Influence of Partial Replacement of NaCl with KCl and $CaCl_2$ on Texture and Color of Dry Fermented Sausages

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A Spanish type of dry fermented sausage, Chorizo de Pamplona, was manufactured with a mixture of (2.29%) different salts (NaCl, KCl, and $CaCl_2$) with an equivalent ionic strength to that of the control manufactured with 2.6% NaCl. The use of this salt mixture affected the texture profile analysis (TPA), giving rise to a significant reduction in hardness, cohesiveness, gumminess and chewiness. Instrumental color values showed higher b* (yellowness) and L* (lightness) values. Sensory texture and color intensity yielded lower scores, but they were classified as acceptable. Principal component analysis was carried out with the instrumental measures. The two principal components explained 76.9% of the variance. Modified and control samples were separated by the first component, which explained 57.1% of the variance and was defined basically by texture parameters.

Keywords: *Dry fermented sausages; salt mixture; color and texture*

INTRODUCTION

Total or partial substitution of NaCl with other ingredients to reduce the sodium content of meat products is an aim of the meat industry. Sodium chloride is a principal ingredient in producing processed meats due to its flavor, preservation, and protein solubilizing properties (Seman et al., 1980). NaCl reduction decreases product acceptability due to lower product firmness, lower salt flavor intensity (Seman et al., 1980; Hand et al., 1982a; Barbut et al., 1988), and shortened shelf life of refrigerated products due to limited microbial inhibition (Sofos, 1984). NaCl dissolved protein assists in binding meat, moisture, and fat, in the formation of desirable gel texture and in color development (Marsh, 1983).

Hand et al. (1982b) suggested that partial (50%) or complete (100%) replacement of NaCl with KCl or LiCl for curing bone-in hams can be achieved without significant reduction in cured color. Keeton (1984) using four curing formulations based on total and partial replacement of NaCl with KCl in country-style hams concluded that aspects as firmness and color were not different at the end of the aging period. Gou et al. (1996) observed that color was not affected by the substitutions of NaCl with glycine, potassium lactate, or KCl in dry cured loins whereas high potassium lactate substitution levels presented color problems in fermented sausages.

The physical properties of dry sausage products make them susceptible to texture measurements (Klettner, 1994). Textural qualities play an important role in the consumer's response to a sausage product and the level of salt can affect textural properties. Sofos (1983) observed that frankfurter texture was softer and less acceptable when salt levels were reduced below 2.0% (20% reduction). Likewise, texture was unacceptable when the salt level was reduced to 1.0% (60% reduction). Seperich et al. (1983) replaced the NaCl with $CaCl_2$ in bologna products and concluded that microbial growth and texture parameters appeared not to be affected. In other studies of cured sausages in which NaCl was reduced and/or replaced with $MgCl_2$, KCl, or $CaCl_2$ (at different percentages) in cured sausages texture was found to be less desirable (Whiting and Richards, 1978; Seman et al., 1980; Olson and Terrell, 1981; Sofos, 1982).

Wierbicki et al. (1957) concluded that the maximum levels of neutral salts for acceptable taste were 2.3% for NaCl, 0.75% for KCl, 0.6% for $CaCl_2$, and 0.5% for $MgCl_2$. Studies reducing or replacing NaCl with just one compound at different percentages have been carried out but significant disadvantages were found in all of them. The negative effects related to high salt concentrations could be reduced by replacing NaCl with an equivalent amount of a mixture of salts.

The purpose of this study was to evaluate the influence of partial replacement of NaCl with a mixture of KCl and $CaCl_2$ on texture and color of dry fermented sausages, through instrumental and sensorial measures.

MATERIALS AND METHODS

Two types of dry fermented sausages, one with traditional formulation (control) and a second one with a reduced sodium content (modified product), were manufactured in a pilot plant. The technological process was the same for both sausages.

