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Development of processed low-sodium Maasdam cheese

[*Desenvolvimento de queijo processado tipo Maasdam com baixo teor de sódio*]

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ABSTRACT

The article assesses the effect of different potassium emulsifying salts concentrations on physicochemical, colorimetric, and texture characteristics of processed cheese manufactured using Maasdam. Except for pH, physicochemical parameters remained unchanged, but the gradual substitution of sodium emulsifying salts with potassium-based salts influenced color and texture. Treatments with at least 50% potassium salts showed a reduction of at least 30% of sodium. The sodium decrease allows the product's classification as processed cheese with low-sodium content (<140mg per 56.7g serving). The data obtained present substantial information that can help the dairy industries develop newly reduced-sodium products.

Keywords: dairy product, maasdammer, healthy eating, new product development, melting salts

RESUMO

O artigo avalia o efeito de diferentes concentrações de sais emulsificantes de potássio nas características físico-químicas, colorimétricas e de textura de queijos processados fabricados com Maasdam. Com exceção do pH, os parâmetros físico-químicos permaneceram inalterados, mas a substituição gradual dos sais emulsificantes de sódio por sais à base de potássio influenciou a cor e a textura. Os tratamentos com pelo menos 50% de sais de potássio mostraram uma redução de pelo menos 30% do sódio. A diminuição do sódio permite a classificação do produto como queijo fundido com baixo teor de sódio (<140mg por porção de 56,7g). Os dados obtidos apresentam informações substanciais que podem ajudar as indústrias de laticínios a desenvolver novos produtos com teor de sódio reduzido.

Palavras-chave: produtos lácteos, maasdammer, *alimentação saudável, desenvolvimento de novo produto, sal fundente*

INTRODUCTION

Dairy products are one of the main sectors of food consumption, responsible for more than 40% of the world export market, and, among the derivatives, cheeses are among the most consumed products and with a high market growth projection (Perspectivas…, 2019). Cheeses with greasy highlights, such as Maasdam, are formed by releasing carbon dioxide during fermentation by *Propionibacterium freudenreichii* spp. shermanii, being a semi-hard cheese with high-fat content, with at least four weeks of maturation and a slightly sweet taste (Mcsweeney *et al*., 2004; Düsterhöft *et al*., 2016; Duru *et al*., 2018).

Among the consumers, there is also a higher selectivity and preference for consuming healthier products (Zacarchenco *et al*., 2017; Miyamoto *et al.*, 2018; Martinelli and Cavalli, 2019; Nguyen *et al.*, 2019). The consumption of sodium in the Western diet is excessive, almost three times greater than the maximum amount of daily consumption recommended by the World Health Organization (less than 5 g) (Guideline…, 2012; Global…, 2019). Additionally, excessive sodium consumption can lead to hypertension development and an increased risk of cardiovascular disease (Adrogué and Madias, 2014). Therefore, consumers increasingly demand sodium-reduced products.

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Processed cheeses are produced by adding emulsifying salts to typical cheeses, combined with homogenization and heating (Talbot-Walsh *et al.*, 2018). These salts interact with the protein matrix, breaking the bonds of calcium phosphate and para-casein, releasing the soluble casein that recomposes itself in the weft, causing the viscosity of the product (Mozuraityte *et al.*, 2019). Precisely because of the melting salts' addition, processed cheeses have a higher amount of final sodium than traditional cheeses (Agarwal *et al.*, 2011).

Several types of emulsifying salts can be used, combined or not, in processed cheese technology, the most common of which is based on sodium phosphate and sodium citrate (Lucey *et al.*, 2011). The sodium reduction in the final product can happen by reducing salt in the cheese production used as a base or by changing the emulsifying salt chosen for the process. However, the reduction of sodium levels in processed cheeses can affect these products' characteristics (Felicio *et al*., 2016), particularly the flavor and texture properties (Nogueira *et al.,* 2018). The choice of emulsifying salt will depend on the cheese's characteristic as a base, the salt's characteristic, the preparation conditions, and the type of processed cheese to be produced (Agarwal *et al.,* 2011).

