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Research Article

Sodium reduction in crackers: optimization of process to keep sensory quality without technological impacts

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ABSTRACT: Excess sodium in foods is one of the factors in chronic non-communicable diseases whose importance is on the rise. Thus, the aim of this study was to optimize a replacement for sodium in an appetizer-type Mignon cracker on an industrial scale. For this, a mixture design consisting of seven formulations were prepared with sodium replacement ranging between 30 and 60 %. The partial sodium replacement used industrial ingredients (Nutek Salt and PuraQ NA4, and modified KCl and flavor), to assess the impact on sodium content and texture (hardness). No significant differences were found in the hardness attribute. Sodium reduction ranged from 943.43 to 637.21 mg 100 g^{-1}, and formulation 7 (F7) with 60 % replacement could cash in on the "Reduced in sodium" appeal. A sensory Quantitative Descriptive Analysis accessed the sensory profiles of formulations, and significant differences were observed ($p <$ 0.05) in salty taste, sweet taste, bread aroma, and formulation 4 (40 % replacement) but were not significantly different from the formulation in salty taste. In PCA, the first main component showed variability between samples of 84.6 %, while the second axis explained 11.5 % of this variability. Acceptance (taste and overall quality) and purchase intention (above > 70 %) showed that the substitution did not affect consumers' perceptions, with no significant difference between controls, F4 and F7.

Keywords: baked products, salt, texture, acceptance, upscale

Introduction

The consumption of processed and/or industrialized foods and sedentary lifestyle, favors the occurrence of chronic non-communicable diseases known as CNCDs, among which the most common are diabetes, cardiovascular diseases and obesity (Benziger et al., 2016; WHO, 2002, 2010). It is estimated that hypertension is responsible for the deaths of nine million people per year worldwide and governments aiming to reduce these numbers, recommend reductions in sodium intake (Kitt et al., 2019; WHO, 2016).

The majority of consumers understand the importance of controlling sodium intake (Benincá et al., 2018). Sodium reduction is based on the direct reduction or use of NaCl substitute salts and other ingredients. This approach is very modern and is widely applied to the reduction of sodium in cheeses, meats and culinary preparations (Di Domenico et al., 2020; Hoffmann et al., 2020; Santos et al., 2020; Vidal et al., 2020).

Many salt substitutes available on the market use KCl as the main ingredient, as it has a salting capacity very similar to NaCl. However, KCl has a bitter taste which is an inconvenience for the food industry (Cepanec et al., 2017). A solution currently on offer to the industry is modified potassium chloride, called Nutek Salt, whose main characteristic is the absence of residual bitter taste. Crystals of modified potassium chloride called Nutek Salt have proven to be a plausible alternative with the potential to replace up to 50 % of sodium chloride (Kanellos, 2012).

Alternative strategies try to develop compounds that enhance the salty taste through the presence of different combinations of molecules, as protein derivatives, modified salts, fermentation compounds and aromas. Certain solutions available in this area also use spices, herbs and yeast hydrolyzate (Taylor et al., 2018). PuraQ NA4 is another of the innovative options developed by the industry of sodium replacement ingredients. This product reduces sodium chloride by up to 30 % (Corbion Puraq, 2013; Seganfredo et al., 2016).

Cracker is a baked product consumed by all age groups and social classes of people, and has a wide variation of ingredients to meet the needs and expectations of different consumers' profiles (Chavan et al., 2016; Mesías et al., 2015). Industrialized products such as crackers are widely appreciated and consumed, and together they contribute to more than half of the recommended daily sodium intake (Arepally et al., 2020; Souza et al., 2013). Therefore, the reduction in sodium intake is directly linked to the reduction in sodium by the food industry (FDA, 2016).

Thus, this study aimed to reduce the sodium content in appetizer-type Mignon salty cracker by using flavoring and salt substitutes. To this end, two separate purposes were identified: 1) Formulate different crackers using a mixture designed to replace sodium chloride with modified potassium chloride and aroma up to the 60 % substitution level; 2) investigate the physicochemical parameters and sensory characteristics of the sodium-replaced crackers.

Materials and Methods

Specification

To reduce sodium content in the crackers, two sodium chloride substitutes were tested: modified potassium chloride, the previously mentioned Nutek Salt, and a flavor, PuraQ NA4. The original formulation, produced by a company established in the state of Santa Catarina (Brazil), was denoted as control formulation. From the original formulation, the other formulations suggested by experimental design are defined in Table 1.

Seven formulations of appetizer-type Mignon salty cracker were constructed according to the mixture design. The cracker has in its composition: wheat flour enriched with iron and folic acid, vegetable fat, sugar, starch, malt extract, soy lecithin, glucose syrup, whey milk powder, micronized salt, chemical yeasts (sodium bicarbonate, ammonium bicarbonate and monocalcium phosphate) and flavoring. On grounds of secrecy, as prompted by the company holding the brand, percentages of each ingredient that make up the control formulation will not be presented. However, it can be disclosed that the formulation contains 2 % micronized NaCl. Moreover, appetizer-type Mignon salty crackers have a crispy characteristic and a V format. NaCl substitutes were used sparingly, as they do not have the same salting power, and may add unpleasant flavors, in addition to being more expensive than NaCl.

