# INFLUENCE OF PARTIAL OR COMPLETE REPLACEMENT OF SODIUM WITH POTASSIUM CHLORIDE BLENDS ON PROTEIN EXTRACTION AND MEAT QUALITY OF SAUSAGES

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**Abstract – The objective of this study was to compare the capacity of NaCl, KCl, KCl-based crystal bound with maltodextrin and citric acid (NTS), NTS/NaCl (50/50), mixture of KCl, maltodextrin, citric acid (Mix), and Mix/NaCl (50/50) to extract myofibrillar proteins and impact meat quality. Fresh pork semimembranosus muscle (4% fat) was ground and mixed with 10% water and 2% of salt with or without 0.4% sodium tripolyphosphate (STP, meat weight basis). Raw meat mix pH, water activity, and the amount and profile of extracted protein were determined. Meat was smokehouse cooked (74 °C internal) for cook loss, textural properties, and cooked color analyses. No difference in protein extractability was detected among various salts without STP (P>0.05). When STP was present, NTS/NaCl extracted more proteins than KCl and Mix/NaCl (P<0.05) while NTS/NaCl and KCl exhibited equivalent capacity to extract proteins as NaCl (P>0.05). Cook loss was equally decreased by the tested salts with or without STP (P>0.05). The hardness of cooked products made with KCl, NTS/NaCl and Mix/NaCl was equivalent to that of products made with NaCl (P>0.05). The results suggested a successful approach to sodium reduction by partial replacement of sodium by NTS in cooked sausages.**

**Key Words – Meat quality, Protein extraction, Sodium reduction**

## I. INTRODUCTION

Sodium chloride has been commonly used in foods as a flavor enhancer, preservative, and fermentation controller. In meat products, salt is capable of extracting salt-soluble myofibrillar proteins which bind water and fat thus improve product quality [1]. However, the hypertensive effect of high sodium intake has drawn attention to sodium reduction by replacing sodium chloride with other salts, particularly, potassium chloride [2]. Potential differences in the ability of salts to extract myofibrillar proteins, which are known for their capacity to stabilize fat and water, could influence the cooking and textural properties of processed meat products. In this study an innovative KCl-based crystal (NTS), bound with maltodextrin and citric acid was tested for its capacity to extract myofibrillar proteins and impact meat quality when compared to NaCl and other KCl salt blends.

## II. MATERIALS AND METHODS

*Materials.* Fresh pork semimembranosus muscle at 6−7 days postmortem was used for this study. Salt ingredients were provided by Nu-Tek Products, LLC (Minnetonka, MN, USA). Reagent grade chemicals were purchased from Fisher Scientific (Indianapolis, IN, USA) or Sigma Sigma Chemical Co. (St. Louis, MO, USA).

*Methods.* Fresh pork boneless cushion was ground through 9.5 mm and 3.2 mm plates sequentially using a commercial grinder. Samples for proximate analysis were stored frozen at −30 °C until analysis and measured according to standard AOAC methods. Ground pork was mixed with 10% water and 2% (meat weight basis) salts in a KitchenAid mixer for 3 min either with or without 0.4% STP. *Raw meat pH* was measured on triplicate samples of the mixed meat (10 g) which was homogenized in 90 ml distilled, deionized water using a polytron for 45 s and filtered through a No.1 filter paper. *Water activity* of the raw mixed meat was recorded using an AquaLab water activity meter (Decagon Devices, Inc., Pullman, WA, USA). *Cooking loss.* The mixed meat batter was stuffed into 30 mm casing and cooked in a smokehouse to an internal temperature of 74 °C. Triplicate samples were measured and the cooking loss was calculated as: [(raw sample weight − cooked sample weight)/raw sample weight] × 100%. *Texture profile analysis.* Hardness, springiness, cohesiveness, and chewiness of the cooked sausages were determined [3] using a texture analyzer (Model TA-HDi Texture Analyzer, Stable Micro Systems Ltd.). Samples were chilled at 4°C overnight, cut to 19-mm diameter by 19-mm high cylindrical cores, and analyzed at approximately 7°C. Eight repeated measures were acquired for each treatment. The *raw meat color* (CIE L*, a*, b* values) was measured on meat patties on day 0, 1, and 3 using a colorimeter (CR-300, 8 mm aperture, illuminant D65, 0° observer angle; Minolta Co., Ltd, Osaka, Japan) calibrated with a white plate (L* 97.06, a* 0.14, b* 1.93). Six readings were recorded on each of the duplicate patties. *Internal color of cooked sausages.* Sausage samples were cut perpendicularly to the length of the product into 18 mm long cylinders. The transverse section was measured using the colorimeter with the same settings described above. Six readings from each sample were recorded. *Protein extractability.* After mixing ground pork with salts, the extracted protein was released by adding 20 mL of brine, containing 2% (w/v) of the same salt used in extraction, to 5 g of the mixed ground pork followed by fierce hand shaking for 1 min. The dispersed solution was filtered through a No. 1 filter paper. Protein content in the filtrate was quantified using the Biuret method at 540 nm and expressed as grams of protein per 100 gram of meat. *SDS-PAGE* was performed to investigate the profile of the extracted proteins according to the method of Laemmli [4] with some modifications. The filtrates from protein extractability analysis were diluted by the same factor to about 2 mg/mL for the majority of the samples with 2% (w/v) NaCl solutions either with or without 0.4% (w/v) STP, depending on if STP was present during extraction. The diluted protein solutions were treated with SDS-PAGE sample buffer and analyzed on a 3% polyacrylamide stacking gel and a 8% polyacrylamide resolving gel together with a protein molecular weight (MW) marker (Bio-Rad laboratories, Hercules, CA, USA) ranging from 6.5 to 200 kDa.