The production of processed cheeses with reduced sodium content has been researched, changing the quantity and quality of the melting salts used in the formulations, diversifying proportions and combinations of the salts in search of rheological characteristics similar to those of traditional processed cheeses (Shirashoji *et al*., 2010; Guinee and O'Kennedy, 2012; Nagyová *et al.,* 2014; Nogueira *et al.,* 2018; Mozuraityte *et al.,* 2019). However, few studies evaluate the substitution of sodium in fine processed cheeses. This work aimed to develop a creamy processed cheese with low sodium content based on Maasdam cheese by exchanging the emulsifying salt based on sodium for anhydrous monopotassium phosphate, evaluating its impact on the physicochemical, colorimetric, and product texture.

MATERIALS AND METHODS

Maasdam cheese (KROON®, Netherlands), used as a basis for processed cheese production, was obtained from local retailers from a single batch, and the expiration date and physical integrity of the product were respected. In addition to cheese, the following ingredients were used: 35% fat sour cream (Verde Campo, Minas Gerais, Brazil); skimmed-milk powder (Nestlé, São Paulo, Brazil); and Joha 4® melting salts (AICL, São Paulo, Brazil); mixtures of sodium polyphosphates and sodium pyrophosphate and anhydrous monopotassium phosphate (AICL, São Paulo, Brazil). All commercial products were for food use, under inspection, and within the expiration date. Potable water was also used.

The experiment was performed in a completely randomized design with five treatments and three replications. All the analysis were performed in triplicate. The five formulations were made using the ingredients in the concentrations shown in Table 1, producing 15 kilograms of processed cheese.

Table 1. Proportion of the mixture of the melting salts used in each treatment to prepare Maasdam processed cheese*

Ingredients	T1	T2	T3	T4	T5
Maasdam cheese	44.0	44.0	44.0	44.0	44.0
Potable water	35.0	35.0	35.0	35.0	35.0
Milk cream (35%)	13.0	13.0	13.0	13.0	13.0
Skim powdered milk	6.8	6.8	6.8	6.8	6.8
Emulsifying salt commercial sodium based	1.2	0.9	0.6	0.3	-
Anhydrous monopotassium phosphate	-	0.3	0.6	0.9	1.2
Total	100	100	100	100	100

* The values are presented in g 100g-1

For each formula the amount of emulsifying salt was gradually changed, using the combination of commercial sodium-based emulsifying salt (Joha 4®) and potassium-based emulsifying salt (anhydrous monopotassium phosphate). The percentages of salt used in the five treatments (T) were: T1 = 100% sodium base, T2 = 75% sodium base and 25% potassium base, T3 = 50% sodium base and 50% potassium base, T4 = 25% sodium base and 75% base potassium, and T5 = 100% potassium base.

Cheese processing was carried out using the Thermomix™ equipment (Vorwerk & Co. Thermomix; Wuppertal, Germany). Initially, the cheese was finely ground for 30 seconds at 1,950 revolutions per minute (RPM). The grinding was followed by the addition of dry ingredients (powdered milk and emulsifying salts) and five-minutes homogenization at room temperature. Afterward, the cream and water were incorporated until entirely homogenized. The mixture was heated to 90ºC, with homogenization at 10,200 RPM for 3 minutes, complete melting, and cremification. The final product was placed in high-density polyethylene containers, hermetically sealed, inverted for complete sterilization of the packaging, and stored at ±4ºC.

The physicochemical analysis of the processed cheese were performed on the 10th day after processing. The time was standardized to represent the period when the product is being commercialized or used by the market, and it gives time for the occurrence of internal interactions in the product such as protein hydration, structure stabilization, and viscosity. Moisture and total solids content were determined by the gravimetric method, fat by the Gerber method, and the fat content in the dry extract was calculated by dividing the fat content of the cheese by the dry extract found, pH values were obtained using the pH-meter (Official…, 2012). Sodium and potassium were quantified by inductively coupled plasma optical emission spectrometry (ICP-OES) (Official…, 2012).

The texture analysis was performed using the Texture Profile Analysis (TPA) method using the TA-XT2i Texture Analyzer (Stable Micro Systems Ltd., Surrey, UK) with the P25 cylindrical stainless steel probe using the compression test and at a speed of 1.0 mm.s^{-1}. The probe was inserted perpendicularly into the cream contained in the package at +10 ºC. The test conditions were: pre-test speed, test, and post-test of 5.0 mm.s^{-1} with 20 mm penetration in the cheese, and the parameters analyzed were hardness, gumminess, and resilience.