Table 1 – Mixture design for limited surfaces.

Formulations[##]	Mixture design[#]					
	Original Components			Pseudo Components		
	X1	X2	X3	X'1	X'2	X'3
1V (F1)	0.70	0.30	0.00	0.50	0.50	0.00
2V (F2)	0.70	0.00	0.30	0.50	0.00	0.50
4C (F3)	0.70	0.15	0.15	0.50	0.25	0.25
7C (2)*(F4)	0.60	0.20	0.20	0.33	0.33	0.33
5C (F5)	0.55	0.30	0.15	0.25	0.50	0.25
6C (F6)	0.55	0.15	0.30	0.25	0.25	0.50
3V (F7)	0.40	0.30	0.30	0.00	0.50	0.50

[#]X1 + X2 + X3 = 1 ou 100 %; X1 = NaCl, X2 = Nutek Salt and X3 = PuraQ NA4; [##]V = vertex, C = centroide; *Repetition.

Experimental design

The experimental design consisted of mixtures for limited surfaces obtained through the module in the Statistica© 7.0 software program with the following variables: X1 - NaCl (micronized salt), X2 - modified KCl (Nutek Salt) and X3 - Flavor (PuraQ NA4). In the control formulation the NaCl content was 2 %, and in all formulations within the minimum and maximum proportions of each of the ingredients, NaCl, together with its substitutes, accounted for 2 % of the total.

The minimum and maximum limits for replacement agents were defined based on information from the manufacturer and previous studies (Bassett et al., 2014; Busch et al., 2013; Souza et al., 2013; Vogel et al. (2011)). Thus, 0 % was the minimum limit and 30 % the maximum. The percentages of substitution transformed into pseudo-components are shown in Table 1.

Production of crackers

The crackers were manufactured on an industrial scale. The process was carried out in a continuous production oven and automated system, following the basic steps showed in Figure 1.

Physicochemical assessment of crackers

All the samples for analysis were collected after the packing stage to ensure there were both sufficient

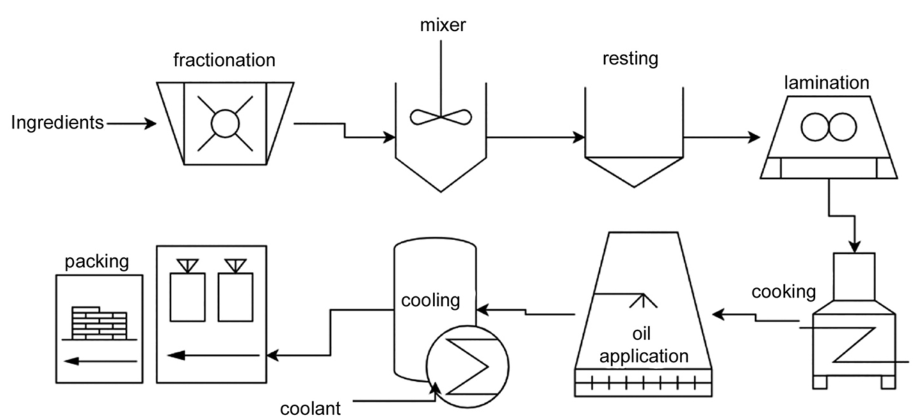

Figure 1 – Flowchart of appetizer-type Mignon cracker's production on industrial scale.

and representative samples for conducting all the experiments. The sodium content was measured with three repetitions in triplicate, and the hardness in ten repetitions. The crackers were analyzed for sodium content using the optical emission spectrometry with inductively coupled plasma (ICP-OES) (AOAC, 2005) method. The samples were analyzed by Shimatzu ICP-OES equipment, Model ICPE-9000 with readings on a wavelength of 589-592 nm and the results expressed in mg of sodium 100 g^{-1}.

Hardness was determined using a TAX-T texturometer (Stable Micro Systems), knife-edge probe (HDP/BS) with a load of 25 kg and a platform (HDP/90). The parameters followed in the test were: pretest speed of 1.5 mm s^{-1}, test speed of 2 mm s^{-1} and post-test speed 10 mm s^{-1}, a distance of 5 mm according to the BIS2/KB protocol and trigger force of 50 kg in accordance with the BIS4/3PB protocol (Stable Micro Systems, 2000). Ten replicates were carried out for each treatment, and the results for hardness were obtained in Newton (N).

Sensory evaluation

The formulations were evaluated following the Quantitative Descriptive Analysis (QDA) method, in addition to the hedonic tests of acceptance, preference and purchase intention. Furthermore, the crackers had been previously subjected to microbiological analyses in order to assure the quality of the prepared product. For the QDA application, all the requirements defined by ISO 2017a, and the methodology described by Stone and Sidel (2004) and Silva et al. (2018) were followed. The Research Ethics Committee (UTFPR), CAEE number 1.361.970, approved this study.

