhesiveness.

cheese hardness, syneresis was observed in the packaged cheese, with consequent reduction in moisture content during maturation. This moisture loss increased the hardness of the cheeses, which is in agreement with other studies that related the cheese acidification during storage with an increase in hardness, probably due to syneresis (Buriti et al., 2005; Oliveira, Garcia, R. de C. R. do E Souza, & E. L. de Q, 2012).

Adhesiveness, cohesiveness, and springiness were affected by the ripening time ($P < 0.05$) (Fig. 2), probably due to the weakening of the protein network caused by proteolysis in cheese (Lawrence, Creamer, & Gilles, 1987). Ayyash and Shah (2011b) found an inverse relationship between hardness and cohesiveness over the storage in Nabulsi cheese with sodium reduction, which was verified in this study. In all texture parameters evaluated, there was no significant difference in treatment versus time interaction ($P > 0.05$).

3.4. Fatty acid profile

A significant difference ($P < 0.05$) was observed in the fatty acid profile of Minas Padrão cheese with sodium reduction at 20 days of ripening (Table 3), with an increase in short chain fatty acids (SCFAs), medium-chain fatty acids (MCFAs) and polyunsaturated fatty acids (PUFAs). NaCl may have an inhibitory effect on lipolysis (Katsiari et al., 2001), and therefore, sodium reduction causes an increase in fatty acids, as observed in the treatment with KCl:NaCl 50:50. The results are in agreement with those found in Cheddar cheese (Lindsay, Hargett, & Bush, 1982), in which salting using a blend (1:1) of NaCl and KCl increased the lipolysis, as also observed for Kefalograviera cheese (Katsiari et al., 2001).

Minas Padrão is a ripened cheese, thus lipolysis is expected. Minas Padrão cheese was made with pasteurized milk and 100% chymosin coagulant, without the addition of lipase, thus the lipolytic enzymes of lactic bacteria were responsible for lipolysis and, to a lesser extent, the natural milk lipases, since they can have been inactivated during milk pasteurisation. Lipases naturally present in milk have a preference for the hydrolysis of MCFAs when compared with long chain fatty acids (LCFAs). In contrast, lipolytic enzymes from lactic acid bacteria are more active on substrates containing SCFAs (Collins, McSweeney, & Wilkinson, 2004), which explains the

Table 3
Fatty acids profile of Minas Padrão cheese manufactured with NaCl and mixtures of NaCl and KCl after 20 days of refrigerated storage.^a

Ripening time (days)	Treatment (KCl:NaCl)		
	0:100	25:75	50:50
Butanoic (C4:0)	1.21 ± 0.06 ^b	1.26 ± 0.07 ^b	1.31 ± 0.08 ^a
Hexanoic (C6:0)	1.32 ± 0.16 ^b	1.42 ± 0.28 ^a	1.48 ± 0.44 ^a
Octanoic (C8:0)	1.11 ± 0.10 ^b	1.32 ± 0.28 ^a	1.39 ± 0.22 ^a
Decanoic (C10:0)	1.85 ± 0.33 ^b	2.26 ± 0.17 ^a	2.62 ± 0.23 ^a
Dodecanoic (C12:0)	2.32 ± 0.43 ^b	2.43 ± 0.28 ^a	2.49 ± 0.23 ^a
Tetradecanoic (C14:0)	9.40 ± 0.05 ^a	9.30 ± 0.33 ^a	9.20 ± 0.23 ^a
Pentadecanoic (C15:0)	1.43 ± 0.03 ^a	1.44 ± 0.38 ^a	1.46 ± 0.32 ^a
Palmitic (C16:0)	37.00 ± 0.28 ^a	36.40 ± 0.39 ^a	35.7 ± 0.05 ^a
Palmitoleic (C16:1)	1.87 ± 0.17 ^a	1.92 ± 0.33 ^a	1.91 ± 0.22 ^a
Stearic (C18:0)	11.60 ± 0.22 ^a	12.40 ± 0.11 ^a	12.6 ± 0.43 ^a
Trans-vaccenic (C18:1t)	2.70 ± 0.07 ^a	2.50 ± 0.24 ^a	2.60 ± 0.22 ^a
Oleic (C18:1c)	26.50 ± 0.33 ^a	25.70 ± 0.07 ^a	25.8 ± 0.11 ^a
Linolenic (C18:2)	0.50 ± 0.56 ^a	0.62 ± 0.48 ^a	0.61 ± 0.22 ^a
α -Linolenic acid (C18:3)	0.17 ± 0.28 ^a	0.18 ± 0.17 ^a	0.17 ± 0.22 ^a
Conjugated linoleic acid	1.20 ± 0.33 ^a	0.83 ± 0.33 ^b	0.65 ± 0.33 ^b
Short-chain fatty acids	1.21 ± 0.43 ^a	1.26 ± 0.22 ^b	1.31 ± 0.39 ^a
Medium-chain fatty acids	6.60 ± 0.38 ^a	7.43 ± 0.12 ^b	7.98 ± 0.44 ^a
Long-chain fatty acids	92.37 ± 0.28 ^a	91.29 ± 0.09 ^a	90.7 ± 0.05 ^b
Monounsaturated fatty acids	31.07 ± 0.06 ^a	30.12 ± 0.33 ^a	30.31 ± 0.44 ^a
Polyunsaturated fatty acids	0.67 ± 0.03 ^b	0.80 ± 0.22 ^a	0.78 ± 0.24 ^a

^a Data (in g 100 g⁻¹ fat) are means ± SEM; means within a row with different superscript letters differ significantly ($P < 0.05$).

increase of SCFAs and MCFAs in cheeses with higher addition of KCl, since NaCl may have an inhibitory effect on lipolysis (Katsiari et al., 2001).

