PARTIAL SUBSTITUTION OF SODIUM CHLORIDE BY POTASSIUM CHLORIDE IN FRANKFURTER FORMULATIONS

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ABSTRACT

Substitution of a portion of the sodium chloride by potassium chloride in frankfurter formulations in order to decrease dietary sodium intake had little effect on the physical characteristics of the frankfurter or its sensory evaluation. Replacements of up to 50% of added sodium chloride with potassium chloride provided an acceptable flavor without excessive bitterness, and reduced total sodium content by 37%. The commercial spice mixture contributed substantially to the sodium levels in the frankfurters.

INTRODUCTION

The daily consumption by Americans of 10-12 g NaCl greatly exceeds the physiological requirement of 0.5 g per day (Meneely 1973; Meneely and Battarbee 1976; IFT 1980; Kolari 1980; Marsden 1980). This excessive consumption is believed to be a major factor in onset of hypertension, cardiovascular disease, and renal failure and in shortening the life span (Meneely and Ball 1958; Lemley-Stone *et al.* 1961; Meneely 1973; Kolari 1980) in the 20 to 40% of the population susceptible to these conditions (Meneely and Battarbee 1976; Abernethy 1979). Although improvement was not total when people having high blood pressure were placed on low sodium diets, cultures having these diets invariably have a low incidence of hypertension (Meneely 1973; Meneely and Battarbee 1976; IFT 1980). A reduction in sodium intake throughout one's total life has been recommended to reduce significantly the later development of hypertension (Meneely and Ball 1958; Senate Select Committee 1977; Abernethy 1979; IFT 1980). Increased dietary potassium levels also appear to lower hypertension and to increase the life span in humans as well

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as rats even if the dietary sodium intake remains high (Meneely and Ball 1958; Lemley-stone *et al.* 1961; Meneely *et al.* 1961; Meneely 1973; Meneely and Battarbee 1976; Abernethy 1979; IFT 1980).

Opportunities exist for reduction of two-thirds of the dietary salt added to food by processors or consumers (IFT 1980), particularly since the organoleptic desire for salt is acquired and is dependent on the current salt intake (Meneely and Battarbee 1976; Abernethy 1979). Marsden (1980) noted that processed meat products contribute over a quarter of the total dietary sodium intake. Frankfurters generally contain 1,110 mg Na/100 g and 230 mg K/100 g (Senate Select Committee 1977) so that one frankfurter could furnish approximately 10% of an adult's average daily salt consumption. Salt is, however, a necessary component of processed meats where it acts in extraction of proteins essential for proper fat emulsification and meat binding (IFT 1980; Marsden 1980).

Olson and Trautman (1969) patented the manufacture of canned luncheon meats containing 1% KCl plus potassium polyphosphates. Zyss (1971) patented a process for a variety of meat products with potassium chloride, potassium phosphates, and ammonium phosphates. Seman *et al.* (1980) have recently reported on the textural and sensory characteristics of bologna made with combinations of NaCl and KCl or MgCl with K_3PO_4.

In this paper we compare relevant functional properties of meat proteins after extraction in NaCl or KCl solutions and evaluate the physical and sensory properties of frankfurters made with the partial replacement of sodium with potassium.

MATERIALS AND METHODS

Beef (chuck), pork (shoulder) lean and pork backfat were obtained from local abattoirs and then ground and stored at 1°C until use. Protein, fat, and water contents were determined by Kjeldahl, Soxhlet, and oven drying procedures, respectively (AOAC 1975).

Functional Tests

Solubilities of the proteins were determined by blending for 1 min, 2 g of meat with 60 ml of 0.6 M NaCl or KCl buffered at various pH values with 0.1 M sodium or potassium phosphate. The resultant slurries were placed in an ice bath for one-half hour and then centrifuged at 1000 × G for 10 min. The soluble protein content of the supernatant was determined by the Biuret method (Gornall *et al.*

1949), and the pH of the supernatant was also determined.

Emulsifying capacity was determined by the procedure used by Whiting *et al.* (1981). Fifteen grams of beef were blended with 45 ml of 1.0 M NaCl or KCl for 1 min. To 2.5 g of this slurry was added 50 ml of the respective 1.0 M NaCl or KCl solutions. Forty milliliters of vegetable oil (Wesson Oil [2]) was then added and blended into an emulsion. Additional oil was added until an abrupt increase in electrical resistance indicated that the emulsifying capacity had been exceeded.