Recruitment and pre-selection of assessors

Initially, 25 employees of the food company were invited to make up the sensory team, considering that these assessors are already part of the company's sensory analysis panel, meaning, trained in accordance with the requirements of ISO, 2012 (E). Of these 25 assessors, 17 had the availability and interest in participating and demonstrated aptitude in previous tests in color identification, basic tastes and sensitivity to olfactory stimuli.

Assessors' selection

The 17 participants underwent 10 triangular tests to verify the ability to discriminate between samples differences (ISO, 2017b). The materials and concentrations used for sample preparation followed the indications of ISO, 2012 (E). The materials (Salty - Sodium chloride; Sweet – Sucrose; Metallic - Iron sulfate heptahydrate $FeSO_4.7H_2O$; Texture-Appetizer-type Mignon salty cracker in different textures were diluted in distilled water at room temperature. Wald's sequential analysis was applied to the results, to analyze the assessors' discriminatory capacity (BS ISO, 2004). The acceptance (Ac) and rejection (Rj) plot lines of the sequential test for the selection of assessors were Ac = 2.085 + 0.50n and Rj = –1.624 + 0.50n.

Establishing the descriptive terminology

The evaluation of the samples for a compilation of terms was carried out according to the Grid method (ISO 13299:2016). The samples were presented in pairs, for comparison and description of terms related to appearance, aroma, taste and texture. Consensus training sessions were held with the panel of assessors to define the most appropriate and important terminology, as well as to establish references for each extreme point on the scale.

Final panel selection

With triangular tests, four training sessions were carried out until the sensory memory of each assessor and uniformity of the placement in the same region of the scale had been formed, through the presentation of reference samples from the extremes of the scales. The training ended when the panel demonstrated that they had no difficulties in evaluating the samples using the evaluation form. In this last stage, of the 17 judges only 10 were selected for appointment to the final QDA panel (6 women and 4 men, aged 22-55 years). The selection of the final QDA panel was carried out with three Mignon cracker formulations (Control, F3 and F7), evaluated in three repetitions, collected before the standardization of the process so the panel could identify differences and the greatest number of attributes.

Analysis of variance (ANOVA) statistically assessed the overall performance of the panel in relation to each attribute in terms of discriminative capacity, consensus and reproducibility. The sample ($p_{sample} <$ 0.05), expressed the discriminative capacity of the panel, and the intercept effect of "Assessor*Sample" expressed the panel consensus. In addition, the intercepts "Sample*Repetition" and "Assessor*Repetition" stated the reproducibility of the panel. In the intercept $p_{interactions} > 0.05$ (Antmann et al., 2011; Worch et al., 2010) was desirable.

Evaluation of samples

Quantitative descriptive analysis of Mignon crackers followed ISO, 2017a using ten trained tasters to evaluate all formulations in three repetitions. The intensity of the sensory descriptors (attributes) were assessed via an unstructured 9-cm scale, with intensity terms anchored at their ends, in ascending order of intensity from left to right.

The samples were presented in a sequential monadic manner, in completely randomized blocks, in order to reduce bias from the order of the samples. The tests were carried out in individual booths under white light. The assessors received approximately 15 g of sample, served on disposable plates encoded with three-random digits.

Hedonic assessment

In the affective tests, the formulations of greatest interest were used, *i.e.* the formulation with the lowest sodium content, the one with the highest sensory evaluations and similarity to control, in addition to the control sample itself. The acceptance, preference and purchase intent tests were applied at the Company's Sensory Laboratory, in accordance with Meilgaard et al. (2007). One hundred employees [61 women and 39 men, aged 18-30 years (41 %), 31-40 years (40 %), 41-50 years (11 %) and 51-60 years (8 %)] which do not have direct contact with the production of crackers.

The assessors were instructed to point out how much they liked or disliked the product in relation to the attributes of interest: taste and overall quality using a 9-point structured hedonic scale ranging from "Like it extremely (9)" to "Dislike it extremely (1)". In the ordering test for preference, weighting 3 is assigned to the most preferred sample, 2 to the next and 1 to the least preferred. In the ordering test for purchase intention, a structured 5-point scale ranging from "I would certainly buy (5)" to "I would certainly not buy (1)" was applied (García-Gómez et al., 2019; Dutcosky, 2013; Stone and Sidel, 2004).

Statistical analysis

Shapiro-Wilk Normality Test checked the hypothesis of normality in physicochemical data, subsequent Analysis of Variance (ANOVA) and Tukey test accessed mean differences, using the Statistica© 7.0 software program, and expressed as averages ± standard deviation. The Response Surface Methodology was also used to assess the influence of NaCl and its substitutes on the responses of chemical and physical parameters.

The sensory data were subjected to the Levene test to verify the homogeneity of the variances in addition to the ANOVA and Tukey test. To verify the correlations between the samples and the sensory attributes, the QDA data set was evaluated by Principal Components Analysis (PCA), and the attributes were used as variables, applying covariance = n-1, in the XLSTAT® 2014 software program.

