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Sodium reduction in margarine using NaCl substitutes

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ABSTRACT

Sodium chloride is traditionally used as a food additive in food processing. However, because of its high sodium content, NaCl has been associated with chronic diseases. Margarine is a popular product that is used in several preparations, but it includes high sodium content; therefore, it is among the products whose sodium content should be reduced. Thus, the objective of this study was to produce margarines with reduced sodium content prepared using a salt mixture. The following 4 margarine formulations were prepared: Formulation A (control - 0% sodium reduction), Formulation B (20.8% less sodium), Formulation C (33.0% less sodium) and Formulation D (47.4% less sodium). The low sodium formulations were produced using a salt mixture consisting of NaCl, KCl, and monosodium glutamate at different concentrations. The margarines were evaluated using an acceptance test and descriptive tests: time-intensity and temporal dominance of sensations. The mixture used is a good alternative for preparing low sodium margarine because the low sodium formulations feature equal salinity and do not produce a strange or bad taste. Furthermore, it may be possible to prepare margarines with up to 47.4% less sodium and that are acceptable to consumers.

Key words: acceptance, KCl, monosodium glutamate, TDS, TI.

INTRODUCTION

Sodium chloride (NaCl) is traditionally used as a food additive in food processing because, in additional to influencing the product taste, it plays an important role in texture and storage. However, due to the high sodium content, NaCl has also been associated with an increased risk of hypertension, development of cardiovascular disease, osteoporosis and kidney stone incidence (Weinsier 1976, Heaney 2006, OMS 2007) and thus the need for low-sodium product development increases (Albarracín et al. 2011).

According to the World Health Organization (WHO 2007, 2010), the upper limit for sodium intake is 2 grams per person per day (approximately one teaspoon), which is equivalent to 5 grams of salt (Frantz 2011). Recently, salt intake has been associated with an increased intake of food

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processed with high salt content, yielding an estimated global average intake of 9 to 12 g per person per day (Brown et al. 2009), which is nearly 3 times greater than the ceiling proposed by the World Health Organization. In Brazil, this estimate is even higher at approximately 13 grams of salt per person per day (Sarno 2009).

Due to concerns over excess sodium intake, several organizations are working to reduce sodium ingestion. The Food Standards Agency in the United Kingdom stablished targets for reducing salt (NaCl) in processed foods; the Food and Drug Administration (FDA) is also working with the US food industry to reduce sodium content in foods (FDA 2010), and the Ministry of Health and the Brazilian food industry agreed to reduce the sodium content in various food categories by 2016. According to the Ministry of Health, much sodium intake is through processed foods, among which margarine is notable (Brasil 2012).

Despite having an average sodium content compared to other products, margarine can be consider an important contributor to sodium intake, since it is used in several food preparations (Heart and Stroke Foundation South Africa 2014, Mhurchu et al. 2010). Therefore, it is important to seek alternatives to reduce sodium content in this product. Salt plays an important role in preserving margarine; however, its main role is to impart a desirable flavor to the product (Brady 2002, Hutton 2002). Thus, it is a challenge for the industry to prepare a low-sodium margarine without changing its taste.

One option for reducing sodium content in processed foods is replacing sodium chloride (NaCl) with another chemical that includes physical properties similar to salt, such as potassium chloride (KCl). However, due to its bitter taste, KCl cannot be the only substitute for NaCl (Nascimento et al. 2007). Thus, developing a salt mixture containing ingredients in proper proportions is an interesting alternative. Therefore, using flavor enhancers to produce a mixture has been highlighted, such enhancers include monosodium glutamate due to its characteristic umami taste and because it masks the bitterness of other salts, such as KCl (Souza et al. 2013, Rodrigues et al. 2014a, b). Monitoring the sensory profile of a product during intake is necessary to better characterize sensory changes; thus, in addition to acceptance testing, a temporal sensory evaluation must be performed, including time-intensity (TI) and temporal dominance of sensations (TDS).

Thus, the objective of this study was to use acceptance test and temporal sensory technics (TI and TDS) to evaluate sensory margarines with reduced sodium content prepared using a salt mixture consisting of NaCl, KCl and monosodium glutamate at different concentrations.