A measurement of the effects of sodium and potassium chloride on the binding strength of the meat proteins was adopted from the procedure of Pepper and Schmidt (1975). Beef was trimmed of excess fat and connective tissue, and cut into 1 cm cubes. These cubes (500 g) were mixed with 50 ml of water and 11.25 g NaCl (2.25% or 0.34M) for 15 min in a Hobart mixer (Model N-50) equipped with a dough paddle. Replacement of sodium chloride with potassium chloride was made on an equimolar basis (11.25 g NaCl being equivalent to 14.34 g KCl). A 50:50 mixture would therefore contain 5.62 g of NaCl and 7.17 g of KCl. The resultant tacky mixture was stuffed into 5 cm fibrous casings, held overnight at 1°C, cooked in an air-conditioned smokehouse to an internal temperature of 71°C, and then chilled with a cold water shower. Weight losses occurring during smoking were determined.

To measure the binding strength of this product, the beef rolls were cut into 2.5 cm sections, warmed to ambient temperature, and placed with the flat surface on the plate of an Instron Universal Testing Instrument. A rounded 0.64 cm thick blade was then forced through the section at 100 mm/min to compress and stress the sample until the binding between the meat pieces failed. The force exerted at this point of failure was recorded as the binding strength.

Frankfurter Manufacture

Frankfurter formulations were based on the proximate analyses of the beef, pork lean, and pork fat and were calculated to contain 11% protein (65% from beef), 30% fat, and 54% water. A typical 1200 g batch contained 415 g beef, 230 g lean pork, 315 g pork fat, 290 g ice, 24.0 g NaCl, 15.0 g spice mix (Baltimore Spice Co.), 20.0 g sugar, 0.15 g sodium nitrite, and 0.51 g ascorbate. The desired salt level, 2.5%, was based upon the weight of the total meat component (lean plus fat). An additional 10% water (ice) was added to the formulation to compensate for moisture losses occurring during smoking and cooking. The beef, pork, salt, spice mix, and one-half of the ice were placed in a Hobart silent cutter (Model 84145) modified to have four knives. The nitrite and ascorbate were dissolved separately in a small volume of water and added to the above ingredients. The fat and remaining ice were added after a 2-min chop, following which chopping continued until the emulsion reached 15.5° C. The total chopping time averaged 11.2 min. The emulsion was stuffed into 29 mm cellulose casings, cooked in an air-conditioned smokehouse with wood smoke to an internal temperature of 71° C, chilled rapidly with a cold water spray and stored at 1° C until tested. Where used, potassium chloride was substituted for sodium chloride on a molar basis.

Frankfurter Testing

Weight loss occurring during smoking and cooking of the frankfurter was measured. Weight changes during a 10-min immersion of the frankfurters in boiling water (severe cook loss) were also observed (Whiting *et al.* 1981). To measure the frankfurter's resistance to penetration, frankfurters were cut into 2.5 cm long sections and the cylindrical pieces were placed on end upon the sensing plate of the Instron. A flat-bottomed plunger, 0.6 cm in diameter, was forced through the sample at 100 mm/min and the maximum force recorded (Whiting *et al.* 1981).

An experienced sensory panel evaluated the frankfurters for texture and flavor using a nine point hedonic scale with nine being the most desirable. Six or seven frankfurters from each formulation were prepared for evaluation by placing them into approximately 450 ml of boiling water, reheating the water just to boiling, and allowing them to stand in the heated water without an external heat supply for a total of 10 min. The panelists evaluated the frankfurters in booths under green lighting and were instructed to rinse their mouths between samples.

Sodium and Potassium Analyses

Sodium and potassium contents of the frankfurters, spice mix, and ice were determined after dry ashing at 525° C, dissolving the ash in nitric acid, and measuring by atomic absorption spectroscopy (AOAC 1975).

RESULTS AND DISCUSSION

Protein Functionality

The amount of extractable protein per gram of muscle increased with increasing pH for both 0.6 M NaCl and 0.6 M KCl solutions (Table 1). Although protein extractability was generally greater with sodium than with potassium chloride, significant differences occurred only with salt solutions having a pH of 6.0 and 6.5. Muscle hydration was reported by Hamm (1960) to increase more with sodium chloride than with potassium chloride at pH values above the isoelectric point, but the salts were equal at pH 5.5 where hydration was the lowest.

Table 1. Extractabilities of protein from bovine muscle by buffered NaCl or KCl solutions

	Solubilized Protein (mg protein/g meat)		
pH	0.6 M NaCl	0.6 M KCl	t-test
5.3	74.9 ± 3.5	68.0 ± 3.4	n.s.
5.6	84.8 ± 3.7	86.6 ± 3.8	n.s.
6.0	93.6 ± 4.0	88.6 ± 3.8	*
6.5	98.1 ± 4.0	92.3 ± 3.9	*
7.0	94.7 ± 4.0	93.8 ± 4.0	n.s.

