INFLUENCE OF POTASSIUM CHLORIDE AND CALCIUM CHLORIDE ON TEXTURE AND EMULSION STABILITY OF LOW SODIUM LOW COST SAUSAGE

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Abstract - The texture profile analysis and emulsion stability of reduced-sodium sausages containing high contents of mechanically separated meat were studied. Nine sausage formulations were prepared with blends of calcium chloride and potassium chloride as partial substitutes for sodium chloride. For comparison between the salts, the strategy was the use of salt blends with ionic strength equivalent to 2% NaCl (control). Formulations containing $CaCl_2$ (F2 - 0.5%; F3 - 0.25%; F4-0.5%; and F6-1.0%) showed the highest hardness values and were different from the control formulation with 2.0% NaCl ($p < 0.05$). Samples with $CaCl_2$ presented lower pH and hence lower emulsion stability. Formulations containing KCl showed values for texture profile and emulsion stability close to the control formulation (2% NaCl).

Keywords - Meat products, Reduced-sodium, Calcium chloride, Potassium chloride

I. INTRODUCTION

The positive correlation between diet and chronic diseases has led health agencies around the world to control the intake of certain food components that can promote health disorders. The reduction of sodium intake is a major challenge due to its role in developing hypertension, one of the most important risk factors for cardiovascular disease [1]. Emulsified meat products require specific concentrations of NaCl in the original formulations to promote the extraction of myofibrillar proteins, especially from the actomyosin complex, which are soluble only in high ionic strength solutions. Myofibrillar proteins extracted in the cominuted process in the presence of NaCl are responsible for water-holding capacity, emulsification and fat-binding properties in the batter and the formation of stable gels in the cooking stage [2, 3]. From a technological standpoint, the sodium chloride has been used to ensure the ionic strength necessary to develop stable emulsions. Other chloride salts such as potassium and calcium emerge as alternatives for reducing the sodium content in meat products. In addition, the use of salt blends aims to promote a balanced intake of salts. In Brazil, mechanically separated poultry meat (MSPM) is widely used as raw material in the formulation of emulsified products because of its low cost and for presenting desirable technological characteristics as fine texture, besides being an important source of protein and fat. Formulations containing high levels of MSPM may present lower emulsion stability and lower levels of protein with emulsifying capacity, thus the use of extenders and high levels of salt are needed to stabilize the final product [4]. Reducing sodium content in meat products containing high levels of MSM is highly relevant to many countries, but has not been sufficiently studied. In this context, the aim of this study was to evaluate the texture profile analysis (TPA) and emulsion stability of reduced-sodium sausages produced with blends of calcium and potassium chloride as salt substitutes.

II. MATERIAL AND METHODS

Salt blends of sodium, calcium and potassium chloride, with ionic strength equivalent to 2% sodium chloride were used to partially replace NaCl (50-75%) in sausages. All treatments were formulated with common ingredients (60% mechanically separated poultry meat; 14% swine palette; 10% pork fat; 10% ice; 0.015% sodium nitrite; 0.04% sodium erythorbate; 0.4% seasonings; 1% soy protein isolate; 2% tapioca starch; and 0.3% sodium tripolyphosphate). All formulations were processed in a pilot plant at University of Campinas (UNICAMP) on the same day according to industrial procedures. Palette swine, pork fat and mechanically separated poultry meat were mixed in the cutter (Mado, model 662 MTK, Germany) with different combinations of salts for 3-4 minutes at low speed to extract the myofibrillar proteins. When the temperature reached 7-8 °C, seasonings and other additives were slowly added. The temperature of the batters was controlled to not exceed 17 °C. Then, the emulsion was stuffed (Mainca, model EC12, Spain) into permeable cellulose casings (Viskase, 1 cm diameter). The sausages were placed in a steam oven (Eller, Italy) at an initial inside temperature of 60 °C and relative humidity of 98-99% for 15 min. Subsequently, the oven temperature was raised at 10 °C every 15 minutes until the final core temperature of 72 °C was reached. At this point, the temperature inside the steam oven was around 85 °C. A thermocouple was placed in the center of one sample to monitor the core temperature. After cooking (~ 1.5 h), the products were immediately cooled in an ice bath and then vacuum-packed (Selovac, CU18 Minivac). The products were stored under refrigeration (5 °C) until analysis. The pH was determined by homogenizing 10 g sample with distilled water in a 1:10 ratio, in triplicate, at pH meter (22 DM, Digimed, São Paulo, Brazil). The water activity (Aw) was determined in triplicate using a water activity meter (Aqua CX-2 Decagon Devices Inc., Pullman, WA). The texture profile analysis of sausages containing salt blends as partial substitutes of sodium chloride was carried out using a texture analyzer TA-XT2i (Texture Technologies Corp., Scarsdale, New York.). All samples were compressed to 30% of their original weight. Ten portions were used for measurements of each treatment. A P-35 probe was used (long shaft, regular base) and the following parameters were determined: hardness (N/cm^2) springiness (cm), cohesiveness, and chewiness (N / cm). The emulsion stability of the sausage formulations (Table 2) was carried out according to [5]. Approximately 50 g of the batters were placed in tubes and centrifuged (2600 rpm, 5 min.). After centrifugation, the samples were heated at 40 °C for 15 min and then at 70 °C for 20 min. The tubes were left to stand upside down for 45 min to release the exudates. The total amount of fluid released was expressed as a percentage of the sample weight. This test was performed in quintuplicate for each formulation. All experiments were performed in triplicate and the averages of all analyses were compared by Tukey's test at 5% confidence level ($p \leq 0.05$) using the SPSS statistical package (SPSS Inc., Chicago, IL, USA) and analysis of variance (ANOVA factorial).

