THE EFFECTS OF POTASSIUM LACTATE AND CALCIUM ASCORBATE AS SODIUM CHLORIDE SUBSTITUTES ON THE PHYSICAL, CHEMICAL, AND SENSORY CHARACTERISTICS OF FRANKFURTER SAUSAGE

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***Abstract*—The objective of this study was to evaluate the effects of sodium chloride (NaCl) substitutes, including potassium chloride (KCl), potassium lactate (K-lactate), and calcium ascorbate (Ca-ascorbate), on the physical, chemical, and sensory characteristics of frankfurter sausage. Frankfurter sausages were manufactured using commercial procedures with 2% NaCl (control) and the following treatments: treatment 1, sausage with 1.2% NaCl and 0.8% KCl; treatment 2, sausage with 1.2% NaCl, 0.6% K-lactate and 0.2% Ca-ascorbate; treatment 3, sausage with 1.2% NaCl, 0.4% K-lactate and 0.4% Ca-ascorbate; and treatment 4, sausage with 1.2% NaCl, 0.2% K-lactate and 0.6% Ca-ascorbate. The combination treatment of K-lactate and Ca-ascorbate had a greater lightness value ($P < 0.001$) and a redder surface ($P < 0.001$) than the control. Moreover, levels of hardness ($P < 0.001$) and firmness ($P < 0.001$) for the control were significantly greater than for treatments 3 and 4, but there were no significant differences between the control and treatment 2. On the other hand, color, flavor intensity and overall acceptability were generally unaffected by the addition of K-lactate and Ca-ascorbate. Therefore, this study concludes that the salt substitutes tested, especially K-lactate and Ca-ascorbate, can be used to manufacture sausage to effectively decrease the sodium content while maintaining the quality of the product.**

***Index Terms*—Salt substitutes, sausage, sodium chloride**

I. INTRODUCTION

Added sodium is found in a wide variety of foods, among them meat and meat derivatives. Excessive sodium intake has been linked to stomach cancer, kidney disease and hypertension (He & MacGregor, 2010). In particular, high salt intake can lead to high blood pressure, which increases the risk of stroke and premature death from cardiovascular disease (Tuomilehto et al., 2001). Recently, several studies reported on possible salt substitutions that could be used to manufacture meat products (Ruusunen & Puolanne, 2005; Gelabert, Gou, Guerrero & Arnau, 2003). Most of them attempted to partially replace sodium chloride (NaCl) with other ingredients, including potassium chloride (KCl) (Guàrdia, Guerrero, Gelabert, Gou & Arnau, 2008), potassium lactate (K-lactate) (Astruc, Labas, Vendeuvre, Martin & Taylor, 2008), and calcium ascorbate (Ca-ascorbate) (Gimeno, Astiasaran & Bello, 2001). However, replacing NaCl entirely with other salt substitutes causes in meat products that taste bitter (KCl, Terrell & Olson, 1981) and acidic (potassium lactate, Gou, Guerrero, Gelabert & Arnau, 1996). Moreover, the effects of Ca-ascorbate on the sensory quality of meat products is still unclear (Gimeno et al., 2001). Therefore, the aim of this study was to evaluate the effects of replacing a percentage of the NaCl with either KCl or different mixtures of K-lactate and Ca-ascorbate on the physical, chemical, and sensory characteristics of frankfurter sausage.

II. MATERIALS AND METHODS

A. Sausage preparation

The different types of frankfurter sausage were made of 69% lean meat (hind legs), 14% back fat, and 17% ice water. The total weight of each meat sample was 1.5 kg. The ingredients added to the control were 20 g/kg NaCl, 2.5 g/kg phosphate, and 20 g/kg soy protein. The addition of the other ingredients and emulsification of the meat mixture were performed in a non-vacuum bowl cutter (Garant MTK 661, Mado Co, Germany) at 10˚C. Four different meat formulas were manufactured by substituting 40% of the NaCl with KCl or various mixtures of K-lactate (60% aqueous solution), and Ca-ascorbate (Table 1). The amount of water in K-lactate solution was subtracted from the total amount of water, thus maintaining the volume in the original formulation. The batter was stuffed into Ø28 mm collagen casings. Each sausage weighed approximately 80 g. Finally, the sausages were smoked and cooked in a smokehouse (ASR 1295, Maurer Co, Germany) for 35 min at 78 ˚C and cooled. The sausages were produced in triplicate.