The increase in PUFAs can be seen as a health benefit in the consumption of cheese with sodium reduction and substitution by KCl. Higher PUFA intake has been associated with a reduction in inflammatory processes and low cardiometabolic risk (Coelho, Silva, Rocha, Lopes, & Alfenas, 2017). In contrast, there was a reduction of LCFAs, which may have been caused by the increased KCl content in the cheese that favoured the release of SCFAs and MCFAs rather than the LCFAs. Lipoprotein lipase, from milk, has a preference for SCFAs over LCFAs (Collins et al., 2004); however, apparently contradictory results were obtained by Fitzgerald and Buckley (1985) who found high levels of oleic, linolenic and palmitic fatty acids in Cheddar cheeses salted only with KCl, MgCl₂ or CaCl₂. In addition, similar fatty acids levels were observed in the cheeses salted with NaCl:KCl 50:50 blends when compared with the control. Felicio et al. (2016) found no differences in short, medium, long, monounsaturated, and polyunsaturated fatty acids, probably because the cheese studied was a fresh cheese and Minas Padrão is a ripened cheese; however, Costa et al. (2018a) assessed the fatty acid profile in Coalho cheese with partial replacement of NaCl by KCl and observed an increase in these fatty acids when the amount of KCl used in the cheese to reduce sodium was higher.

A reduction of conjugated linoleic acid (CLA) was also observed in Minas Padrão cheese salted with KCl. Felicio et al. (2016) found a reduction in CLA in Minas Frescal probiotic cheese with sodium reduction and replacement by KCl. The decrease in CLA needs to be taken into account in sodium reduction of cheeses since CLA confers health benefits to consumers (Koba & Yanagita, 2014). Further studies are needed to explain the relationship between sodium reduction and the decrease in CLA in cheeses.

3.5. Sensory evaluation

Significant differences were observed in the consumers' acceptance test among the treatments ($P < 0.05$) for the attributes appearance, texture, flavour, and overall acceptance (Table 4). The cheese with 50% KCl (w/w) presented lower flavour scores ($P < 0.05$) due to the residual flavour caused by the higher KCl ratio. The replacement of NaCl by potassium chloride (KCl) or magnesium chloride (MgCl₂) in cheeses can lead to higher sourness tone and a reduction in salty taste (Cruz et al., 2011). Lower appearance scores were also observed for the cheeses of the treatment NaCl:KCl 50:50 when compared with the other treatments. The appearance of cheese is related to texture, since this attribute is the result of the combination of physical properties such as size, shape, and structural conformation of the constituents that can be perceived by touch, sight, and hearing (Delahunty & Drake, 2004). Possibly, the higher proportion of KCl may have influenced the scores for these two attributes, which were lower than the other treatments.

Table 4
Scores for the attributes of Minas Padrão cheese manufactured with NaCl and mixtures of NaCl and KCl obtained in the sensory evaluation after 20 days of refrigerated storage.^a

Attribute	Treatment (KCl:NaCl)		
	0:100	25:75	50:50
Appearance	6.64 ± 0.11 ^a	6.42 ± 0.12 ^a	6.04 ± 0.11 ^b
Aroma	6.35 ± 0.11 ^a	6.22 ± 0.11 ^a	6.09 ± 0.11 ^a
Flavour	6.19 ± 0.12 ^a	6.22 ± 0.14 ^a	5.43 ± 0.13 ^b
Texture	6.05 ± 0.12 ^a	6.10 ± 0.14 ^a	5.46 ± 0.13 ^b
Overall acceptance	6.37 ± 0.11 ^a	6.35 ± 0.12 ^a	5.76 ± 0.12 ^b

^a Data are means ± SEM; means within a row with different superscript letters differ significantly ($P < 0.05$).

Flavour and texture were correlated with overall impression at 0.79 and 0.81, respectively. Cheeses with lower flavour and texture scores, as observed in the treatment NaCl:KCl 50:50, also received lower scores in the overall impression, with a significant difference ($P < 0.05$) when compared to the other treatments.

Although a change in the fatty acid profile was observed among the treatments due to the use of KCl, the aroma of the cheeses was not affected, according to the consumers' opinion, probably due to the higher precision of the equipment used in the detection of the fatty acids, when compared to assessors' perception. In addition, this type of sensory test is performed with untrained assessors, which may have also influenced the results obtained in the sensory evaluation for the attribute aroma.

The cheese with 25% KCl was not significantly different from the control ($P > 0.05$). Some authors have reported that the sodium reduction with replacement by blends containing 50:50 NaCl and KCl did not affect the biochemical, sensory, and texture characteristics. However, 70:30 and 60:40 proportions of NaCl and KCl can reduce the sodium content satisfactorily without altering the cheese flavour (Cruz et al., 2011), which was verified in this study. Minas Padrão cheese with 25% sodium reduction and replacement by KCl presented satisfactory results in the acceptance test, as also observed in other studies of Minas Frescal cheese (Gomes et al., 2011), and Mozzarella (Thibaudeau et al., 2015).

4. Conclusions

The partial replacement of NaCl by KCl did not affect the physicochemical characteristics, pH, proteolysis, and texture profile of Minas Padrão cheese for all treatments. However, significant changes were observed during ripening, including pH reduction, greater proteolysis, and increased hardness. The sodium reduction also interfered in the fatty acid profile. The partial substitution of 25% of sodium chloride with potassium chloride in Minas Padrão cheese was well accepted by consumers, demonstrating that it is possible to use KCl for partial sodium reduction in the manufacture of Minas Padrão cheese.

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