A Mixture of Potassium, Magnesium, and Calcium Chlorides as a Partial Replacement of Sodium Chloride in Dry Fermented Sausages

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A mixture of 1.00% NaCl, 0.55% KCl, 0.23% $MgCl_2$, and 0.46% $CaCl_2$ was used to replace the NaCl in dry fermented sausages. Sodium content decreased from 1.88 in the control (made with 2.6% of NaCl) to 0.91 g/100 g in the modified products. The increases in potassium, magnesium, and calcium were from 0.55 to 1.11 g of K/100 g, from 25.60 to 182.00 mg of Mg/100 g, and from 82.60 to 182.90 mg of Ca/100 g. The mixture of salts gave rise to a greater acidification and water activity. No effects were found in the lactic acid bacteria counts but a decrease of *Micrococcaceae* was observed. Furthermore a decrease in nitroso heme pigments was found in the final products made with this mixture of salts. Sensorial acceptability was lower mainly due to the lower salty taste.

Keywords: *Fermented sausages; salt substitution; chloride salts; nutritional advantages*

INTRODUCTION

Epidemiology and experimental evidence have demonstrated a positive correlation between sodium intake and blood pressure (Truswell, 1994). Reducing dietary sodium has been recommended to decrease the incidence of hypertension and subsequent occurrences of cardiovascular disease, stroke, renal failure, and decreased life span in individuals susceptible to these conditions (Pearson and Wolzak, 1982; Sebranek et al., 1983). About 20−30% of excess of sodium intake is due to the consumption of meat products (Wirth, 1989).

Many compounds have been used to substitute or reduce the NaCl in cured meat products. Potassium chloride has been applied successfully in many products (Ibañez et al., 1995, 1996, 1997; Gou et al., 1996; Askar et al., 1993), but a bitter taste can result (Leak et al., 1987; Keeton, 1984). On substituting glycine for NaCl, use of more than 40% can produce an unacceptable sweet taste and an inconsistent texture (Gou et al., 1996). Askar et al. (1993) and Gou et al. (1996) observed that replacement of 40% of NaCl with potassium lactate in dry fermented sausages did not cause important sensory or technological defects.

Magnesium chloride and calcium chloride have also been employed in meat products. An inverse association of magnesium intake and other dietary factors with blood pressure has been established (Joffres et al., 1987). Low calcium intake is associated with osteoporosis, hypertension, and colon cancer incidence. Heaney and Barger-Lux (1991) suggested that processed meat products could provide an important opportunity for calcium supplementation since such products are consumed by people of all ages. However there are few experiments using $CaCl_2$ and $MgCl_2$ as substitutes for NaCl. Seman et al. (1980) studied the partial replacement of sodium chloride by magnesium chloride or potassium chloride in bologna and did not find any sensory defects at low levels. Seperich and Ashoor (1983) experimented with replacing the NaCl with $CaCl_2$ in bologna and did not find any effects on microbial growth or texture. Hand et al. (1982) suggested that magnesium chloride would not be a satisfactory substitute for sodium chloride (100% or 35%) in frankfurters.

The use of a mixture of salts could reduce the negative effects observed with an excessive concentration of each one. In this work, the effect of a partial replacement of NaCl with an equivalent ionic strength of a mixture of KCl, $MgCl_2$, and $CaCl_2$ on the stability, nitrosation process, and some sensorial parameters was studied on production of chorizos, a dry fermented sausage. Changes in sodium, potassium, calcium, and magnesium content were also analyzed.

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 same raw material, ingredients, and technological process were employed for both sausages.

The different types of sausages were made with a standard formulation comprising lean pork meat 75% and pork back fat 25%. The cutting ingredients in the traditional formulation were added as follows: NaCl 26 g/kg of mixture, dextrin 15 g/kg, lactose 10 g/kg, dextrose 3 g/kg, polyphosphates 2 g/kg, sodium ascorbate 0.5 g/kg, $NaNO_2$ 0.2 g/kg, red pepper 20 g/kg, cayenne pepper 0.5 g/kg, garlic 6 g/kg, ponceau 4R (E-124) 0.15 g/kg, and oregano 1 g/kg. The starter culture was a mixture of *Lactobacillus plantarum* (10%) and *Staphylococcus carnosus* (90%). The amount added was 10^3-10^4 cfu/kg of mixture. In the modified formulation, NaCl was substituted by the following salts mixture: NaCl 10 g/kg, $MgCl_2$ 2.35 g/kg, KCl 5.52 g/kg, and $CaCl_2$ 4.64 g/kg (ionic strength equivalent to that of 2.6% NaCl).