Table 1. Percentage (%) of sodium chloride and substitutes in the different treatments

	Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Sodium chloride	100	60	60	60	60
Potassium chloride	-	40	-	-	-
Potassium lactate	-	-	30	20	10
Calcium ascorbate	-	-	10	20	30

Control: sodium chloride 20 g/kg product.
All treatments had an equal ionic strength to that of the 2.0% NaCl.

B. Physico-chemical analysis

Sausage pH was measured using a spear type electrode (PH 27-SS, IQ scientific Instruments Inc., USA). The weight loss of the sausages was estimated before and after cooking. Lightness (L^*), redness (a^*) and yellowness (b^*) were measured with a Minolta chromameter (CR-300, Minolta Camera Co., Japan). All determinations were performed in triplicate.

C. Texture profile analysis

A texture analyzer (TA-XT Express, Stable Micro System, Surrey, England) was used to conduct the texture profile analysis (TPA). The texture profiles of eight pieces of sausage from each sample were measured and all the analyses were performed in triplicate. Cubed samples measuring 1.5 cm^3 were placed under a cylindrical probe with a 10 mm diameter, which compressed the samples twice to 70% of their original height. Textural analyses were performed at an ambient temperature. Force-by-time deformation curves were recorded at a crosshead speed of 2 mm/s and recording speed was also 2 mm/s. The texture profile criteria evaluated included hardness, adhesiveness, springiness, cohesiveness, gumminess, and chewiness.

D. Sensory evaluation

Twelve selected and trained panelists, consisting mainly of staff members from Korea University, carried out the sensory evaluation of 1 cm^3 cubes of cooked sausages. Panelist training was performed according to published sensory evaluation procedures (Meilgaard, Civille & Carr, 1991). The panel members were served 5 randomized samples per session with a 1 hr break between servings to reduce fatigue. Subjective descriptors for color intensity, firmness, juiciness, flavor, saltiness, acidic taste, and overall acceptability were measured. To rate the samples, the panelists used 9-point scales, where 1 represented the absence of the descriptor and 9 represented the high intensity of the descriptor.

E. Statistical analysis

The data were subjected to analysis of variance and expressed as the mean ± standard deviation. Analysis of variance (ANOVA) and difference among samples were determined by Duncan's multiple range tests using the Statistical Analysis System (SAS Institute, 2004) program. $P < 0.05$ was used as the criterion for statistical significance.

III. RESULTS AND DISCUSSION

Table 2 showed color, weight loss and pH values in sausage samples from the different treatments. Compared to the control, L^* and a^* values were not significantly different from treatment 1. All treatments had higher L^* ($P < 0.001$) and a^* values ($P < 0.001$) and lower b^* values ($P < 0.001$) than the control, with the exception of treatment 1. Sausages from each treatment had significantly different pH values. The control group had the lowest pH value (6.46, $P < 0.001$), whereas treatment 4 had the highest pH value (7.80, $P < 0.001$). However, the salt substitutions had no significant effect on weight loss between the control and treatment groups.

The TPA parameters for the control and salt substitute treatments are shown in Table 3. Significant differences were found in hardness ($P < 0.001$), adhesiveness ($P < 0.001$), springiness ($P < 0.001$), gumminess ($P < 0.001$), and chewiness ($P < 0.05$), and no clear differences were found in the cohesiveness. Treatments 1 and 2 had no differences compared to the control in hardness, cohesiveness, gumminess, and chewiness. According to Gimeno et al. (2001), the addition of calcium ascorbate to sausages had significant effects on TPA hardness. The results from the current study

(treatment 3 and 4) support this.

In the case of the sensory characteristics (Table 4), the firmness of the control was significantly different from treatment 4 (6.45 vs. 3.70, $P < 0.001$). This was in agreement with the data on hardness, which is found in TPA. With the exception of the KCl treatment, the panelists reported less juiciness ($P < 0.05$) and saltiness ($P < 0.001$) in the treatments (salt level 1.2%). However, there were no significant differences in color intensity, flavor, acidic taste, and overall acceptability.