Color parameters were measured using the CM-600d portable colorimeter (Konica Minolta, Japan), using the CIELab scale in which the color space parameters studied were: luminosity (L*), dimension between red and green (a*), dimension between blue and yellow (b*). The Yellowness Index (YI) was also determined, calculated from the average of the values of L * a * b *, according to equation 1 (Coimbra *et al.*, 2020).

$$\mathrm{YI} = 142.86\left(\frac{b*}{L*}\right) \quad (1)$$

The entire experiment was repeated five times, and the analyses were performed in triplicate. The results of the physicochemical, colorimetric, and texture analysis were evaluated by Analysis of Variance (ANOVA) and Tukey's test at the level of $p < 0.05$, using the XLSTAT for Windows 2014 program (Adinsoft, Paris, France).

RESULTS AND DISCUSSION

Both the Maasdam cheese used as a base and the processed cheese produced were analyzed, the physicochemical composition parameters of Maasdam cheese used as a basis for processed cheese production were fat 27.34%, FDM 47.82%, moisture 42.83%, pH 6.13, Sodium 155mg.100g^{-1} and Potassium 267mg.100g^{-1}.

The physicochemical parameters and the results of the processed cheese produced are shown in Table 2.

The Maasdam cheese displayed an average of 6.13 pH, 42.83% moisture, 27.33% fat, 48.4% fat in dry extract (FDM), 0.15g of sodium (Na), and 0.022g of potassium (K), corroborating with Düsterhöft *et al.* (2016), who characterized Maasdam cheese as a semi-hard cheese, high in fat (40 - 50%) and pH 5.2 - 5.4 after an average maturation of six weeks. Our results are also in agreement with Lamichhane *et al.* (2018), who evaluated the composition and texture of Maasdam cheeses after maturation and obtained a pH of 5.28, 44.86% moisture, 23.9% fat, 43.31% FDM, and 1.53% salt.

Table 2. Physical-chemical composition parameters of processed cheese

Formulation	Fat ($g.100g^{-1}$)	FDM ($g.100g^{-1}$)	Moisture ($g.100g^{-1}$)	pH	Sodium ($mg.100g^{-1}$)	Potassium ($mg.100g^{-1}$)
T1	17.80 ± 0.110^{a}	45.21 ± 0.243^{a}	60.61 ± 0.269^{ab}	6.02 ± 0.037^{a}	288.9 ± 0.001^{a}	14.5 ± 0.000^{e}
T2	17.85 ± 0.156^{a}	45.47 ± 0.498^{a}	60.74 ± 0.310^{a}	5.93 ± 0.042^{b}	249.0 ± 0.000^{b}	20.6 ± 0.003^{d}
T3	17.86 ± 0.182^{a}	45.41 ± 0.419^{a}	60.67 ± 0.179^{a}	5.83 ± 0.066^{c}	201.5 ± 0.003^{c}	34.7 ± 0.000^{c}
T4	17.91 ± 0.167^{a}	45.43 ± 0.310^{a}	60.50 ± 0.327^{ab}	5.83 ± 0.063^{c}	189.1 ± 0.009^{d}	49.0 ± 0.000^{b}
T5	17.94 ± 0.125^{a}	45.12 ± 0.096^{a}	60.29 ± 0.232^{b}	5.88 ± 0.034^{bc}	152.7 ± 0.006^{e}	59.5 ± 0.0001^{a}

Different superscript lower case letters in the same column indicate statistically significant differences between treatments ($P < 0.05$) (Tukey test)

As for the physicochemical parameters evaluated after the production of the different processed cheese treatments, no significant differences were observed for the fat and FDM contents ($p> 0.05$), with a slight difference among the T5, T3, and T4 moistures ($p< 0.05$). The lower moisture content of the T5 sample, although not sufficient to alter product quality parameters, may be related to the lower protein-binding strength of potassium ions than sodium ions and are defined as weak chaotropic ions (Vrbka *et al.,* 2006), being a weak hydrophobic structure breaking and decreasing the product's water retention capacity. Bearing in mind that this is the parameter that most varies in cheese production, it can be considered that there was linearity in the production of processed cheese. These results agree with Patel *et al.* (2013) and Nogueira *et al.* (2018), who also observed linearity in the humidity levels as substituting sodium-based emulsifying salts with potassium-based ones during the production of processed cheese, without observing significant alterations for this parameter.

