Optimization of partial replacement of sodium chloride by potassium chloride in the formulation of French bread: effect on sensory parameters

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ABSTRACT – This study aimed to optimize the replacement of sodium chloride (0.4–1.6%) by potassium chloride (0.2–0.8%) in French bread formulation and evaluate its effect on sensory characteristics. For the preparation of bread, we used a factorial design 2² with 4 factorial points and 3 central points, totaling 7 experiments. The sensory evaluation of bread was performed using quantitative descriptive analysis, with 12 sensory terminologies. Response variables of salty taste and sensory chewiness generated statistically significant models. The results indicated optimal ranges of 0.2 to 0.5% of potassium chloride, and 1.0 to 1.6% for sodium chloride, and proved the technical feasibility of producing French bread with 50% salt reduction, which would provide bread with lower amount of sodium compared to a standard formulation.

KEYWORDS: hypertension; prevention; potassium chloride; french bread.

RESUMO – O objetivo do trabalho foi otimizar a substituição do cloreto de sódio (0,4 a 1,6%) por cloreto de potássio (0,2 a 0,8%) na formulação de pão francês e avaliar seu efeito sobre as características sensoriais. Para elaboração dos pães foi utilizado um planejamento fatorial 2², com 4 pontos fatoriais e 3 pontos centrais, totalizando 7 experimentos. A avaliação sensorial dos pães foi realizada por meio de Análise Descritiva Quantitativa, com 12 terminologias sensoriais. As variáveis de resposta sabor salgado e mastigabilidade sensorial geraram modelos estatisticamente significativos. Os resultados indicaram faixas otimizadas de 0,2 a 0,5% de cloreto de potássio, e 1,0 a 1,6% para o cloreto de sódio, e comprovaram a viabilidade tecnológica de se produzir pão francês com até 50% de redução de sal, o que proporcionaria pães com a quantidade de sódio menores em relação a uma formulação padrão.

PALAVRAS-CHAVE: hipertensão; prevenção; cloreto de potássio; pão francês.

1. INTRODUCTION

The word trend can be defined as the tendency of individuals to modify habits already established. The action is the result of economic, social, cultural and political movements, large and complex, that translate into constant influence on people's lives. Trends "healthiness and well-being" are originated on factors such as the aging of populations, scientific discoveries linking certain diets to diseases, as well as income and life in big cities, influencing the search for a healthier lifestyle. There are several consumer segments that are
emerging from these trends, including products with reduced sodium content (better-for-you) are being valued by consumers in several countries (Sullivan et al., 2013).

The agreement signed by the Brazilian Ministry of Health provides for gradual reduction of sodium in 16 food categories that should be met by the food industry by 2014 and deepened until 2016, raising once again the question of the importance of the adequacy of sodium intake among population. Products such as instant noodles, French bread, broth and ready spices, sausages, processed meats and processed products offer an abusive amount of this component (Brasil, 2012).

Bread is one of the foods consumed by humans. It is estimated that one unit of French bread of 50 g has approximately 320 mg of sodium (Sosa et al., 2003), being this single unit responsible for 15% of the daily sodium intake recommended by the World Health Organization (WHO), making this food a major contributor to the sodium intake in many countries (Dötsch et al., 2009; Bolhuis et al., 2011).

Studies have found that it is feasible to decrease to 99.7% of the sodium in the formulation of white bread, without compromising the rheological properties, but generate an impact on the sensory acceptance by consumers (Silva et al., 2003). In Ireland, it was possible to produce bread with 0.3% and 0.6% salt compared to control (1.2% salt) without compromise the rheology of the dough and the quality characteristics (Lynch et al., 2009).

Another way to reduce sodium is partially replaced by another salt. The most commonly used is potassium chloride (KCl), which has similar properties to NaCl and recognized as safe, can be used without loss of functionality. However, addition of potassium chloride is restricted due to bitter taste that gives the product when in large quantities. In wholemeal bread, a replacement of 55.2% of potassium chloride, 69.0% magnesium chloride and 34.8% calcium chloride was possible (Charton et al., 2007).

Knowing that the excess of sodium in diet is responsible for a number of health problems, and considering the need to reduce sodium content in French bread, it is proposed in this study to evaluate the effects of lowering the concentration of the sodium chloride content and its partial replacement by potassium chloride on the sensory of French bread.