The PCA allows for a set of correlated variables to become a set of uncorrelated main components (PCs) (Granato et al., 2018). The new coordinates are obtained from the covariance matrix, X T X, producing the A pairs of eigenvalues and eigenvectors. PCs are extracted so that the maximum amount of data variation is associated with the first PC. For significant PCA results, it is crucial to report factorial loads, factor values and the amount of explained variance. The dominant patterns present in the samples and variables are plotted in the columns of the scoring matrix and the loading matrix, respectively (Granato et al., 2018).

Results and Discussion

Physicochemical assessment of crackers

The results showed that KCl (Nutek) and Aroma (PuraQ NA4) can be used to replace NaCl and produce a considerable reduction in sodium in Mignon-type crackers with minimal impact on sensory and technological quality.

All formulations of the control formulation had a reduction in sodium (Figure 2). The F7 formulation with a value of 637.21 mg 100 g^{-1} stands out on account of its lowest content among the formulations. Formulations F4, F5, F6 and F7 had sodium (Na) results lower than 905 mg 100 g^{-1}, an average result of 91 brands of crackers in the salty category (Cream Cracker and similar) found in research carried out by the FDA (FDA, 2016). Furthermore, F4, F5, F6 and F7, can use the term "sodium reduced" on the label, justified by sodium reduction higher than 25 %, as established by the Brazilian regulation RDC n. 54 (ANVISA), and only F7 could do the same according to FDA 21CFR101.56 (reduction must exceed 50 %).

Hardness is a positive and sought-after feature in products with low moisture content, as in the case of salty crackers. The results for hardness (between 22.88 N – 26.67 N) of the formulations, showed no significant differences ($p > 0.05$). This indicated and corroborated that NaCl removal and addition of replacers had no significant interference in the parameters' moisture and aw of the crackers (see supplementary material).

In bakery products, salt contributes to the hydration of proteins and enhances the bonds between them and fats, promoting the development of the gluten network (Taylor et al., 2018). In the present findings, the decrease in sodium chloride did not interfere in the hardness of crackers.

The response surface for hardness was better represented by the linear adjustment, whereas the sodium content was better represented by the quadratic adjustment. The asterisks presented along with the coefficients of the equation mean that they were significant and not neglected in the equation (Table 2).

The adjustment of data to the model was evident ($p < 0.05$) and no significant missing adjustment was identified ($p > 0.05$), which demonstrated the normality of the data and adequate constant variance of the error (Table 2). The linear adjustment for the hardness parameters, and the quadratic adjustment for the Na content in terms of pseudo-components (Figure 3A and B), demonstrated that the addition of Nutek Salt (X'2) as well as the increase in NaCl (X'1) contributed to the lowest hardness values. Consequently, the replacement PuraQ NA4, led to an increase in the hardness parameter.

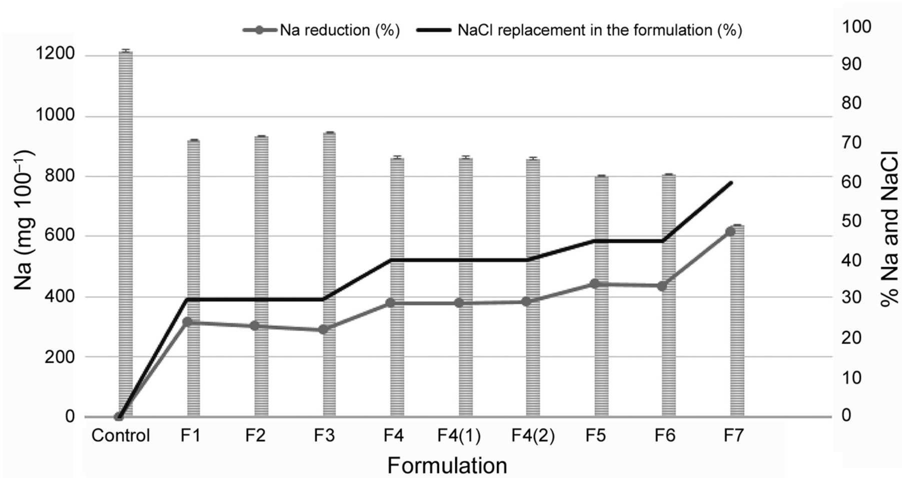

Figure 2 – Reduction in sodium content of the formulations compared to the control formulation.

Table 2 – Values of the coefficients of the linear model for hardness and the quadratic model for sodium content in terms of pseudocomponents, in addition to the ANOVA for the responses.

Parameters	PSEUDOCOMPONENTS#					
Hardness	X'1	X'2	X'3			
Coefficients	22.88	23.02	29.53			
	*	*	*			
Standard error	1.202	1.202	1.202			
Sodium content	X'1	X'2	X'3	X'1X'2	X'1X'3	X'2X'3
Coefficients	1103.90	549.30	566.90	366.90	380.30	315.60
	*	*	*	*	*	*
Standard error	14.673	14.673	14.673	34.910	34.910	34.910
ANOVA						
Hardness	SS (Sum of Squares)	DF (Degrees of Freedom)	AS (Average Square)		F value	*p*-value
Model	9.08	2	4.54		7.06	0.027
Total error	3.86	6	0.64			
Missing adjustment	2.91	4	0.73		1.54	0.431
Error	0.95	2	0.47			
Total adjusted	12.94	8	1.62			
Sodium content	SS	DF	AS		F value	*p*-value
Model	69659	5	13931.77		3451.84	0.000
Total error	12.11	3	4.04			
Missing adjustment	2.69	1	2.69		0.57	0.53
Error	9.42	2	4.71			
Total adjusted	69671	8	8708.87			

#X'1 = NaCl, X'2 = Nutek Salt, X'3 = PuraQ NA4.