The elaborated product, regardless of the salt used, can be classified as fat cheese, with an average fat content between 45.0% and 60%, of very high humidity (above 55%), characterized by having a soft mass and with good spreadability, configuring as spreadable processed cheese (Codex, 1978a, 1978b). Nogueira *et al.* (2018), processed cheese using Mozzarella cheese as a base, and although the fat content was much lower (20%) due to the type of base cheese used, the moisture content was above 60%, which also checked the product's spreadability. The spreadability can change when adding polymerized protein isolates in processed cheese production since the isolate improves the product's emulsifying characteristic (Solowiej *et al.*, 2020).

The processed cheese's pH values displayed significant changes, which decreased since the first treatment and underwent changes as the proportions of emulsifying salts were changed, presenting the lowest values for T3, T4, and T5, following the trend of decrease as the number of anhydrous monophosphates increased. Phosphate is used as a pH control agent in dairy products (milk, cheese, processed cheese, and pasteurized processed cheese) as a nutritional supplement, sequestering/chelating, emulsifying, acidifying, and stabilizing (Technical…, 2016). The results obtained are reinforced by Barth *et al.* (2017), who concluded that at low pH (5.2 and 5.6), cheeses tend to have a granular structure. However, at a more neutral pH (6.0 to 6.8), the structure becomes more continuous, homogeneous, and fluid since the casein matrix charge change promotes higher water absorption and the connection between water and protein.

A study conducted to replace the emulsifying agent for processed cheese production pointed out a substantial drop in pH, resulting in significant texture changes, increasing the firmness, and decreasing the product's adhesiveness (Rohani and Rashidi, 2019). The pH variation effect on processed cheese's rheological properties was also evaluated by Ong *et al.* (2020), who observed that the decrease in pH led to a denser protein microstructure with higher aggregation, generating a firmer cheese. These results were also observed by Mozuraityte *et al.* (2019), who concluded that the reduction of sodium-based emulsifying salt causes a pH decrease. However, potassium phosphate's higher solubility compared to sodium phosphate causes an increase in pH in cheeses that use only potassium-based emulsifying salt, so it is crucial to monitor this change and correct it when necessary.

pH increase becomes a problem in reduced-in-sodium products, as it is one hurdle less against the microorganisms and because it eases enzymatic processes, contributing to the expirydate reduction of the product. According to Bansal and Mishra (2020), the analysis of sodium reduction's influence is highly significant to manage the product's quality and safety. Reduction strategies must focus on preserving the same pH modification rate as the control product because it is the most critical factor to the cheeses' quality and safety. The present study's pH modification behaviors preserve their potential as a microbiological hurdle, even contributing to the texture alteration.

Despite being the most significant contributor to the sodium content in processed cheeses, the emulsifying salt separates micelles and submicels of casein, breaking calcium phosphate bonds, and incorporating sodium into its chemical form, exposing polar and nonpolar sites, and increasing the molecular hydration space. This modification of the protein network allows a stable colloidal suspension to occur, accompanied by an increase in the viscosity of the product, which depends on the solution pH balance, which must remain between 5.5 and 6.1 (Guinee *et al.,* 2004; Lucey *et al.,* 2011; Mozuraityte *et al.,* 2019).

As expected, the sodium and potassium levels of cheese products were significantly affected by changes in emulsifying salts ($p < 0.05$). As the proportions of emulsifying salts changed, there was a decrease in sodium content and an increase in the potassium content, so that T1 had the highest value for the sodium amount (288.9 $mg.100g^{-1}$), and T5 had the highest potassium content (152.7 $mg.100g^{-1}$). While the World Health Organization recommends a maximum of 5g per day for sodium intake, the Dietary Guidelines recommends that Americans take less than 2.3mg of sodium daily while encouraging increased potassium intake for 3.8 mg in children aged 3 to 14 years and 4.7mg for people aged 14 and over (Guideline…, 2012; Dietary…, 2015). A Canadian study co-elaborated by the academies of science, engineering, and medicine in dietary food, of reference for sodium and potassium, concluded that high sodium intake correlates with chronic diseases. Given the high intake meta-analysis of sodium and indicators of chronic diseases, the authors concluded that the reduction in sodium intake reduces systolic blood pressure, diastolic blood pressure, the incidence of hypertension, and cardiovascular disease (Macfarlane *et al.,* 2019).