MATERIALS AND METHODS

INGREDIENTS

The materials used to prepare the samples include commercial unsalted butter, unsalted cracker to serve as a vehicle in sensory analysis, potassium chloride - 99% (Vetec® - Duque de Caxias, RJ, Brazil), monosodium glutamate - 99% (Aji-no-moto®, Brazil) and sodium chloride, 99% (Vetec® - Duque de Caxias, RJ, Brazil).

MARGARINE PREPARATION

The samples were prepared at the Sensory Analysis Lab of the Department of Food Science at the Federal University of Lavras using a mixer and aliquoted into four glass beakers with a capacity of 500 mL each. We used four glass sticks (Mixing systems), one in each beaker for re-homogenization.

Using the commercial unsalted margarine, four treatments were prepared considering the ideal salt levels in margarine: 0.6%. The ideal concentration of sodium chloride was determined based on information regarding commercial butter and pretests. We used a salt mixture (NaCl, KCl, and

MSG) at different concentrations that maintained the same salt power of the brine that contained only NaCl to produce margarines with 25, 50 and 75% less NaCl. The salt mixtures were determined based on the results of Gonçalves (2013) and Rodrigues et al. (2014a, b). Salt power was calculated according the results found for the sodium chloride substitutes by Souza et al. (2013), Feltrin et al. (2014) and Freire et al. (2014). Because NaCl includes 388 mg/g of sodium, and MSG includes 123 mg/g of sodium, the final treatments included 20.8, 33 and 47.4% less sodium relative to the control (margarine with 0.6% of NaCl) as shown in Table I.

TIME-INTENSITY ANALYSIS

Time-intensity analysis was performed in accordance to Rodrigues et al. (2014b). We selected 30 participants (15 men and 15 women between 24 and 56 years of age) without allergies to the ingredients and with experience in sensory evaluation, who consumed margarine at least once per week and who had interest as well as available time for the time-intensity sensory panel analysis using questionnaires. For data acquisition and analysis, the program SensoMaker (Nunes and Pinheiro 2012) was used. Through a graphical interface that used a 10-point scale, wherein 0 indicates no perception, and 10 indicates an extreme salty taste perception, each tester indicated the intensity of an attribute using a mouse, and the sample stimuli were presented one-by-one using a balanced complete block design (Walkeling and MacFie 1995). Thus, the panelist clicked the "start" button and ingested the full sample during two seconds; thereafter, using the mouse, the panelist indicated the intensity of the particular sensory attribute (salty flavor) using the scale in twenty-five seconds. After the analysis, a message indicated the end of the test, and the panelist proceeded to another sample.

The TI data were analyzed using the TI curves, which were computed using the software SensoMaker (Nunes and Pinheiro 2012). The curves were plotted using Microsoft Excel 2012.

TEMPORAL DOMINANCE OF SENSATIONS (TDS)

The TDS analysis was performed using thirty participants, without allergy to the ingredients used in the margarine preparation, in accordance with Rodrigues et al. (2014a). Panelists Recruitment was conducted by questionnaires, in which the frequency of margarine consumption (at least once a week) and experience with a sensory analysis were considered. The panelists were trained regarding the concept of sensations temporality (TDS) and were introduced to the data acquisition program SensoMaker (Nunes and Pinheiro 2012). The panelists were asked to click the "start" button and, in two seconds, place the margarine sample (approximately 5 g) in their mouth and immediately begin the evaluation. Using the mouse, the participants were requested to select the dominant taste over twenty-five seconds. The sensations

TABLE I
Margarine formulations.

Treatments	Salts (g)*			NaCl reduction	Sodium (Na) reduction
	NaCl	KCl	GMS		
A	3.000	0	0	0%	0%
B	2.250	0.645	0.400	25%	20.8%
C	1.500	0.430	1.610	50%	33.0%
D	0.750	0.430	2.615	75%	47.4%

*Quantities used to prepare 500 g of product.

evaluated were salty, bitter, sweet, umami, sour, spicy and astringent tastes as well as an off-taste.

The samples were presented in balanced order (Macfie et al. 1989) in disposable white plastic cups coded with three-digit numbers. The samples were served monadically, and the assessors were asked to rinse their mouth with water between each sample.