The different types of sausages were made with a standard formulation of lean pork meat 75% and pork back fat 25%. The ingredients in the traditional formulation were added as follows: NaCl 26 g/kg, red pepper 30 g/kg, dextrin 15 g/kg, lactose 10 g/kg, powdered milk 12 g/kg, dextrose 5 g/kg, sodium ascorbate 0.5 g/kg, sodium caseinate 10 g/kg, garlic 3 g/kg, polyphosphates 2 g/kg, curavi (a mixture of nitrate, nitrite, and citrate) 3 g/kg, and pounceau 4R (E-124, synthetic red coloring equivalent to cochineal) 0.25 g/kg. A mixture of *Lactobacillus plantarum* (10%) + *Staphylococcus carnosus* (90%), 10^6-10^7 cfu/g, was used as a starter culture. In the modified formulation NaCl was substituted with the following salt mixture: NaCl 10 g/kg, KCl 5.52 g/kg, and $CaCl_2$ 7.38 g/kg (ionic strength equivalent to that of 2.6% NaCl).

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10.1021/jf980597q CCC: $18.00
Published on Web 02/24/1999

Lean pork meat and pork back fat were minced in a cutter to a particle size of about 3 mm and subsequently mixed with the other ingredients in a vacuum kneading machine and stuffed into artificial casings (60-mm diameter). The sausages were fermented in a laboratory ripening cabinet (Kowel model CC-I) at 24 °C and RH saturation for 24 h, 22 °C and RH 85% for 24 h, and 20 °C and RH 80% for 24 h. Subsequently, the sausages were transferred to a drying chamber at 17 °C and RH 78% for 7 days and at 11.5 °C and RH 76% until the end of ripening (28 days). Samples were taken on the 28th day.

Chemical Parameters. pH was determined by using the potentiometer Orion Research Microprocessor Ionalyzer-901 using needle electrodes for solid samples (ISO, 1974). Moisture was determined according to the AOAC method (AOAC, 1997a). Total fat was determined by an extraction technique with petroleum ether (AOAC, 1997b). Protein was analyzed according to the Kjeldahl method (AOAC, 1997c). The factor 6.25 was used for conversion of nitrogen to crude protein. The method used for ash determination was according to AOAC (AOAC, 1997d). Sodium and potassium levels were determined by using a flame photometer according to the AOAC method (AOAC, 1997e). Calcium and magnesium were determined by atomic absorption spectrophotometry according to the AOAC method (AOAC, 1997f).

Objective Color Measurement. The samples were covered with a polythene film, with pressure to obtain a uniform, bubble-free surface. Reflectance spectra were determined with a UV/vis Perkin-Elmer Lambda 5 spectrophotometer from 400 to 700 nm, using an integrating sphere with the conditions established by Ansorena et al. (1997). Each sample was measured at four locations on the surface of the dry fermented sausages.

Texture Profile Analysis (TPA). An Universal TA-XT2i texture analyzer was used to conduct texture profile analysis (Bourne, 1978). Square samples with 1 × 1 × 1 cm were compressed twice to 60% of their original height with a compression platen of 75 mm in diameter. Textural analyses were performed at ambient temperatures. Force−distance deformation curves were recorded at a crosshead speed of 5 mm/s and recording speed was also 5 mm/s. Hardness (N), springiness (cm), cohesiveness, gumminess (N), and chewiness (N × cm) were evaluated. These parameters were obtained by using the available computer software.

Sensory Evaluation. Color intensity and hardness were evaluated by a panel of 10 judges by quantitative descriptive analysis (QDA) described by Zapelena et al. (1997). Samples about 2 mm thick were presented on white backgrounds with two-letter codes and randomly distributed. Modified sausages were compared with control sausages which were taken as a reference value (five points for both parameters). Modified products were scored on a 1−9 point scale. A range between 4 and 6 was considered as acceptable and extreme scores (1−3.9, 6.1−9) were considered objectionable.

Statistical Analysis. Eight pieces of each type of product were analyzed. Two determinations of each parameter were measured for each piece except for color instrumental measures in which four determinations were carried out. Results shown in the tables are the means of eight determinations, their standard deviations, and the coefficient of variation. Student's *t* test was used to determine whether there were differences between the control and modified products. Instrumental measures of color and texture were submitted to a principal component analysis (PCA). Data analysis was carried out with the Statgraphics STSC Inc. program (version 4.0), a registered trademark of Statistical Graphics Corp.