Values are means and standard errors of the mean from triplicate determinations of two animals.
n.s. — not significant
*($p \leq .05$)

For the binding strength determinations, five batches of beef rolls were made with different salt mixtures ranging from 100% NaCl to 100% KCl. Weight losses during the smokehouse cooking varied from 15.0 to 15.8% with no significant differences ($p \geq .05$). The binding strengths were also not significantly different and ranged from 8.9 to 10.2 kg.

Increased protein solubility occurring with pH near 6 with the use of sodium chloride was evident with the emulsification capacity test. Proteins solubilized by sodium chloride exhibited a slight but significantly ($p \leq .05$) greater ability to coat the oil than those solubilized with potassium chloride, with respective values of 92.9 and 87.6 ml of oil per 0.62 g of meat.

Frankfurter Characteristics

Frankfurters were made with varying ratios of sodium and potassium chlorides (Table 2). The 100:0 ratio represents 2.5% NaCl based on the meat portion with no added KCl. The severe cook test also showed little effect from these substitutions, except for an anomalous value at the 50:50 ratio. Frankfurter texture, as measured by penetration force and sensory panel scores, was not significantly affected by altering the salt ratio.

Table 2. Evaluation of frankfurters made with various ratios of sodium chloride and potassium chloride

Na:K Ratio	Smokehouse Weight Loss (%)	Severe Cook Loss (%)	Penetration Force (Kg)	Sensory Score	
				Flavor	Texture
100:0	9.7 A	0.57 A	0.80 A	6.3 A	6.3 A
75:25	9.1 A	0.83 A	0.77 A	5.9 A	6.3 A
50:50	8.8 A	1.43 B	0.74 A	5.8 A	6.8 A
25:75	8.8 A	0.71 A	0.79 A	4.5 B	6.7 A

Values in each column with the same letter are not significantly different ($p \geq .05$)

Flavor ratings (Table 2) did decrease with increasing potassium content, but the decline was not significant ($p \geq .05$) until more than half of the sodium was replaced by potassium. These results agree with Zyss (1971) who reported that potassium chloride produced a bitter taste in meat products when concentrations exceeded 1.5%. The percentage of potassium chloride in table salt that was found to be organoleptically acceptable was 30-40% (Ball and Meneely 1957) and 50% (Frank and Mickelsen 1969; Mickelsen *et al.* 1977).

A frankfurter formulation containing a 50:50 salt ratio was acceptable, and this ratio was chosen for further studies. Reduction of the total salt concentration from the standard 2.5% to 2.0% was examined as a means of reducing the sodium content and the undesirable flavor of the potassium (Table 3). The texture scores of frankfurters produced with the lower salt concentration were largely unaffected. Flavor scores were lower on the frankfurters having decreased salt concentration. The number of samples involved in this comparison was too small to analyze statistically. Any lowering of the total salt concentration in processed meats should be evaluated further regarding the flavor and microbial effects of such changes.

Although frankfurters containing the 50:50 ratio of sodium and

Table 3. Evaluation of 2.0% and 2.5% salt in frankfurters made with an equal molar ratio of sodium and potassium

Salt Level (%)	Smokehouse Weight Loss (%)	Severe Cook Loss (%)	Penetration Force (Kg)	Sensory Score	
				Flavor	Texture
2.5	7.0	3.71	0.62	6.0	5.6
2.0	7.2	1.10	0.61	5.4	5.8

potassium were not significantly different from the 100% sodium standard, an attempt was made to improve the overall flavor scores of the frankfurter formulations containing a 50:50 ratio and 2.5% salt by increasing the spice and/or sugar levels by one-third. Four spice and sugar combinations were tried (Table 4) with the levels of sugar and spice being expressed as a percentage of the amount normally included in the formulation.

Table 4. Evaluation of increased quantities of sugar and spice in frankfurters made with an equal molar ratio of sodium and potassium

Composition[a]	Smokehouse Weight Loss (%)	Severe Cook Loss (%)	Penetration Force (Kg)	Sensory Score	
				Flavor	Texture
100% Sugar 100% Spice	7.7 A	1.29 A	0.65 A	6.3 AB	6.5 A
133% Sugar 100% Spice	7.5 A	0.46 A	0.72 A	6.8 A	6.8 A
100% Sugar 133% Spice	7.3 A	0.95 A	0.70 A	6.4 AB	6.4 A
133% Sugar 133% Spice	7.6 A	2.08 A	0.72 A	6.0 B	7.0 A

[a]100% sugar and spice correspond to the standard additions of 20 g and 15 g per batch, respectively
Values in each column with the same letter are not significantly different ($p \geq 0.05$)

Increasing the spice or sugar content had no significant effect on smokehouse weight losses, severe cook weight losses, penetration forces, or sensory texture scores. There was also no significant improvement in flavor scores, although the highest score was given to the frankfurters with increased sugar. A significant improvement in flavor might be achieved by a change in the spices. Spice mixtures specifically formulated for potassium chloride containing frankfurters could contain bitterness masking components (Frank and Mickelsen 1969).