2. MATERIAL AND METHODS

The experiment was an applied research, conducted in loco, developed in real conditions on a baking company located in the city of João Pessoa - PB.

2.1 Raw materials and formulation of French bread

The experiments were performed starting with a standard French bread formulation using wheat flour fortified with iron and folic acid (100%), Water (40%), ice (12.5%), baking powder (3%) margarine (1.25%) and flour improver (1%). The percentages of ingredients are calculated based on the amount of flour (100%). The effect of replacing sodium chloride with potassium chloride was analyzed from a factorial design $2^2$, with 4 factorial points (levels $\pm$1) and three central points (level 0), totaling 7 experiments, having as independent variables the sodium chloride content (0.4 to 1.6%) and the contents of potassium chloride (0.2 to 0.8%) relative to wheat flour weight.

The choice of sodium chloride levels was based on the regulation issued by the Ministry of Health on the reduction of NaCl levels in the formulation of French bread (Brazil,
The choice of KCl levels was based on the positive results of previous studies in French bread (Charton et al., 2007; Ignácio et al., 2013).

2.2 Manufacturing process of French bread

The production of bread follows the straight dough process with batch of 4.0 kg of wheat flour. The ingredients were mixed in Supreme dough mixer (model SR 15, Sao Paulo, Brazil). This step was performed in two phases: slow speed (90 rpm) for 5 minutes and fast speed (180 rpm) for 5 minutes until the dough reached full development of the gluten. Water temperature used was approximately 10 °C to obtain dough with a final temperature of about 28 °C. After mixing, the dough was divided into pieces of 1.8 kg, subdivided into 60 g portions, which were molded into the form of French bread, in a modeler 0.5 Hp HM2 model (Hypo Ferraz Vasconcelos, SP Brazil), arranged in wire mesh and left to ferment in fermentation chamber with temperature around 32 °C and relative moisture of 80% at 8 h period, where it was observed an increase in the volume of about two times its initial volume. Before the beginning of molding, the dough rest for 20 minutes, fixed for all tests. Subsequently, after fermentation, was conducted the cutting of the surface of the dough and baking in an electric furnace with steam injection for 10 minutes at 220 °C. The cooling of bread was performed in wire mesh at room temperature.

2.3 Sensory Evaluation

The work was submitted to the Research Ethics Committee of the Health Sciences Center of the Federal University of Paraiba CCS / UFPB by Brazil platform where the certificate was issued for performing activities under No. 0280/13, CAAE: 1503713.4.0000.5188; all participants signed the Informed Consent and Clarified (IC), agreeing to voluntarily participate in the tests, as required by resolution n.466 / 2012 of the National Health Council. French bread samples were subjected to most probable number analysis and total and thermotolerant coliforms and Salmonella sp (FDA, 2011).

Sensory evaluation was performed by Quantitative Descriptive Analysis (QDA) technique developed by Stone et al. (1974). Initially were recruited 33 volunteers between groups of students of the Federal University of Paraiba Technology Center - CT / UFPB; after the steps of pre-selection and training, 14 judges were selected based on their discriminative capacity (pF samples <0.50), reproducibility (pF repetitions> 0.05) and consensus with team (> 80% of descriptors).

The evaluated attributes were: peel color, purity of the Surface color, opening of the peel, crumb color, crumb structure, fermented aroma, salty taste, residual bitter, peel crispness, softness of crumb, chewiness and moisture. The evaluation of the attributes described was performed using unstructured scales of nine centimeters, anchored at the ends.

2.4 Statistical analysis

The results were evaluated by analysis of variance (ANOVA) using Statistica version 5.0 software (Statistica 2004) where the effect of certain variables and coefficients of the models for experimental responses were estimated. Statistical analysis was based on a significance level of 95% (p ≤ 0.05).
3. RESULTS AND DISCUSSION

The microbiological evaluation showed microorganism counts below the limits established by law for coliforms and thermotolerant (<10² NMP g⁻¹) and absence of Salmonella sp, thus being breads fit for human consumption.

The responses of sensory variables of French bread are shown in Table 1. For the attributes of peel color, purity of the surface color, opening of the peel, crumb color, crumb structure, fermented aroma, residual bitter, crispiness of the peel, crumb softness and moisture, it was not possible to establish meaningful models, i.e., the experimental data does not incorporate the model (1st order), this result indicates that in spite of variations in sodium chloride and potassium chloride concentration, these did not influence the sensory characteristics described, obtaining a uniform product to the treatments studied.