To assess the TDS results the TDS curves were plotted in accordance with the methodology in Pineau et al. (2009) using the SensoMaker. Briefly, two lines were drawn in the TDS graphical display, the "chance level" and the "significance level". The "chance level" is the dominance rate that an attribute can obtain by chance, and the "significance level" is the minimum value that the dominance rate should equal to be considered significant (Pineau et al. 2009). The significance level was calculated using a binomial proportion confidence interval based on a normal approximation in accordance with the equation of Pineau et al. (2009) (1).

$$\mathrm{Ps} = \mathrm{Po} + 1.645\sqrt{\frac{Po(1-Po)}{n}} \quad (1)$$

Ps: lowest significant proportion value (a = 0.05) at any point in time for a TDS curve; n: number of subjects *replication. Po = 1/p, wherein p is the number of attributes, and n = the number subjects per replication.

To analyze the curve results, we considered the significant sensations (i.e., above the "significant level" line).

SENSORY ACCEPTANCE MARGARINE EVALUATION

The margarine formulations were analyzed using an acceptance test. The test was conducted in individual booths. The 60 panelists without an allergy to the ingredients used in preparing the margarine, recruited by applying questionnaires, received approximately 5 g of each sample on a cracker at room temperature in plastic cups coded with three-digit numbers that were served in monadic order. The presentation order was balanced in accordance with the proposal by Walkeling and Macfie (1995). The panelist evaluated the acceptance of a salty flavor and their overall impression using a nine-point hedonic scale that ranged from "extremely dislike" to "extremely like" in accordance with the methodology described by Stone and Sidel (1993).

The acceptance test results were assessed with an analysis of variance using the statistical program SISVAR (Ferreira 2002) and with the acceptance means.

RESULTS AND DISCUSSION

TIME-INTENSITY

Figure 1 shows the intensity of salty flavor for the margarines formulations over time: A (control - without sodium reduction), B (20.8% less sodium), C (33% less sodium) and D (47.4% less sodium).

As shown in Figure 1, the formulations produced similar salty taste profiles over the analysis time. The margarine formulation without less sodium (A) produced a maximum salty flavor intensity of 4.32, and it required approximately 12 seconds of ingestion time; Formulations B (20.8% less sodium), C (33% less sodium), and D (47.8% less sodium) reached maximum salty flavor intensities of 4.67, 4.71 and 4.88 after 13, 13.1 and 14.8 seconds, respectively.

The low salty flavor intensity variations indicate that the salt mixture proportions correspond to a similar level of the sodium chloride salt that was replaced, which ensures similar salinity levels in the various margarine formulations. Consequently, the formulations approached the salty taste of sodium chloride. This was possible since KCl has a potency similar to NaCl (approximately 80%) (Souza et al. 2013), and the monosodium glutamate acts by activating the receptors in the mouth and throat, potentiating the salt taste (Brandsma 2006). Thus, the mixture used is a good alternative for

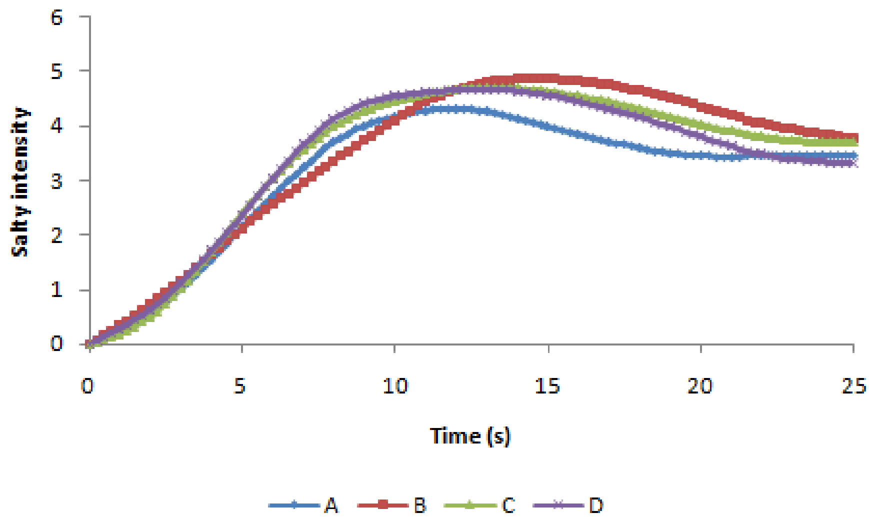

Figure 1 - Graphical representation of the salty taste intensity over time for margarines: **a** (control - Without sodium reduction), **b** (20.8% less sodium), **c** (33% less sodium) and **d** (47.4% less sodium).

preparing margarine with less sodium to obtain equal salinity.