Lean pork meat and pork back fat were minced in a cutter to a particle size of about 16 mm and subsequently mixed with the other ingredients in a vacuum mixer and stuffed into

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artificial casings (60 mm diameter). The sausages were fermented in a laboratory ripening cabinet (Kowel Model CC-I) at 24 °C and 100% relative humidity (RH) 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 (21 days). Samples were taken on the 3rd, 7th, 15th and 21st days.

Analytical Methods. *A. Chemical Analysis.* pH was determined with a pH meter micropH 2000 with Needle electrode (CRISON Instrument S. A., Barcelona). Water activity (A_w) was determined using a Novasina (Model 5803) meter. Moisture was determined using ISO R-1442 Method (ISO, 1973). Sodium and potassium levels were determined using a flame photometer according to the AOAC method (AOAC, 1995a). Calcium and magnesium were determined by atomic absorption spectrophotometry according to the AOAC method (AOAC, 1995b).

B. Parameters Related to the Nitrosation Process. Heme pigments were extracted by the Hornsey method (Hornsey, 1956) and nitroso heme pigments were measured using the same method as modified by Gorospe et al. (1986). This modification consisted of adding the extract to a flask with 1 mL of HCl for 5 min to transform the nitroso heme pigments into acid hematin in order to avoid interferences with colorants used in the products. All these parameters were determined using a Perkin-Elmer Lambda 5 UV/vis Spectrophotometer (Perkin-Elmer, CT). The color-forming ratio (CFR) was calculated as the percentage of nitroso heme pigments to the total heme pigments.

C. Microbiological Parameters. Ten grams of sausage were homogenized into 90 mL of peptone water (under sterile conditions for 2 min with a Stomacher). From this suspension decimal dilutions in peptone water were then prepared and spread on the corresponding plates.

De Man Rogosa and Sharpe Agar No. 1 (MRS, Oxoid, Unipath, SA, Madrid) for lactic acid bacteria (30 °C/72 h) in an anaerobic jar with a CO_2 enriched atmosphere (BBL Gaspack Plus, Cockeysville, MD) and *Staphylococcus* medium no. 110 (Oxoid) for *Micrococcaceae*−*Staphylococcus* and *Micrococcus* (30 °C/48 h) were used.

D. Sensory Analysis. Quantitative descriptive analysis (QDA) was carried out according to the method of Zapelena et al. (1997). Twelve people were selected with a triangle test according to Cross et al. (1978) and trained during three 1-h sessions with this type of product. A total of 8 samples were analyzed by each judge (2 replicates from each one of the four pieces). The panelist were asked to score on a 1−9 point scale color intensity and salty taste (1 = low color, not salty; 9 = very intense color, very salty) of the modified samples, which were compared with the control samples taken as reference value (5 points for both parameters). The acceptability of the products were analyzed in separate sessions in the same way (1 = not acceptable; 9 = very acceptable; 5 points for the control). They were also invited to comment the detection of some strange taste as bitter, acidic, or sour.

E. Statistical Analysis. Four sausages of each type of product were analyzed at the different times of ripening. Two determinations for each parameter were measured in each sample. Results shown in the tables are the means of the four sausages, 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 for each analyzed property. Analysis of variance was used to determine significant differences ($p < 0.05$) for every parameter at the different times, in the same type of sausage.

RESULTS AND DISCUSSION

The mixture of salts had nutritional benefits in relation to its minerals content. The amounts of Na, K, Ca, and Mg in the elaborated sausages are shown in Table 1. Sodium content decreased from 1.88 g/100 g in the control to 0.91 g/100 g in the modified product.

Table 1. Minerals Content at the End of Processing[a]

	control	modified	LS[b]
sodium (g/100g)	1.88 (0.04; 2.13)	0.91 (0.05; 5.49)	***
potassium (g/100g)	0.55 (0.01; 1.82)	1.11 (0.02; 1.80)	***
calcium (mg/100g)	84.60 (4.20; 4.96)	182.90 (5.03; 2.75)	***
magnesium (mg/100g)	25.60 (0.05; 0.19)	182.00 (0.06; 0.03)	***

[a] Mean values with its standard deviation and coefficient of variation in the parentheses. [b] LS, level of significance for the difference between control and the modified sausage: *** ($p < 0.001$).

In previous work, partial replacement of NaCl with only KCl gave rise to a product with 1.29% sodium (Ibáñez et al., 1995) in comparison to 1.80% of sodium in the control (Ibáñez et al., 1996). On the other hand, the potassium content increased from 0.55 to 1.11 g/100 g.