This occurred as Nutek Salt contains maltodextrin in its composition, a known water-retention agent (Marcus, 2019) leading to lower hardness values.

To the increase of Na content, as expected, X'1 made an important contribution, as from the three components it is the only one that contains sodium. The decrease in this parameter was observed as the concentration of the substituents X'2 and X'3 increased, and the combination of both (0.5) promoted the greatest reduction in Na content, since they do not have sodium in the formulation.

Sensory descriptive analysis

Establishment of descriptive terminology

From 17 assessors evaluated in order to compose the final panel, 10 were selected, considered suitable for performing QDA tests. They listed the similarities and differences observed in the samples. The assessors, based on the panel's suggestions (Table 3), established the definition of the descriptive terms and the references for each extreme point on the scale.

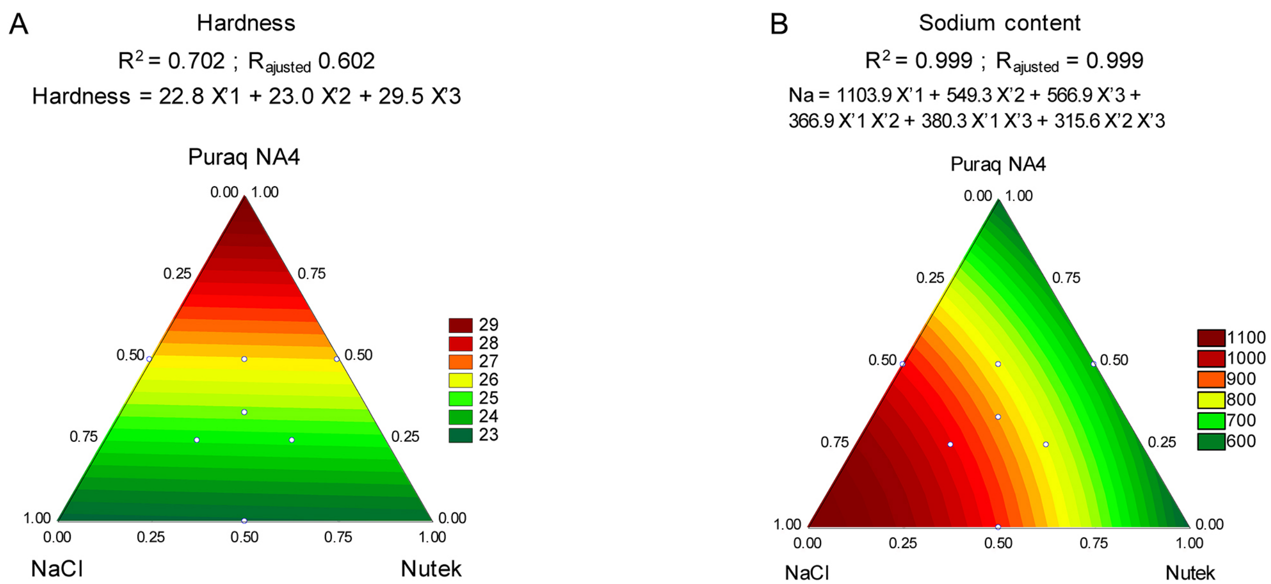

Figure 3 – (A) Ternary diagram of the response surface of the linear model for hardness and (B) quadratic model for sodium content (mg 100 g^{-1}).

Table 3 – Descriptive terms (attributes) and reference materials for Mignon-appetizer cracker.

Attributes		Definition	Reference
APPEARANCE	Color uniformity	Color homogeneity along the biscuit surface	Little: Brand A Mignon cracker Much: Brand B Mignon cracker
	Roast color	Color associated with the baking process	Little: Mignon cracker with –1.5 min cooking. Much: Mignon cracker with + 1.5 min cooking.
	Thickness	Standard cookie height: 6.2 ± 1 mm	Little: Brand A Mignon cracker Much: Brand B Mignon cracker
	Brightness	Perception of light reflection intensity	Little: Brand A Mignon cracker Much: Mignon Cream cracker Parati©
AROMA	Roast aroma	Aroma associated with the baking process	Weak: Brand A water and salt cracker Intense: Brand B water and salt cracker
	Mignon cracker flavor	Characteristic aroma of Mignon cracker	Weak: Mignon cracker – 70 % aroma Intense: Mignon cracker with + 30 % aroma
	Bread aroma	Aroma associated with the taste of bread.	Weak: Brand A water and salt cracker Intense: Brand B water and salt cracker
TASTE	Salty Taste	Taste associated with the perception of salt	Weak: Mignon cracker with – 80 % NaCl Intense: Mignon cracker with + 30 % NaCl
	Sweet taste	Taste associated with the presence of sweetness	Weak: Mignon cracker with – 30 % sugar Intense: Mignon cracker with 70 % sugar
	Aftertaste (bitter or metallic residual)	Taste related to bitter and / or metallic residual	Weak: Mignon cracker with 20 % KCl Intense: Mignon cracker with 60 % KCl
TEXTURE	Hardness	Strength to break the cracker with the incisor teeth	Little: Mignon cracker kept for 4 h at 90.2 % RH at 25 °C Much: Mignon cracker kept for 12 h in an oven at 35 °C
	Crunchiness	Force exerted so that the product disintegrates	Little: Brand A Cream cracker Much: Brand B Cream cracker