Further batches of frankfurters were made using the most promising formulations (Table 5). Smokehouse processing weight losses were all higher than those found previously, but were not greatly affected by the compositions. All severe cook losses were low and differences in penetration forces were nonsignificant. The sensory panel did not differentiate the flavor of the 50:50 salt-normal sugar mixture from the 100% NaCl control, but did score the frankfurters with additional sugar lower than they had previously (Table 4). The

Table 5. Evaluation of frankfurters made with potassium chloride and increased sugar

Composition[a]	Smokehouse Weight Loss (%)	Severe Cook Loss (%)	Penetration Force (Kg)	Sensory Score Flavor
100% NaCl 100% Sugar	11.0 B	0.70 A	0.53 A	7.00 A
50% NaCl 50% KCl 100% Sugar	10.7 AB	0.98 A	0.55 A	6.58 AB
50% NaCl 50% KCl 133% Sugar	10.4 A	1.20 A	0.48 A	5.88 B
50% NaCl 50% KCl 133% Sugar	10.3 A	0.44 A	0.54 A	7.25[a]

Values in each column with the same letter are not significantly different ($p \geq 0.05$)
[a]The sensory score for this sample was determined separately, see text for details

final batch of frankfurters having a 50:50 salt mixture and added sugar were presented to the sensory panel as a single sample test in order that no direct comparison could be made to other formulations. To simulate normal consumption, the frankfurters were served in a bun and the panelists were given a choice of mustard or catsup. With this consumer-style presentation, the frankfurters were given a sensory flavor score of 7.25, the highest any frankfurters were given. Apparently the potassium flavor was partly masked by the bun and condiments.

The sensory panelists appeared to adjust to the potassium taste. The panel scores of the frankfurters made with the 50:50 salt mixtures and served unaccompanied by bun or condiments, increased as the panelists were asked to make repeated judgments over a 5-month period. The flavor scores (presented in this paper in their chronological order) increased from the initial score of 5.76 (Table 2), to 6.00 (Table 3), 6.30 (Table 4), and 6.58 (Table 5).

Sodium and Potassium Content

The analyses of frankfurters for sodium and potassium content (Table 6) showed that the formulation having a 50:50 mixture of sodium and potassium chlorides contained 37% less sodium than the 100% NaCl standard. Sources of sodium common to both formulations include the spice mixture and the residual, which in this case was defined as all sources except salt and spice. The amounts of sodium and potassium in the ice were negligible, although the water could potentially be a significant source of sodium. The commercial spice mixture contained 96 mg Na/g and listed sodium chloride as an ingredient.

Table 6. Sodium and potassium content of the frankfurters[a]

	Sodium		Potassium	
	100% Na	50:50	100% Na	50:50
Added Salt	8.0	4.0	0.0	6.8
Spice	1.4	1.4	0.05	0.05
Residual	1.4	1.4	2.9	2.9
Total	10.8	6.8	3.0	9.8

[a]Values are mgNa or mgK/g frankfurter

The potassium content of the frankfurters was increased from 3.0 to 9.8 mg/g frankfurter by substituting 50% KCl into the formulation. Because substitutions were made on a molar basis, 4.0 mg Na was replaced by 6.8 mg K per gram of frankfurter.

The optimum dietary sodium to potassium ratio is unknown, but anthropological data indicated that a ratio of 1:200 was satisfactory (Abernethy 1979). Studies of the present U.S. diet have found ratios ranging from approximately 1:1 (Frank and Mickelsen 1969) to 2.4:1 (Meneely and Battarbee 1976). If the salt added to our diet by manufactured foods and home use was entirely replaced by an equimolar sodium and potassium salt mixture, the dietary sodium intake could be reduced by about one-third. This substitution would then raise potassium intake to levels approaching the currently recommended dietary maximum (NAS 1980).

Other workers also have reported successful substitutions of potassium chloride for sodium chloride. Frank and Mickelsen (1969) claimed that hams cured with a 1:1 mixture were practically indistinguishable in taste or appearance from the standard hams. Seman *et al.* (1980) demonstrated the feasibility of this substitution in bologna. Mixtures of sodium and potassium chlorides have been tried in other foods, including bread and butter (Mickelsen *et al.* 1977).

The 37% reduction in the amount of added sodium and the concomitant increase in potassium does not make the resultant frankfurter an acceptable dietary food for those people who must severely restrict their sodium intake. This product's importance would be for those individuals who wish to reduce their dietary sodium intake because of a susceptibility to hypertension or for general nutritional health reasons. Such people would be able to enjoy a traditional food product while decreasing their dietary sodium intake.

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