Table 1 - Responses of sensory attributes of French bread with partial replacement of sodium chloride (NaCl) by potassium chloride (KCl)

<table>
<thead>
<tr>
<th>Sensory attributes *</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>2.87±1,17</td>
<td>3.09±1,25</td>
<td>3.85±1,08</td>
<td>4.36±1,25</td>
<td>3.52±1,18</td>
<td>5.19±1,26</td>
<td>3.31±1,33</td>
</tr>
<tr>
<td>PCS</td>
<td>3.00±1,43</td>
<td>1.61±1,19</td>
<td>4.14±1,06</td>
<td>4.25±2,00</td>
<td>4.56±1,69</td>
<td>1.46±0,99</td>
<td>5.45±1,10</td>
</tr>
<tr>
<td>AP</td>
<td>4.35±1,78</td>
<td>2.55±1,35</td>
<td>5.98±1,39</td>
<td>6.20±1,68</td>
<td>5.56±1,00</td>
<td>3.54±2,07</td>
<td>5.05±1,12</td>
</tr>
<tr>
<td>CM</td>
<td>1.89±0,89</td>
<td>1.95±0,79</td>
<td>1.86±0,89</td>
<td>1.62±0,80</td>
<td>2.19±084</td>
<td>2.12±0,93</td>
<td>1.80±0,92</td>
</tr>
<tr>
<td>EM</td>
<td>5.14±1,47</td>
<td>5.01±1,89</td>
<td>5.13±1,77</td>
<td>5.34±1,79</td>
<td>4.91±1,44</td>
<td>4.91±1,44</td>
<td>5.46±1,86</td>
</tr>
<tr>
<td>AF</td>
<td>2.16±1,59</td>
<td>2.39±1,90</td>
<td>2.06±1,57</td>
<td>2.12±1,49</td>
<td>2.07±1,46</td>
<td>2.88±1,69</td>
<td>2.03±1,39</td>
</tr>
<tr>
<td>SS</td>
<td>1.31±0,66</td>
<td>3.74±1,25</td>
<td>2.09±1,42</td>
<td>4.10±1,73</td>
<td>2.98±1,35</td>
<td>2.30±0,94</td>
<td>2.52±1,19</td>
</tr>
<tr>
<td>RA</td>
<td>1.52±1,44</td>
<td>0.86±1,15</td>
<td>1.70±1,60</td>
<td>0.63±0,56</td>
<td>0.87±1,12</td>
<td>1.60±1,70</td>
<td>1.10±1,41</td>
</tr>
<tr>
<td>CRC</td>
<td>2.01±1,09</td>
<td>1.37±0,92</td>
<td>1.89±1,36</td>
<td>2.04±1,44</td>
<td>2.12±1,41</td>
<td>2.43±1,29</td>
<td>1.64±1,10</td>
</tr>
<tr>
<td>MM</td>
<td>6.63±0,93</td>
<td>7.09±0,94</td>
<td>6.82±1,05</td>
<td>6.88±1,12</td>
<td>6.80±1,00</td>
<td>8.56±1,14</td>
<td>7.01±1,11</td>
</tr>
<tr>
<td>MAS</td>
<td>5.94±1,28</td>
<td>5.17±1,48</td>
<td>6.05±1,61</td>
<td>6.35±1,44</td>
<td>5.90±1,19</td>
<td>6.04±1,23</td>
<td>5.82±1,58</td>
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<tr>
<td>UM</td>
<td>5.39±1,41</td>
<td>6.00±1,43</td>
<td>5.09±1,31</td>
<td>5.66±1,21</td>
<td>5.60±1,29</td>
<td>5.22±1,26</td>
<td>5.70±1,24</td>
</tr>
</tbody>
</table>

x1 - NaCl (% flour); x2 - KCl (% wheat flour); CC (Peel color); PCS (purity of the surface color); AP (Opening of the peel); CM (crumb color); MS (crumb structure); AF (fermented aroma); SS (Salt Taste); RA (Residual Bitter); CRC (peel crispness); MM (Softness of the crumb); MAS (Chewiness); UMI (Moisture).