IV. CONCLUSION

Frankfurter sausage manufactured with 1.2% NaCl and NaCl substitutes (K-lactate and Ca-ascorbate) were redder in surface color and softer in texture than sausage made with 2% NaCl. However, color intensity did not differ between the control and NaCl substitute samples. Moreover, when marking their overall decision for acceptability, the panelists reported no significant differences between the control and other treatments. Therefore, this study concludes that the salt substitutes analyzed (especially K-lactate and Ca-ascorbate) can be used in the tested amounts to manufacture sausage that contains less sodium and that retains its level of quality.

Table 2. Effects of sodium chloride substitutes on color, weight loss, and pH values in the different treatments

	Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Level of significance
Lightness (L^*)	72.81^{b} ±0.58	73.17^{b} ±0.51	74.09^{a} ±0.42	74.02^{a} ±0.23	74.25^{a} ±0.40	***
Redness (a^*)	2.76^{c} ±0.09	3.07^{b} ±0.11	3.66^{a} ±0.22	3.83^{a} ±0.37	3.79^{a} ±0.24	***
Yellowness (b^*)	10.31^{a} ±0.18	10.34^{a} ±0.12	9.70^{bc} ±0.19	9.55^{c} ±0.05	9.82^{b} ±0.25	***
Weight loss (%)	2.33 ±0.59	2.90 ±0.49	2.59 ±0.71	2.87 ±0.71	3.19 ±0.46	NS
pH	6.46^{a} ±0.02	6.38^{b} ±0.08	7.28^{c} ±0.01	7.57^{d} ±0.03	7.80^{e} ±0.02	***

Level of significance: NS = not significant; *** $P < 0.001$.
[a-e]Least square means with different superscripts in the same row differ significantly ($P < 0.05$).

Table 3. Effect of sodium chloride substitutes on textural profile analysis in the different treatments

	Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Level of significance
Hardness (g)	578.3^{a} ±91.04	584.0^{a} ±78.82	585.2^{a} ±149.29	503.0^{b} ±68.80	426.0^{c} ±65.48	***
Adhesiveness (g s)	-26.48^{a} ±24.66	-51.59^{b} ±29.98	-67.31^{b} ±35.96	-93.32^{c} ±48.47	-73.06^{bc} ±50.28	***
Springiness (cm)	0.65^{b} ±0.12	0.71^{a} ±0.08	0.72^{a} ±0.08	0.77^{a} ±0.06	0.75^{a} ±0.06	***
Cohesiveness	0.46 ±0.07	0.44 ±0.03	0.47 ±0.04	0.48 ±0.04	0.47 ±0.06	NS
Gumminess (g)	266.8^{a} ±59.66	258.7^{a} ±43.93	268.8^{a} ±48.90	239.3^{a} ±39.00	200.6^{b} ±42.61	***
Chewiness (g cm)	173.0^{ab} ±48.13	183.7^{a} ±34.40	193.7^{a} ±43.38	184.3^{a} ±35.30	151.5^{b} ±37.60	*

Level of significance: NS = not significant; * $P < 0.05$, *** $P < 0.001$.
[a-c]Least square means with different superscripts in the same row differ significantly ($P < 0.05$).

Table 4. Effect of sodium chloride substitutes on sensory evaluation in the different treatments

	Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Level of significance
Color intensity	4.61 ±1.50	4.59 ±1.14	4.64 ±1.26	4.55 ±1.44	4.57 ±1.60	NS
Firmness	6.45[a] ±1.67	6.39[a] ±1.67	6.06[a] ±1.73	4.79[b] ±1.69	3.70[c] ±1.78	***
Juiciness	5.09[a] ±1.62	4.84[ab] ±1.26	4.52[b] ±1.53	4.36[b] ±1.45	4.31[b] ±1.48	*
Flavor	5.33 ±1.77	5.16 ±1.73	5.21 ±1.76	5.09 ±1.62	5.30 ±1.70	NS
Saltiness	6.61[a] ±1.73	6.68[a] ±1.80	5.63[b] ±2.02	5.42[b] ±1.74	5.52[b] ±1.74	***
Acidic taste	4.46 ±1.38	4.71 ±1.37	4.12 ±1.49	4.24 ±1.20	4.44 ±1.39	NS
Overall acceptability	4.51 ±1.82	4.56 ±1.54	4.91 ±1.87	4.46 ±1.55	4.26 ±1.82	NS

Level of significance: NS = not significant; * $P < 0.05$, *** $P < 0.001$.
[a-c]Least square means with different superscripts in the same row differ significantly ($P < 0.05$).

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