DISCUSSION

Modified products were manufactured to contain 2.29% of a salt blend (1% NaCl, 0.55% KCl, and 0.74% $CaCl_2$) which was equivalent in ionic strength to that of the control (2.6% NaCl). No significant differences were found in moisture, protein, and fat content. A lower ash content was found in the modified products because of the lower total amount of salts employed. Significant differences were observed in most of the parameters measured. Sodium levels were decreased 40% and potassium and calcium levels increased 285.71% and 213.33%, respectively, in comparison with the control products. These changes can be considered as a nutritional advantage. Magnesium content did not change.

Table 1. Mean Values for Proximate Analysis and Salt Ions in Dry Fermented Sausages[a]

	control	modified	LS[b]
moisture, %	36.85 (0.55; 1.49)	37.39 (0.43; 1.15)	ns
protein, %	23.87 (1.00; 4.19)	24.15 (1.06; 4.39)	ns
fat, %	30.65 (1.25; 4.08)	30.01 (0.06; 0.20)	ns
ash, %	5.34 (0.01; 0.19)	4.81 (0.05; 1.04)	*
Na^+, g/100 g	1.35 (0.03; 2.22)	0.82 (0.03; 3.66)	*
K^+, g/100 g	0.21 (0.01; 4.76)	0.60 (0.02; 3.33)	*
Ca^{2+}, mg/100 g	154.50 (8.40; 5.44)	318.9 (15.44; 4.84)	*
Mg^{2+}, mg/100 g	41.64 (1.42; 3.41)	43.16 (0.78; 1.81)	ns

[a] Standard deviation and coefficient of variation in the parenthesis. [b] Student's *t* test: LS, level of significance for the difference between control and modified sausage; ns, not significant; *, $p < 0.001$.

Instrumental color results are shown in Table 2. Significant differences were found in every analyzed parameter as determined by the CIE Lab system except a^* values. A negative effect has been observed for meat color during storage by the addition of NaCl (Andersen et al., 1990; Trout, 1990). Sakata and Nagata (1992), analyzing the effect of curing agents on the heme pigment (HP) content, found that HP decreased with increase NaCl concentration. Ansorena et al. (1997) in a comparative study of different color evaluation systems in fermented sausages established that the Hunter system was better for separating samples according to redness (a^*), whereas the CIE system was better for separating samples according to yellowness (b^*). Modified products showed significant higher b^* values ($p < 0.001$).

Different studies have confirmed that luminosity (L^* CIE) was the most informative parameter to show color changes (Oellingrath and Slinde, 1985; Mielnik and Slinde, 1983). Modified products had higher L^* values. This indicates that products tended to be lighter, which was confirmed by the lower scores obtained in the sensory evaluation of color intensity. The subjective results also agreed with the results obtained for b^* values. Sensory panelists detected slight yellow shades in the modified products which decreased the intensity of red color. Ibáñez et al. (1995) replaced 3% NaCl with 1.5% NaCl + 1% KCl and observed a higher nitrosation intensity in dry fermented sausages. Leak et al. (1987) studied the production of boneless dry-cured hams in which NaCl was replaced with KCl up to a level of 30% and they concluded that subjective evaluations of color and general appearance were not affected. The color of modified products was evaluated by the panel, although a lower score than the control was considered acceptable (range 4−6).

Boyle et al. (1994) found that calcium supplementation lightened internal color of frankfurters and they were less red as compared to controls. In addition, the degree of lightening increased as the amount of calcium incorporation increased. The authors explained this fact because calcium supplements were white in color. In our case, the amount of added calcium salt ($CaCl_2$) was too low (7.38 g $CaCl_2$/kg) to have any influence on internal color.

Table 2. Mean Values for Color Measures in Dry Fermented Sausages: CIE $L^*a^*b^*$ System and Sensorial Evaluation[a]

	instrumental color values			
	lightness *L*	redness a^*	yellowness b^*	subjective color evaluation
control	51.43 (1.79; 3.48)	20.40 (2.10; 10.29)	12.30 (1.57; 12.76)	5.00
modified	56.80 (1.62; 2.85)	22.64 (2.40; 10.60)	17.76 (2.79; 15.71)	4.12
LS[a]	*	ns	*	*

[a] Standard deviation and coefficient of variation in the parenthesis. [b] Student's test: LS, level of significance for the difference between control and modified sausage; ns, not significant; *, $p < 0.001$.