The studies by Souza et al. (2013) and Rodrigues et al. (2014a, b) also showed using butter, mozzarella and spicy taste, respectively, that a salt mixture composed of KCl and monosodium glutamate promotes an equivalent salt power compared with NaCl, which aids in developing products with less sodium and salty flavor profiles similar to traditional products. Moreover, in the present study, the proportion of salts aid in developing products with a slightly greater salt taste intensity, which indicates that it may be possible to further reduce the sodium content in margarine.

TEMPORAL DOMINANCE OF SENSATIONS

Figure 2 shows the dominant temporal sensations profile (TDS) of the four margarine formulations studied. Each curve represents the dominance of a particular attribute over time. In the graphical representation of the TDS analysis, two lines indicate the ‘chance level’ and ‘significance level’. The “chance level” is the dominance rate that an attribute can obtain by chance, and the “significance level” is the minimum value that the dominance rate should equal to be considered to be significant (Pineau et al. 2009).

The graphical representation that corresponds to the TDS analysis of the commercial margarine sample containing only sodium chloride (A - without sodium reduction), wherein the ideal product curing at 0.6% (w/w), showed that only a salty taste was significantly dominant over time. The graphs show a similar result for samples containing 20.8% and 33% less sodium (B and C). However, the salty taste was perceived with a lower dominance rate, which is a measure that increased with a decrease in NaCl content. According to Mooster (1980), compared with sodium chloride, other cations, such as potassium, present a less salty perception. This justifies the lower dominance rate in treatments B and C. It is notable that the TI test saltiness intensity for each formulation is similar. Perhaps the lower dominance rate of the salt taste is related to the higher concentration of monosodium glutamate used in the formulation, which can yield other tastes, such as umami and sweet (Brandsma 2006, Desmond 2006, Souza et al. 2013).