Sensory profile of Mignon cracker sodium replaced

The average results of each attribute for the evaluated formulations were submitted to the Levene test, all of which presented homogeneous variances ($p > 0.05$). The formulations showed a significant difference ($p < 0.05$) for the attributes of bread aroma, salty taste and sweet taste (Figure 4), and for the other attributes there was no significant difference.

For the bread aroma attribute, F2 and F6 presented the highest mean values (Figure 4) followed

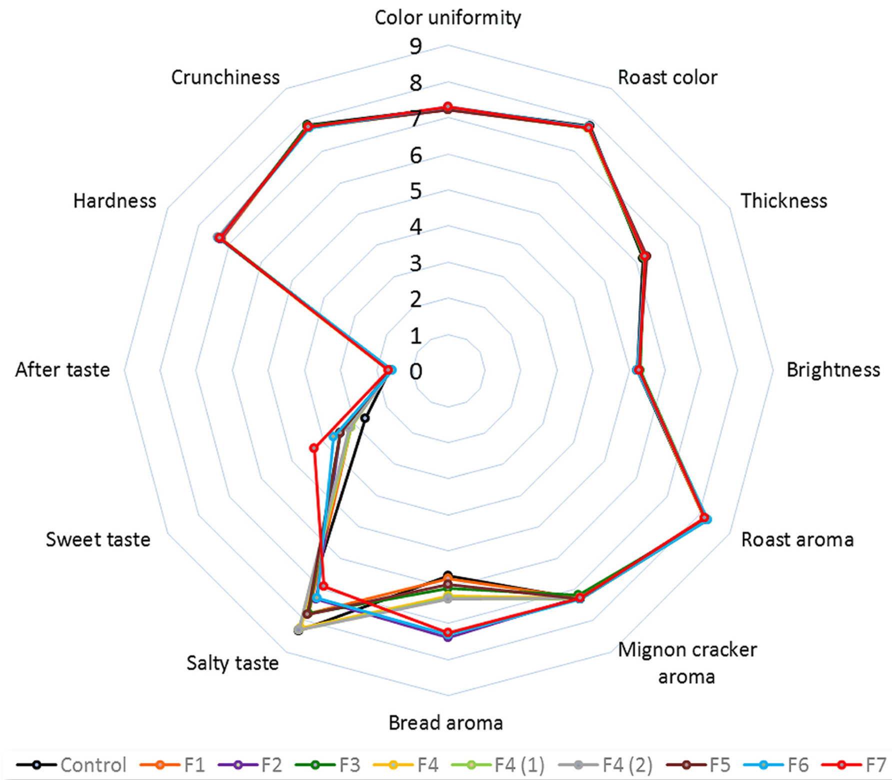

Figure 4 – Graphical representation (spider/radar chart) of the results from the quantitative descriptive analysis of the Mignon appetizer crackers.

by F7, which did not differ statistically ($p > 0.05$) from F6, which is related to the fact that F2, F6 and F7 have 30 % of the PuraQ NA4 substitute. Moreover, PuraQ NA4 was confirmed as a flavor enhancer used to reduce sodium in foods, which, in addition, and adds a salty taste to the product intensifying other flavors (Corbion Puraq, 2013). Therefore, it can be considered that the addition of PuraQ NA4 30 % was responsible for the perception of greater bread aroma. Similarly, F3 and F5 had an addition of 15 % PuraQ NA4 and did not differ statistically from each other ($p > 0.05$). F1 and control formulations had the lowest values for bread aroma, a result that is associated with the absence of PuraQ NA4 in the formulation.

As expected, the salty taste exhibited significant differences between samples. This was considered the key attribute, a descriptor of great industrial interest, where the control formulation presented the highest value and did not differ statistically ($p > 0.05$) from F4. It is important to highlight that the different NaCl substitution formulations, F1 (Nutek Salt 30 %), F3 (Nutek Salt 15 % and PuraQ NA4 15 %) and F5 (Nutek Salt 30 % and PuraQ NA4 15 %), did not differ statistically ($p > 0.05$) from each other, which suggests that different combinations of NaCl and its substitutes provided the same perception of salty taste. Nevertheless, formulations F1 and F5 demonstrate that KCl is the substitute that best contributes to the salty taste since F3 presented a lower mean value than F1 and F5. F2 and F6 were statistically equal, although they have different substitution percentages. It can be seen that F5 and F6 (45 % NaCl substitution) differed and F5 has a higher percentage of Nutek Salt in the formulation, which provided a more pronounced salty taste. F7 with 60 % NaCl replacement differed statistically ($p < 0.05$) from all samples with the lowest perception of salty taste.