Table 3. Mean Values for Texture Measures in Dry Fermented Sausages: Texture Profile Analysis (TPA) and Sensorial Evaluation[a]

	control	modified	LS[b]
hardness, N	71.65 (7.18; 10.03)	62.33 (9.31; 14.94)	*
springiness, cm	0.64 (0.04; 6.25)	0.61 (0.05; 8.20)	ns
cohesiveness	0.54 (0.02; 3.70)	0.44 (0.03; 6.82)	**
gumminess, N	38.47 (3.96; 10.30)	27.84 (4.82; 17.32)	**
chewiness, N × cm	24.84 (3.31; 13.32)	16.89 (2.81; 16.66)	**
subjective hardness evaluation	5.00	4.02	**

[a] Standard deviation and coefficient of variation in the parenthesis. [b] Student's *t* test: LS, level of significance for the difference between control and modified sausage; ns, not significant; *, $p < 0.05$, **, $p < 0.001$.

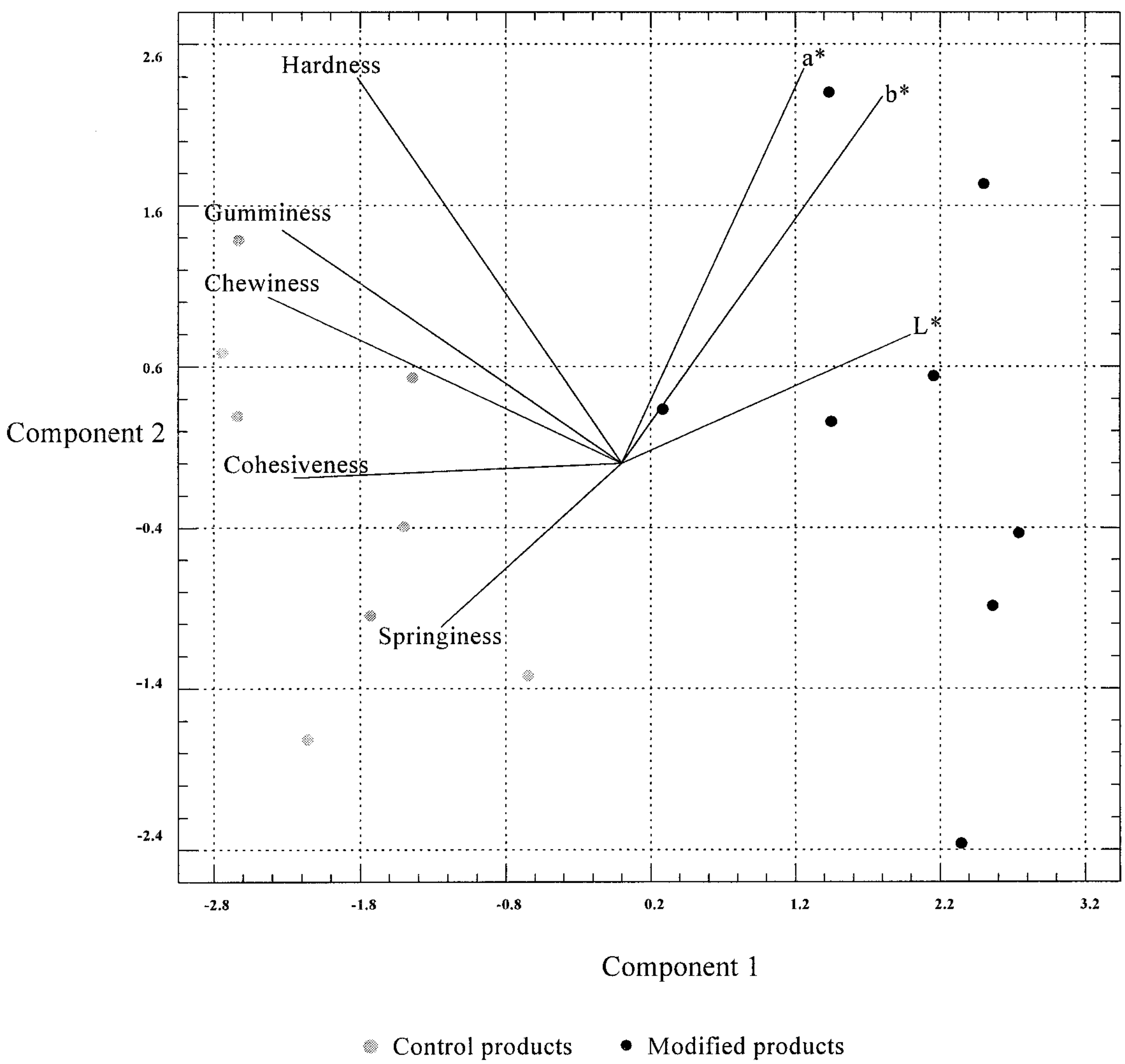

Figure 1. Biplot for first two principal components computed from the instrumental variables obtained for control and modified dry fermented sausages.

Instrumental texture analysis showed significant differences in the texture of both types of products (Table 3). A significant reduction in hardness of −9.32 N was detected in modified products. Gou et al. (1996) compared instrumental texture parameters of fermented sausages and found products with KCl to be less hard by −0.29 to −2.93 kg (−2.84 to 28.71 N).

The significantly lower pH observed in the modified products (4.86) in contrast to control products (5.04) could explain these results. The higher acidification could have caused a greater denaturation process, decreasing the binding capacity of proteins. The addition of $CaCl_2$ to these type of products has been related to the decrease in pH values (Whiting, 1987; Terrell et al., 1981). Matulis et al. (1995) studied sensory characteristics of frankfurters as affected by fat, salt, and pH, and they concluded that as salt increased, hardness, juiciness, saltiness, and flavor intensity scores increased. In this study they suggested that acceptable frankfurters could be manufactured with a minimum of 11.25% fat and 1.3% salt at pH 6.0. Young et al. (1987) analyzed the influence of different salts on textural characteristics of chicken breast meat patties and observed that as NaCl increased the patties became softer and springier. Instrumental evaluation of bologna textural characteristics by Seman et al. (1980) indicated that salt reduction (from 2.5% to 1.25) resulted in lower hardness, compressed peak force, gumminess scores, and increased elasticity.