Most persons consume high sodium amounts through salt ingestion (corresponding to a mean 9-12g per person a day) without consuming sufficient amounts of potassium (less than 3.5g). The high sodium intake and insufficient potassium intake contribute to hypertension, increasing cardiovascular diseases, and AVC (Folha…, 2019). The potassium supplementation in the diet, or by including in the diet foods rich in this mineral, can be an efficient adjuvant in the pharmacological anti-hypertensive therapy of patients affected by this disease (Araújo *et al.*, 2010; Fonseca *et al.*, 2015). In this form, the present study's product may become a relevant contributor to a healthy diet.

The Food and drugs Administration (Food…, 2020) classifies a product with at least a 25% sodium reduction compared to the standard product as "reduced-in-sodium." A low-in-sodium product must contain a maximum of 140 mg of sodium per serving (2 oz or 56.7 g). As the product contains a maximum of 35 mg sodium per serving, the FDA classifies it as "very low sodium." If the sodium content is lower than 5 mg per serving, it is classified as salt/sodium-free (Food…, 2020). In this context, Table 3 highlights that the formulations T3, T4, and T5 obtained compatible values for sodium reduction (at least 30%), and can also be classified as low sodium content, respectively, showing 114.25mg, 107.22mg, and 86.58mg per serving. Among dairy products, several pieces of research include cheeses as significant contributors to high sodium intake: during their processing, there is the salting stage, which contributes to both sensory and microbiological characteristics. The sodium content in cheese can vary from 40 to over $1900mg.100g^{-1}$ for most natural cheeses (El-Bakry, 2012; Matera *et al.,* 2018), or it can be as high as $1620mg.100g^{-1}$ in processed cheeses (Bansal and Mishra, 2020). Assessing the sodium content in Cheddar, Colby, Jack, and Pizza Cheese, Agarwal *et al.* (2011) observed that the average content among cheeses was $668mg.100g^{-1}$. Matera *et al.* (2018) evaluated the constituent sodium content in natural cheeses most commonly consumed in Brazil, such as White *Frescal* cheese, White cheese, and Curdled cheese, verifying an average variation of 300 to $1,903mg.100g^{-1}$.

Table 3. Proportion of sodium reduction and amount of sodium per serving

Formulation	Sodium reduction	Sodium content per serving (56.7mg/2 oz)
T1	---	163.8
T2	13%	141.18
T3	30%	114.25
T4	34.5%	107.22
T5	47.1%	86.58

According to Ferrão *et al.* (2016), the sodium reduction in processed cheeses is a challenge due to changes in processed cheese's physicochemical, sensory, and rheological characteristics. For more than a decade, several researchers have discussed different combinations in proportion and quality of emulsifying salts to determine levels that interfere less in essential issues for consumer acceptance and consequently boost the production of healthier and safer products (Cruz *et al.*, 2011; Lucey *et al.*, 2011; Ferrão *et al.*, 2016; Nogueira *et al.*, 2018; Silva *et al.*, 2018; Dougat-Bony *et al.*, 2019; Mozuraityte *et al.*, 2019; Salek *et al.*, 2019; Ong *et al.*, 2020).

Paes and Ravazi (2018) claimed that the food industry faces difficulties in reducing sodium in processed cheeses due to the reduced number of available techniques to reach this result. Even if there are many substitutes prepared with potassium chloride (KCl), many firms develop their combined formulae due to the necessity to preserve the technological features of their products, and the acquisition cost of the ready ingredients, using reducing salts with technical parameters, and guarantee the 50% salt reduction, being frequently the solution for the industries. This observation sustains the relevance of this study results as facilitating industrial production.

According to Szafrańska and Sołowiej (2020), sodium-based emulsifying salts have bacteriostatic action, improve the product's microbiological quality, and can be used in conjunction with other techniques.

Dougat-Bony *et al.* (2019) concluded that in addition to sensory changes, the drastic decrease in sodium content might accelerate the proteolytic process, especially in soft cheese, as they reduce barriers to bacterial growth. The formulation using 50% of each emulsifying salt helps preserve the microbiological quality of the final product. Although it is known that certain emulsifying salts (especially phosphates) can aid in controlling spoilage and pathogenic bacteria (Tanaka *et al.*, 1986), this study focused on produce investigating the effects of replacing sodium-based emulsifying salts with monopotassium phosphate on the physicochemical and sensory properties of spreadable processed cheese as a strategy to decrease the sodium content of the final product.