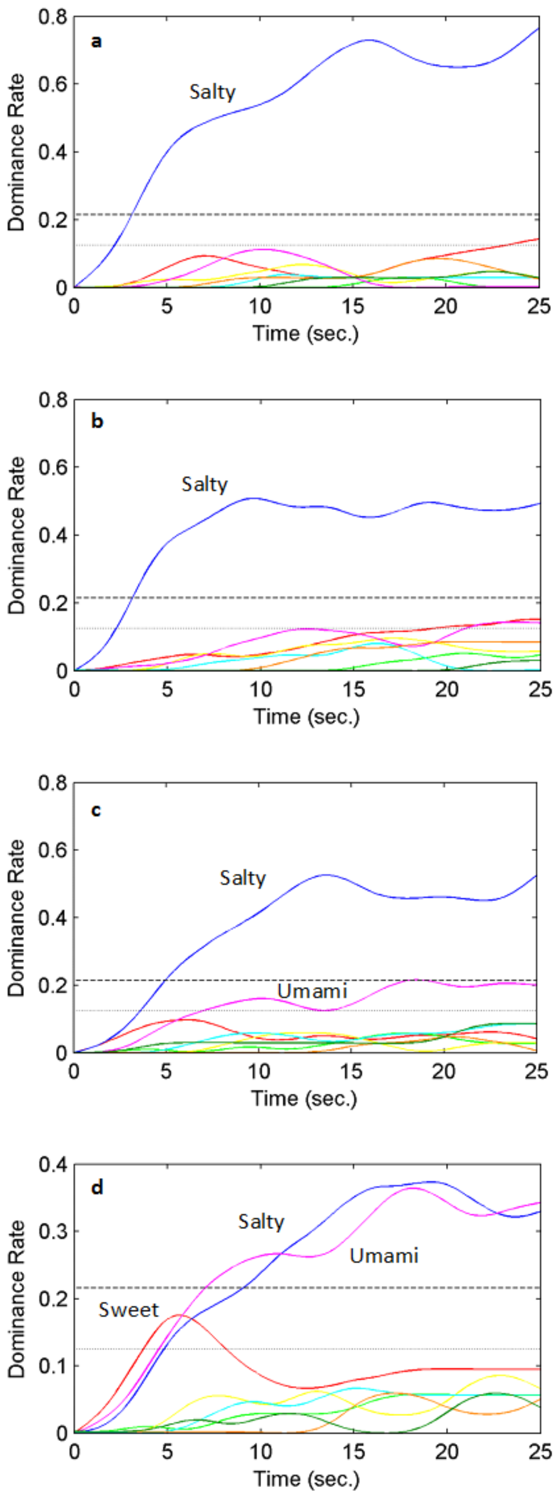

Figure 2 - Graphical representation of the temporal dominance of sensations profile for margarines: **a** (control - without sodium reduction), **b** (20.8% less sodium), **c** (33% less sodium) and **d** (47.4% less sodium).

In the graphical representation that corresponds to a commercial margarine sample containing a 47.4% sodium reduction (D), we found that, in addition to the salty taste perception, an umami taste was also significant and it is due to monosodiumglutamate. According to Solms (1969) and Kawamura and Kare (1987), in addition to generating fewer strange tastes, monosodium glutamate can be used as a food additive that confers a distinctive taste to foods that is recognized as "umami" in Japanese, which means "tasty" (Solms 1969, Kawamura and Kare 1987). Furthermore, Mojet et al. (2004) showed that the umami taste perception assists in the food salinity, and their study predicts that foods with a high umami content may have to be used to decreased NaCl content without decreasing consumer acceptance.

Several studies on enhancing low sodium products indicate that potassium chloride yields a bitter perception and metallic taste, which is attributable to potassium chloride and results in sensory rejection of the product (Seman et al. 1980, Askar et al. 1994, Armenteros et al. 2012). Moreover, in this present study, the margarines with less sodium show that these tastes are not significantly dominant, which may be due to using both potassium chloride and monosodium glutamate.

ACCEPTANCE TEST

The results of the acceptance test were analyzed by analysis of variance, which indicated no significant differences ($p > 0.05$) relative to acceptance of the of margarine formulations for the attributes evaluated.

Table II shows the averages for acceptance relative to the salty taste and the overall impression of the different margarine formulations studied.

Thescores for both attributes in margarines were between "like slightly" and "like moderately", which indicates that the margarines were considered acceptable in the product reviews. These results

TABLE II
Sensory acceptance of the margarine formulations.

Formulations	Salty taste	Overall Impression
A	6.72	6.50
B	6.72	6.43
C	6.50	6.30
D	6.74	6.56

A (control - without sodium reduction), B (20.8% less sodium), C (33% less sodium) and D (47.4% less sodium).

are similar to the results obtained for Rodrigues et al. (2014a, b) in mozzarella and salt and garlic spice. Moreover, in this present work, we use a salt mixture that had already been applied to other food matrices and demonstrated that it is effective in lipid-based products.

Several studies related to reducing sodium in foods show good sensory acceptance of low sodium products compared with traditional formulations. Among these, several studies were related to the partial replacement of sodium chloride by potassium chloride or by a salt mixture containing KCl (Guinee and O'Kennedy 2007, Nascimento et al. 2007, Ayyash et al. 2013, Cruz et al. 2011). This demonstrates that the use of NaCl substitutes is a viable alternative for developing products with less sodium considering the consumer aspirations and expectations.

According to Bertino et al. (1982) and Lampuré et al. (2015), the preferred salt level in food depends on the salt level consumed, and the preferred level can be decreased after sodium intake is reduced. Therefore, it is extremely important to reduce the sodium content in basic products used for preparing other products, such as margarine, which can be consumed alone but is also used in various food preparations.

The sensory characteristics, functional properties and shelf life, are the characteristics most affected by reducing salt in foods (Guinee and O'Kennedy 2007). Thus, more studies involving the shelf-life of these products must be conducted.

CONCLUSIONS

The use of salt mixtures containing KCl, NaCl and monosodium glutamate allowed preparing margarine containing a 33% sodium reduction with a sensory profile similar to the traditional product. Despite the detection of the umami flavor in the sample with 47.4% sodium reduction, this did not compromise the product acceptance. In this study, we use a mixture of salts that had already been applied to other food matrices and demonstrated effectiveness for lipid-based products. This work aids development of new products with less sodium and that are acceptable to consumers.

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