Chewiness, gumminess, and cohesiveness were significantly ($p < 0.001$) lower in modified products. Chewiness represents an overall assessment of the product texture because it is calculated as the product of all the other textural traits (Young et al., 1987). All these data showed that there was a modification of the product texture. In some types of dry fermented sausages, a modification of the texture, especially a reduction of hardness, can be considered as a positive effect (Melendo et al., 1996). Whereas, in "chorizo de Pamplona", as a consequence of its lower minced size (3 mm), a significant softening could be considered as a defect. The sensory panel detected differences in hardness between control and modified products. The last received significantly lower scores but they were above 4.0, which implies that they could not be considered as objectionable.

The analysis of principal components carried out with all the instrumental variables related to color and texture gave rise to two principal components which explained 76.9% of the variance. The first component (1PC) explained 57.1% of variance and the second (2PC) 19.8% of the variance. The weights of the linear combinations forming each principal component were

$$1PC = (-0.443)\text{chewiness} + (-0.425)\text{gumminess} + (-0.410)\text{cohesiveness} + 0.363L^* + (-0.331)\text{hardness} + 0.329b^* + 0.229a^* + (-0.227)\text{springiness}$$

$$2PC = 0.525a^* + 0.513\text{hardness} + 0.488b^* + 0.310\text{gumminess} + 0.221\text{chewiness} + (-0.218)\text{springiness} + 0.171L^* + (-0.019)\text{cohesiveness}$$

Figure 1 shows each sample PC distribution by function of these two PC. Modified and control samples were separated by the first component defined basically by texture measures.

Summarizing, the results have indicated that the modified product could significantly lower the sodium content and could be considered acceptable in texture and color properties although slight modifications were observed. Further research should be carried out to confirm the commercial viability of the product.

ACKNOWLEDGMENT

We thank Prof. Mohino for his scientific advice.

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Received for review June 4, 1998. Revised manuscript received October 8, 1998. Accepted December 23, 1998. We thank the Government of Navarra, PIUNA, and Foundation Roviralta for their contribution to the financial support of this work.

JF980597Q