The increase in calcium was also significant. Although the main dietary source of calcium is dairy products, the modified sausages contained 182.90 mg/100 g of calcium and could be a significant source of calcium since 100 g of product would contribute 22% of the recommended allowances (RDA) for adults (800 mg) (NRC, 1989) in contrast to 8% that would be contributed by the control products. Also the great increase observed in the magnesium content would imply that these products could be taken into account as a source of this mineral as 100 g of modified product would contribute 87% of the RDA of Mg while 100 g of control would only contribute 12%.

The moisture content decreased in a similar way in both types of products (Table 2). Some significant differences were found at two of the analyzed times of ripening but the final products showed similar values. Different results have been found for the influence of salts on the drying process. Keeton (1984) did not find any differences in the moisture content when KCl was used as a substitute for NaCl in country-style hams. Hand et al. (1982) made frankfurters with different chloride salt treatments at an equivalent ionic strength to that of the control (2.8% NaCl). They did not find any difference in the moisture content. Terrell et al. (1981) found that the replacement of NaCl with any chloride salts (with an equivalent ionic strength), except $CaCl_2$, significantly decreased moisture loss in raw and cooked processed meats. Ibañez et al. (1996) found less drying occurred in products with 1.5% NaCl and 1% KCl than in products with 3% of NaCl.

Although no differences were observed in the water holding capacity, probably as a consequence of the equivalent ionic strength, water activity was higher during the ripening process in the modified products. This water activity increment although being significant was not so great as when a mixture of NaCl and KCl was employed without reaching an equivalent ionic strength to that of the control (Ibáñez et al., 1996). The shelf life of the products probably will not be affected by the observed increment in the water activity because the final values (0.891) can be considered as normal (Chasco el al., 1993). A decrease in the pH was also found in the modified products which would contribute to their stability. This greater acidification observed in the modified products during all the ripening ($p < 0.001$) was not related with the lactic acid bacteria evolution. Lactic acid bacteria counts were similar for control and

Table 2. Moisture and Water Activity during the Ripening[a]

	moisture (%)			water activity		
	control	modified	LS[b]	control	modified	LS[b]
3 days	57.62[d] (1.37; 2.37)	58.28[c] (0.79; 1.35)	ns	0.935[d] (0.001; 0.110)	0.965[d] (0.001; 0.104)	***
7 days	46.80[c] (0.11; 0.24)	44.93[b] (0.38; 0.84)	***	0.929[c] (0.002; 0.215)	0.956[c] (0.001; 0.105)	***
15 days	38.51[b] (0.31; 0.83)	35.12[a] (0.32; 0.93)	***	0.864[b] (0.000; 0.058)	0.903[b] (0.000; 0.055)	***
21 days	35.06[a] (0.53; 1.52)	34.49[a] (0.81; 2.35)	ns	0.835[a] (0.001; 0.120)	0.891[a] (0.001; 0.112)	***

[a] Mean values with its standard deviation and coefficient of variation in the parentheses. Within a column, different letters denote significant differences ($p < 0.05$) between the times of ripening. [b] LS, level of significance for the difference between control and modified sausage: ns, not significant ($p > 0.05$), *** ($p < 0.001$).

Table 3. Parameters Related to Nitrosation Process[a]

	nitroso heme pigments (ppm hematin)			heme pigments (ppm hematin)			CFR (%)		
	control	modified	LS[b]	control	modified	LS[b]	control	modified	LS[b]
3 days	55.42[a] (2.82; 5.09)	51.04[a] (0.38; 0.74)	ns	65.66[a] (0.95; 1.45)	63.70[a] (1.01; 1.58)	ns	84.30[a] (3.06; 3.63)	80.12[a] (0.67; 0.84)	ns
7 days	74.26[b] (3.28; 4.42)	74.91[b] (4.41; 5.89)	ns	88.60[b] (2.35; 2.65)	84.68[b] (2.14; 2.53)	ns	83.89[a] (5.93; 7.08)	88.42[b] (2.98; 3.37)	ns
15 days	74.54[b] (1.94; 2.60)	76.19[b] (0.18; 0.24)	ns	93.90[b] (4.70; 5.01)	96.90[c] (0.95; 0.98)	ns	79.79[a] (4.50; 5.64)	78.62[a] (0.58; 0.74)	ns
21 days	94.51[c] (0.59; 0.62)	89.88[c] (0.28; 0.31)	**	120.09[c] (1.51; 1.26)	106.40[d] (0.07; 0.06)	**	78.70[a] (0.49; 0.62)	84.46[ab] (0.31; 0.37)	**

[a] Mean values with its standard deviation and coefficient of variation in the parentheses. Within a column, different letters denote significant differences ($p < 0.05$) between the times of ripening. [b] LS, level of significance for the difference between control and modified sausage: ns, not significant ($p > 0.05$), ** ($p < 0.01$).