In the spider or radar graph (Figure 4), the similarity between the samples for most attributes and the low values provided for aftertaste and sweet taste are clearly evident. For the sweet taste F7 (60 % NaCl substitution) presented a value which was significantly higher (approximately 3) than the other formulations followed by F6. Formulations F2, F3 and F5 were statistically equal ($p > 0.05$), followed by F1, F4 and their repetitions. The increase in sweet taste was directly related to the higher percentage of NaCl substitution, and was influenced by the combination of flavor enhancer substituents.

It is worth mentioning that where there was a significant difference ($p < 0.05$) F4 (20 % X2 and 20 % X3) stood out from the others for presenting a salty taste equal to the control sample. It was evident that formulation F7 (30 % X2 and 30 % X3) showed the greatest differences when compared to the control formulation, in terms of increases in the sweet taste and bread aroma attribute and a reduction in the salty taste. However, the difference between the highest and lowest averages (between 6 and 9 points in the salty taste) did not exceed two points on the hedonic scale, demonstrating proximity between the results.

As for the appearance attributes, there was no significant difference between formulations, which is important as they avoid the visual impact on consumers during purchase. It was confirmed that an understanding of sensory properties of products with reduced sodium content is important, since the reduction in salinity triggers congruent effects such as an increased sensation of sweetness, which may influence characteristic aromas, appearance and texture (Raithatha, 2014).

Multivariate exploratory assessment: PCA

Quantitative Descriptive Analysis through Principal Component Analysis (PCA) identifies much of the study's variability (Figure 5). The first main component F1 was the source of 84.6% of the variability among the samples while the second axis (F2) accounted for an additional 11.5 % of this variability, thereby explaining 96.1 % of the total variability. These results indicated that the attributes had been selected properly in QDA, *i.e.*, close to the sensory perception power of the assessors, which were able to convincingly distinguish the samples.

Formulation F4 and its repetitions showed greater intensity of "salty taste", being closer to the control sample, and descriptive terminology, namely, "roast color", "Mignon cracker aroma" and "roast aroma". The formulations F1, F3 and F5 showed similar characteristics and stand apart on account of their higher values in the "after taste" and "crispness" attributes. The F1 and F5 samples were closer to each other and both had 30 % usage of Nutek Salt while F3 had 15 % PuraQ NA4 and 15 % Nutek Salt. Formulations F2 and F6 were similar and presented the highest averages for "color uniformity" and "bread aroma", and both samples show 30 % of PuraQ NA4 associated with the greater intensity of the "bread aroma" attribute.

The F7 formulation was distinguished by its greater proximity to the "sweet taste", a fact already discussed previously. It can also be said that the "sweet taste" was negatively correlated with the "salty taste", corroborating the difference between control and F7. It is worth mentioning that even with 60 % replacement, the F7 sample was not positively correlated with the aftertaste (bitter / metallic), contrary to what was observed in the formulation of breads with 50-75 % sodium replacement (Lynch et al., 2009).

Acceptance and purchase intention

Samples F4, F7 and Control were used in consumer tests as F4 formulation showed no difference for most attributes in relation to control, F7 as it had the lowest sodium content (< 699 mg Na 100 g^{-1} of cracker), and the control formulation for being the reference sample (Table 4).

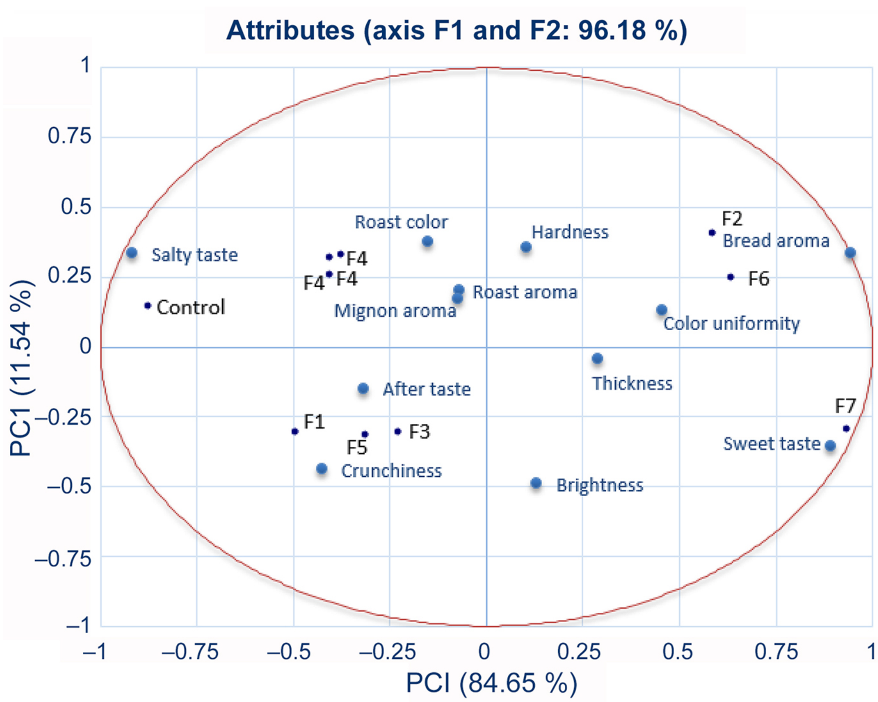

Figure 5 – Projection of attributes and formulations of sodium reduced crackers in the PCA of Quantitative Descriptive Analysis (QDA) data.