Table 1. Formulations of sausages containing salt substitute blends

Trataments	NaCl	$CaCl_2$	KCl
FC1	2,0	0	0
FC2	1,5	0	0
FC3	1,0	0	0
F1	1,5	0	0,5
F2	1,5	0,5	0
F3	1,5	0,25	0,25
F4	1,0	0,5	0,5
F5	1,0	0	1,0
F6	1,0	1,0	0

III. RESULTS AND DISCUSSION

The results for pH, Aw, and emulsion stability of the samples are shown in Table 2. Three control formulations were prepared containing respectively 2.0, 1.5 and 1.0% NaCl for comparison with other formulations containing blends of potassium chloride and calcium chloride. It is observed that addition of $CaCl_2$ to the salt blends decreased the pH values of both the batter and the final product ($p <0.05$). Similar results were found in other studies [6, 7]. The emulsion stability is markedly influenced by the availability of myofibrillar proteins present in the meat matrix, which in turn is a function of the extraction efficiency when increasing the ionic strength by adding sodium chloride, in traditional formulations. The formulation containing 1% $CaCl_2$ and 1% NaCl (F6) showed the highest amount of liquid released ($p <0.05$). This fact associated with a drop in pH observed in the same formulation results in decreased protein solubility, especially myosin, and reduction of emulsified functional properties of the system under study. As expected, the control formulation (FC1) containing 2% NaCl was the most stable batter regarding the liquid release, followed by formulations containing blends of sodium chloride and potassium chloride, both monovalent ions (F1 and F5) . It was observed that a single 50% reduction of NaCl (FC3) significant decreased the emulsion stability ($p < 0.05$). No differences were observed for the values of water activity. Table 3 reports the results of the texture profile for hardness, springiness, cohesiveness and chewiness. The lower hardness values, as expected, were observed for the formulation FC1 (2.0% NaCl) and FC2 (1.5% NaCl). Moreover, all formulations containing $CaCl_2$ (F2-0.5%; F3-0.25%; F4-0.5%; and F6 - 1.0%) showed higher hardness values and were different from the control formulation with 2.0% NaCl ($p < 0.05$). The highest value for this parameter was assigned to formulation containing 1.0% $CaCl_2$ (F6). These results are in agreement with those obtained for emulsion stability, since the formulation F6 showed the highest percentage of exudate under the conditions studied. It has been reported that the increase in hardness of emulsified products is due to the bound water in the batter, lost during cooking process. Thus, the negative contribution of the divalent salt $CaCl_2$ was confirmed by the texture attributes of the sample containing this salt in the blend. Similar results were reported by other authors who studied the texture profile of reduced sodium and fat sausages in formulations containing 0.5% $CaCl_2$ added to NaCl [8]. According to the authors, these results were due to a low gel compression in the protein matrix. The formulations containing 0.25 and 0.5% $CaCl_2$ (F2, F3, and F4) were not different from formulation FC3 with 50% NaCl, which is considered the most critical formulation for presenting the lowest ionic strength ($p < 0.05$). Replacing 50% NaCl for KCl (F5) resulted in different hardness values, which were higher than the control formulation (FC1 - 2.0% NaCl). However, the formulation F1 with 25% replacement of NaCl by KCl was not significantly different from FC1. The interpretation of chewiness values is similar to that of the hardness attribute, since the first markedly influences the second. The formulation F6 presented the highest value for chewiness, unlike FC1, FC2 and FC3 ($p < 0.05$). However, the formulations F2, F3, F4, F5 and F6 did not differ. For the attribute springiness, no differences between formulations ($p < 0.05$) have been reported. With regard to cohesiveness, despite the reported differences and the impact on the texture, the gross values are very close to each other.