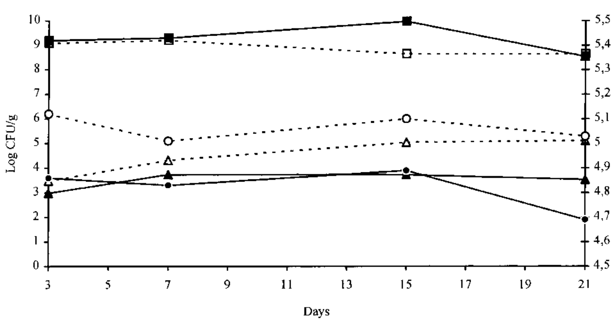

Figure 1. Evolution of pH, lactic acid bacteria counts, and *Micrococcaceae* during the ripening; pH of control sausage (○) and of modified sausage (●); lactic acid bacteria of control sausage (□) and of modified sausage (■); *Micrococcaceae* of control sausage (△) and of modified sausage (▲).

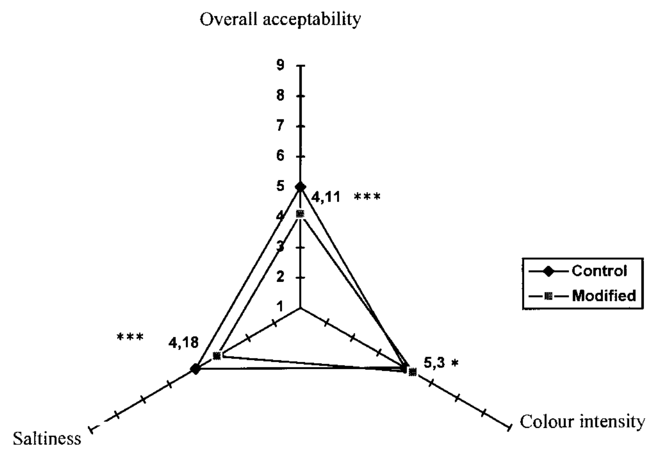

Figure 2. Sensory analysis. Control products: 5 points for every parameter. LS (level of significance for the difference between control and modified sausage scores): * ($p < 0.05$), *** ($p < 0.001$).

modified products (Figure 1). The lower pH could be explained by the added salts. Terrell et al. (1981) also observed that $MgCl_2$ and $CaCl_2$ decreased pH values. Whiting (1987) found that Mg and Ca chlorides caused a drop of approximately 0.25 pH units in meat batters.

Micrococcaceae are added to ensure the nitrosation process (Geisen, 1992). Terrell et al. (1983) found that *Micrococcaceae* counts were not affected by reduction or replacement of NaCl with KCl or $MgCl_2$. In this case *Micrococcaceae*, acid-sensitive microorganisms, showed significant lower counts in modified product during the ripening, probably as a consequence of the greater acidification. Sakata and Nagata (1992) observed a decrease in heme pigment (HP) content with increase of NaCl concentration. No significant differences were found in nitroso heme pigments (NOHP), HP, and the color-forming ratio (CFR) until the final of the ripening (Table 3). At the end of the process NOHP content was lower in the modified products in agreement with the *Micrococcaceae* decrease observed in the last day of ripening. However, the CFR was higher in the modified products as a consequence of a lower content of HP in the modified products at the end of the process. Ibáñez et al. (1996) observed an increase in the CFR in products with a partial replacement of NaCl with KCl, but no differences in the HP content were found during the ripening.

The incidence of these changes on the sensorial attributes of the products was analyzed (Figure 2). A slight but significant ($p < 0.05$) increase in the color intensity was observed. Strange tastes were not detected. Furthermore in products with a similar change of salts (Gimeno et al., 1998) no effect on hardness was detected. However, the panel observed a significant lower salty taste which would probably be related to the lower scores showed by the overall acceptability.

These results pointed out that the greater acidification caused by the employed mixture of salts led to changes in *Micrococcaceae* evolution and in the intensity of nitrosation process leading to a little modification in the color of the products. Also products showed a deficient salty taste being difficult to know if it could be accepted for the most of the consumers. Further studies with an untrained panel should be performed in order to know if this formulation could have a practical application.

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