* Mean of three replicates (± standard deviation).

For the peel color attribute, samples were considered by the sensory panel as clear staining score ranging from 2.87 to 5.19. The peel of French bread should be golden, homogenous and shiny. Usually gets a more golden peel when you add sugar in the bread formulation. The brightness of the French bread crust is important as it highlights the gold, and this effect is optimized using the water vapor during and a few minutes before breads being put into the oven. The attribute purity of surface color which is related to the brightness of the peel, scores ranged from 1.46 to 5.45. This variation can be explained because the production of water vapor is not uniform inside the oven.

The opening on the bread peel should not be obstructed, the cuts should be regular, well-defined, with a smooth surface and well highlighted edges. Scores for this attribute ranged from 2.55 to 6.20. For fermented aroma attribute, all trials were considered mild flavor...
Jensen et al. (2015) evaluated the sensory profile of breads with manioc flour and obtained mean score for that attribute between 2.09 and 7.77.

Breads had the crumb color ranging from 1.62 to 2.19, indicating crumbs with white to lightly cream color. Crumb structure was classified as very homogeneous and without holes (4.32 to 5.46).

As for attributes salty taste and bitter taste, samples were considered insufficiently salty (1.31 the 4.10) and with a very small residual bitter taste (the 0.86 1.70).

Regarding crispness, samples were considered slightly crunchy (1.37 the 2.43), it was not observed by Carr and Tadini (2003), when evaluating the commercial French bread had a mean score of 6.8 and 6.5. For crumb softness, samples were considered soft by sensory panel (6.63 to 8.56). For moisture, the same author found values between 5.46 to 5.82, that were similar to those determined by this work.

For the sensory response variable salty flavor was possible to establish meaningful models. The data varied from 1.31 to 4.10 (Table 2). It was found after analysis of the results that coefficient of sodium chloride model (X1) and the mean were statistically significant for the 95% level of confidence. The encoded model (Response = β0 + β1x1 + β2x2 + β3x1x2) is shown in Equation 1, with statistically significant coefficients in bold.

\[
\text{Salty taste} = 2.72 + 1.11\text{NaCl} + 0.20\text{KCl} - 0.11\text{NaClKCl} \tag{1}
\]

Analyzing the response surface for saltiness (Figure 1- A) it was seen that, mainly by increasing the concentration of the sodium chloride content, it is obtained a higher salty taste. Breads assays of 2 e 4 were considered more salty by sensory panel, the tests 5, 6 and 7 were considered intermediate salty flavor and tests 1 and 3 were considered the least salty; adopting these assays as to the sodium chloride content, it is obtained optimum tracks for the salty taste, which corresponds to 1.0 to 1.6% of sodium chloride.

Notes to the chewiness attribute fit the 1st order model. It was found after analysis of the results that the model coefficients, average, potassium chloride (X2) and the interaction between sodium chloride and potassium chloride (X1X2) were statistically significant at the 95% level of confidence. The encoded model is shown in Equation 2, with statistically significant coefficients in bold.

\[
\text{Chewiness} = 5.90 - 0.12\text{NaCl} + 0.32\text{KCl} + 0.27\text{NaClKCl} \tag{2}
\]

Analyzing the response surface (Figure 1-B) it follows that, mainly by increasing the concentration of potassium chloride are obtained increased chewiness, i.e., the potassium chloride was primarily responsible for the increase in sensory chewiness in French bread. During the training sessions for the ADQ, the tasters reported that extreme chewiness values would not be desirable for acceptance of the samples. Therefore, it is possible to obtain lower MAS values when the potassium chloride content reaches values between the lower limit and high (0.2 - 0.5%) and when the sodium chloride content reaches values between the midpoint and upper limit (1.0 to 1.6%).

Figure 1 - Response surfaces for the salty taste response (A) and sensory chewiness (B)
4. CONCLUSIONS

The results of this study indicate that, in the researched levels, the addition of potassium chloride contributed to the documentation of French bread with lower sodium content, and did not significantly alter their quality parameters. The addition of the same was also primarily responsible for the increased sensorial chewiness, noting that the optimum range for use in French toast was 0.2 to 0.5%. For sodium chloride, it can be optimized range of 1.0 to 1.6%, values below these would leave the bread sensory not accepted by consumers.

5. REFERENCES