Table 2. Effect of reducing NaCl content on pH, Aw and emulsion stability

	pH batter	pH sausage	Aw	Estability of emulsion (ml exudates)
FC1	6.29^{c}(0,03)	6.34^{b}(0.03)	0.97^{a}(0.00)	1.95^{e}(0.33)
FC2	6.28^{d}(0,01)	6.28^{d}(0.01)	0.97^{a}(0.00)	2.38^{d}(0.50)
FC3	6.36^{a}(0,03)	6.39^{a}(0.04)	0.97^{a}(0.01)	8.52^{b}(1.09)
F1	6.32^{b}(0,02)	6.32^{c}(0.02)	0.97^{a}(0.00)	2.82^{d}(0.46)
F2	6.12^{f}(0,01)	6.12^{f}(0.01)	0.97^{a}(0.00)	5.26^{c}(1.80)
F3	6.19^{e}(0,01)	6.21^{e}(0.03)	0.97^{a}(0.01)	4.26^{c}(1.97)
F4	6.14^{f}(0,01)	6.13^{f}(0.01)	0.97^{a}(0.00)	5.74^{c}(0.53)
F5	6.33^{b}(0,01)	6.33^{bc}(0.01)	0.97^{a}(0.00)	2.54^{d}(0.40)
F6	6.02^{g}(0,02)	6.01^{g}(0.02)	0.97a(0.00)	16.88^{a}(0.70)

Table 3. Texture Profile Analysis of low sodium sausage

	Hardness	Elasticity	Cohesiveness	Chewiness
FC1	10.57^{d}(1.27)	0.91^{a}(0.02)	0.80^{e}(0.02)	7.75^{bc}(0.88)
FC2	11.07^{c}(1.07)	0.91^{a}(0.02)	0.83^{a}(0.01)	8.40^{b}(1.49)
FC3	12.43^{b}(1.27)	0.91^{a}(0.03)	0.81^{de}(0.03)	7.75^{bc}(1.70)
F1	10.40^{c}(0.79)	0.91^{a}(0.03)	0.82^{bcd}(0.03)	7.75^{bc}(0.70)
F2	13.37b(1.07)	0.91^{a}(0.02)	0.81^{de}(0.02)	9.95^{a}(0.76)
F3	12.47^{b}(1.48)	0.91^{a}(0.02)	0.82^{cd}(0.02)	9.23^{a}(1.17)
F4	12.28^{b}(1.11)	0.91^{a}(0.02)	0.83^{ab}(0.02)	9.30^{a}(0.87)
F5	12.07^{b}(1.28)	0.91^{a}(0.03)	0.83^{abc}(0.03)	9.21^{a}(1.10)

F6	14.04[a](1.27)	0.89[a](0.02)	0.82[abcd](0.02)	9.37[a](0.95)

FC2: Control 1.5% NaCl;
FC3: Control 1% NaCl;
F1: 1.5% NaCl + 0.5% KCl;
F2: 1.5% NaCl + 0.5% $CaCl_2$;
F3: 1.5% NaCl + 0.25% $CaCl_2$ + 0.25% KCl;
F4: 1.0% NaCl + 0.5% KCl + 0.5% $CaCl_2$;
F5: 1.0% NaCl + 1.0% KCl;
F6: 1.0% NaCl + 1.0% $CaCl_2$.
Same letters in the same column do not differ significantly at $p < 0.05$ (Tukey's test)

IV. CONCLUSION

The present study suggests that the use of KCl and $CaCl_2$ blends as salt substitutes contributed greatly to the texture profile attributes and emulsion stability, even in formulations containing high levels of mechanically separated poultry meat. However, complementary analysis regarding the physico-chemical, microbiological and sensory stability throughout the shelf life of the product are needed.

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