Table 4 – Sensory attributes of Mignon crackers in the acceptance tests.

Formulation	Acceptance#		
	Taste	Overall quality	Purchase intention (%)
Control	7.19 ± 1.50[a]	7.21 ± 1.37[a]	80.6
F4	7.27 ± 1.23[a]	7.35 ± 1.25[a]	82.8
F7	6.95 ± 1.51[a]	7.19 ± 1.29[a]	74.4

#values (mean ± standard deviation) in the columns accompanied by equal letters do not differ from each other by the Tukey test (p < 0.05).

As for the acceptance, in relation to the overall quality and taste, the formulations did not differ significantly (p < 0.05) from each other, indicating that the substitutions of Nutek Salt and PuraQ NA4 for NaCl did not compromise the acceptance of the product by consumers. Thus, the replacement of up to 60 % NaCl by the substituents proposed in the percentages applied (max. 30 %), can be used by the industry, safe in the knowledge that it would not significantly influence acceptance.

In the preference test, the two formulations F4 (40 % NaCl substitution) and F7 (60 % NaCl substitution) scored more than 70 % purchase intention, which is considered an adequate value (Dutcosky, 2013) for the acceptance criterion. The fact that the F4 sample had a higher percentage of purchase intention than the control sample, demonstrated that substitution, even at 40 %, can be carried out without changing the purchase intention of the appetizer-type Mignon cracker; moreover, there might be a possible preference increase.

The higher the replacement percentage, the greater the increase in the cost of cracker production, as sodium chloride has a relatively lower cost compared with the substitutes. To be more precise, Nutek Salt and flavor PuraQ NA4 ingredients raised fabrication costs by 5.0 % and 7.5 % comparing F4 and F7 with the control sample, respectively. Up to now, there have been no studies showing the cost of NaCl replacement by its industrial replacements. According to Busch et al. (2013), public awareness of healthiness is a major factor of success for the acceptance of a product with a higher cost, which encourages the type of replacement run in the present findings.

In the quest to have better consumer perception beyond the global projection, specific sensory modalities can help and lead to better discrimination. The masking of certain parameters to the detriment of others, can assist in specific assessments, as in studies with wine, where red light was used to mask differences in appearance or color (Smith and McSweeney, 2019). The red light influenced evaluations by the participants and affected the description of the tested products. Another way to improve the assessment is word association (WA) and the product personality profile (PPP), which can be used independently or complementarily (Gámbaro et al., 2019). WA provides information on the characteristics of the different formulations and the product's personality profile (PPP) gives information about the image consumers have of each product.

Conclusions

An effective sodium replacement was proposed on an industrial scale for the appetizer-type Mignon cracker. The optimization demonstrated that KCl (Nutek Salt) and flavor (PuraQ NA4) can be used to partially replace NaCl in the production of appetizer-type Mignon crackers, in partial substitutions up to 60 % of NaCl without compromising the characteristics of hardness, sensory acceptance and purchase intention.

The reduction in sodium content with a 60 % replacement reached the reference value of 699 mg Na 100 g^{-1} of cracker, and could therefore use the term "Reduced in Sodium" on the label according to the FDA, justified by the reduction of more than 50 % in sodium content.

The Quantitative Descriptive Analysis (QDA) presented significant differences for the attributes "salty taste", "bread aroma" and "sweet taste" among the formulations. Multivariate analysis of Principal Components (PCA) explored similarity of samples, where formulation with 40 % replacement was statistically equal (p < 0.05) to the control, for the attribute of greatest interest (salty taste). This formulation represents a 5.0 % cost increase in the process, exemplifying an intermediate increase when compared to F7 (60 % replacement), with 7.5 %. In the acceptance test, there was no significant difference (p < 0.05) between control, F4 and F7 formulations for taste and overall quality. Finally, these two formulations showed more than 70 % of purchase intention, demonstrating that minor differences perceived in QDA by trained assessors went unnoticed by consumers.

Authors' Contributions

Conceptualization: Pieta, F.; Pieta, A.; Burgardt, V.C.F.; Machado-Lunckes; Lucchetta, L. **Data acquisition:** Pieta, F.; Pieta, A. **Data analysis:** Pieta, F.; Pieta, A. **Design of methodology:** Pieta, F.; Pieta, A.; Burgardt, V.C.F.; Prado, N.V.; Machado-Lunckes; Lucchetta, L. **Writing and editing:** Pieta, F.; Pieta, A.; Marques, C.; Burgardt, V.C.F.; Prado, N.V.; Machado-Lunckes; Lucchetta, L.

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