Besides the sensory and food safety challenges, the sodium reduction in foods is also a matter of economic worries: sodium-based salts are cheap, so any substitute will increase the final product's cost. The production of reduced-in-sodium foods requires reformulations and additional costs associated with consumer tests and pilot plant studies (Doyle and Glass, 2010). The product developed in the present study is relatively cheap due to the insertion of ingredients with high water content, increasing the yield while preserving the product's required quality standards.

Table 4 and 5, respectively, describe the results obtained for the color and texture analysis.

Table 4. Colorimetric indices results obtained for the five formulations of processed cheese.

Formulation	L*	a*	b*	**YI
T1	99.71 ± 0.044^{b}	0.73 ± 0.015^{a}	25.13 ± 0.010^{b}	36.01 ± 0.024^{b}
T2	97.54 ± 1.511^{c}	0.58 ± 0.005^{b}	23.24 ± 0.015^{d}	34.05 ± 0.526^{c}
T3	101.06 ± 0.146^{a}	0.60 ± 0.010^{b}	27.02 ± 0.018^{a}	38.20 ± 0.054^{a}
T4	100.87 ± 0.097^{a}	0.55 ± 0.027^{b}	24.05 ± 0.129^{c}	34.03 ± 0.172^{c}
T5	94.83 ± 0.112^{d}	0.21 ± 0.007^{c}	24.79 ± 0.024^{bc}	37.08 ± 0.062^{ab}

Different superscript lower case letters in the same column indicate statistically significant differences between treatments ($P < 0.05$). *lightness (L*), the red-green dimension (a*) and the yellow-blue dimension (b*). **YI= yellow index.

Table 5. Texture parameters obtained by TPA for the five formulations of processed cheese.

Formulation	Hardness	Gumminess	Resilience
T1	671.044±127.48^{c}	692.10± 103.88 ^{c}	0.032± 0.006^{a}
T2	808.58±36.061^{b}	861.35±75.88^{b}	0.032±0.001^{a}
T3	287.15±57.325^{e}	303.87±53.890^{e}	0.020±0.004^{b}
T4	547.90±59.361^{d}	540.34±27,404^{d}	0.025±0.001^{b}
T5	1161.30±118.713^{a}	1174.81±99.625^{a}	0.032±0.003^{b}

Different superscript lower case letters in the same column indicate statistically significant differences between treatments ($P < 0.05$).

According to USDA recommendations for Swiss cheese standards, the cheese's color must be between white and light yellow (United…, 2011). Wadhwani and McMahon (2012) observed that cheeses without added dye and with high-fat content tend to have higher values for b* and lower for a*, presenting a paler yellow shape. However, when added dye, the values of a* increase significantly, evolving to a more orange color, and when reducing the fat content, the most significant change occurs in L*, showing the formation of more opaque products. Generally, the increase in yellowing is directly related to the amount of fat due to adipocyte saturation with beta-carotene from animal metabolism (Pathare *et al.*, 2012). However, all samples had similar fat levels, which are not influencing the color change. Thus, it is suggested that the change in the proportion of emulsifying salts in the colorimetric indices is influencing the color of the products and may connect to changes in pH, humidity, sodium, and potassium levels.

From five formulations produced, T3 showed the highest L* values (101.06), b* (27.02), and YI (38.30), which means that this treatment was the most yellow and with the highest luminosity, being the palest yellow of the samples. T1 had the highest value for * (0.73), while T5 had the lowest value (0.21), indicating that cheeses produced with 100% potassium salt had the least pronounced red spectrum compared to the one produced with 100% sodium ($p <0.05$). The higher loss of red color at T5 may be related to a decrease in pH, which influences the degradation of carotenoids of the product's fat and the Maillard reaction during processing (Andrés-Bello *et al.,* 2013). The formulations with mixtures of salts (T2, T3, and T4) had intermediate values of a* (0.58, 0.6, and 0.55, respectively).

Similar results were observed by Nogueira *et al.* (2018), pointing out that the color change was influenced not only by fat but also by the protein network built during the formation of the gel, and its colloidal dispersion influences the dispersion of visible light and clarifies the mass. The parameter b* change was also observed as partially replacing the sodium salt with KCl and KMg-citrate during Cream Cheese production, which slightly increased the yellowing, but without significant changes for the total difference of colors (Lucan *et al.,* 2020). Contrary to this, Chavhan *et al.* (2015) reported no significant difference in the color and appearance of low sodium mozzarella cheese and low sodium processed mozzarella cheese during storage. In agreement with this observation, a non-significant difference between whole sodium cheddar cheese and reduced-sodium cheddar cheese was observed in color and appearance scores during 60 days of the ripening period (Khetra *et al.,* 2019).

Texture parameters were unique in all treatments ($p<0.05$), except for resilience, when values of T1 and T2 were different from the values of T3, T4, and T5. Besides, changes in texture parameters did not follow a linear pattern with the sodium substitution for potassium. The sample that obtained the highest values for the texture parameters was T5 (produced 100% with anhydrous monopotassium phosphate), while the lowest values obtained were the formulation T3 (50% for each emulsifying salt) revealing a softer product, homogeneous and with better spreadability.

The pattern observed in the texture change of the studied samples may have occurred due to the influence of several factors related to the characteristics of the products, such as the type and size of the phosphate chain used, its ability to interact with water and proteins, the ionic strength the different salts used or the pH change generated by the change in salts (Cini and Ball, 2014; Nagyová *et al.,* 2014). Therefore, the interaction of sodium salts (polyphosphates) with potassium salts (monophosphates) in the same proportion (50/50%) seems to have affected the ability of each type of phosphate to bind to processed cheese structures, such as caseins, calcium, and water, forming less strong and cohesive structures, carrying a product with less hardness and gumminess.

Kloss *et al.* (2015) advocate the same texture standard for the reduced-in-sodium processed cheese production, mainly using tripotassium citrate and trisodium citrate. Besides reducing the cheese melting capacity, these salts affect the final product's taste due to the metallic note of potassium.

Similar results were observed with the characterization of the texture of processed cheeses after the homogenization stage. Mohammadi and Fadaei (2018) found that both the decrease in fat globules and phosphate presence salts were responsible for increasing texture values. Nagyová *et al.* (2014) observed that the proportion of phosphates of different sizes of chains significantly influences the texture of processed cheese and, in general, the increase in the proportion of polyphosphates can generate a less hard mass, while higher proportions of monophosphates can improve the bonds between calcium ions and caseins, generating harder products. However, Sádlíková *et al.* (2010) tested different phosphate salts in the production of processed cheeses and observed an increase of the cheese's mass hardness when polyphosphate was added in proportions above 50%, even when combined with di or triphosphates. The mass's hardness increase shows that regardless of the salt used, the proportion of 50/50% hinders the interactions between processed cheese components.

Changes in texture patterns are due to interacting between the present proteins: the more significant the interaction, the more cohesive and less resilient the product mass. Souza *et al.* (2014) supported this evidence by observing an increase in texture parameters with increased protein concentration in processed cheese formulations. The same happens when the emulsifying salt content is elevated, but the addiction of polymerized protein isolate, as suggested by Solowiej *et al.* (2020), can balance the hardness and adhesiveness increases. It is also observed that the fat and moisture amount influences the product texture: processed cheeses with a reduction in fat content obtained a reduction in firmness, gumminess, and elasticity with no alternative for the recovery of the desired patterns. Simultaneously, increasing the hardness before the addition of protein concentrates can be solved by adding water that has given a return of the product's desired softness (Silva *et al.*, 2012).

CONCLUSIONS

Quality parameters for processed cheeses were reached in all formulations, and the sodium content was well below the ones found in natural cheeses or ordinarily processed cheeses. The processed cheese produced was influenced by the replacement of the sodium emulsifying salt for the potassium salt, mainly related to its texture, which is an essential feature in accepting this type of product. Using a 50% proportion of each emulsifying salt significantly changed the color and texture of the product, generating a more yellowish product, less cohesive, and less firm. These texture changes may or may not be desirable, depending on the final product's desired characteristics. These treatments allowed a reduction of at least 30% of sodium compared to the original product, classified as low sodium content, a healthier product that can be indicated even for infant feeding. This study developed a new product with characteristics promoting the consumers' health and well-being, reducing the incidence of chronic diseases related to excessive sodium consumption, but without significantly altering the product's natural characteristics, with a relatively cheap production process, providing evident technological advance. The data obtained express important information that can help the dairy industries develop new reduced-sodium products. However, studies aimed at applying sensory methodologies to assess consumer acceptance and perception of such products are still needed.

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