*Statistical analysis.* This experiment was replicated three times. Proc Mixed of SAS (2000) was used to determine treatment differences. When a difference was detected ($P < 0.05$), means were separated by pairwise comparisons using the pdiff option.

## III. RESULTS AND DISCUSSION

According to proximate analysis, the average moisture, fat, ash, and protein content of the pork meat used in this study were 74.4%, 4.3%, 1.0% and 20.3%, respectively. NTS when used with NaCl in a 50/50 blend produced a meat pH equal to NaCl ($P > 0.05$) but lower than KCl ($P < 0.05$) (Table 1). Water activity of NTS/NaCl was equal ($P > 0.05$) to NaCl and KCl. Although some statistically significant differences were detected among the salt-containing treatments, the largest difference was 0.006 which likely lacks practical significance. No differences ($P > 0.05$) in cooking loss were found among the salt-containing treatments. STP addition elevated meat pH.

Table 1 pH and water activity ($A_W$) of raw meat and cooking loss means of uncured pork sausages influenced by salts.

| Treatments[1] | pH STP- | pH STP+ | $A_W$[2] | Cooking loss (%)[2] |
|---|---|---|---|---|
| Control | $6.14^{aby}$ | $6.44^{ax}$ | $0.999^{a}$ | $14.56^{a}$ |
| NaCl | $6.10^{bcy}$ | $6.37^{bcx}$ | $0.987^{c}$ | $11.39^{b}$ |
| KCl | $6.14^{ay}$ | $6.40^{abx}$ | $0.990^{b}$ | $11.90^{b}$ |
| NTS | $6.04^{dy}$ | $6.28^{ex}$ | $0.993^{b}$ | $11.78^{b}$ |
| NTS/NaCl | $6.09^{cdy}$ | $6.36^{cdx}$ | $0.991^{bc}$ | $11.49^{b}$ |
| Mix | $6.14^{aby}$ | $6.32^{dx}$ | $0.992^{b}$ | $11.90^{b}$ |
| Mix/NaCl | $6.09^{cdy}$ | $6.32^{dex}$ | $0.991^{b}$ | $11.41^{b}$ |
| SE | 0.02 | | 0.001 | 0.45 |

SE: standard error of difference

$^{a-d}$Means with unlike superscript letters within a column are different ($P < 0.05$).

$^{xy}$Means with unlike superscript letters within a row and pH are different ($P < 0.05$).

[1]Treatments: Control: no salt added; NTS: Nu-Tek advanced formula potassium chloride; NTS/NaCl: 50:50 blend of NTS and NaCl; Mix: potassium chloride mixed with 12.5% maltodextrin and 0.75% citric acid; Mix/NaCl: 50:50 blend of Mix and NaCl; STP-: without sodium tripolyphosphate; STP+: with sodium tripolyphosphate.

[2]Means pooled across phosphate treatments (STP-, STP+) since there were no differences ($P > 0.05$).

From texture profile analysis (Table 2), it showed that when STP was not included, the hardness of the cooked sausages was only negatively affected when NTS and Mix were used alone, compared to NaCl ($P < 0.05$). When STP was present, sausages made with NTS/NaCl and Mix/NaCl had a softer texture than that made with NaCl ($P < 0.05$) but had the same hardness, cohesiveness, and chewiness as that made with KCl ($P > 0.05$). STP, which causes an elevated meat pH, generated firmer products when used in combination with any salt tested ($P < 0.05$; analysis not shown).

Table 2 Textural property means of smokehouse cooked uncured sausages influenced by salts.

| | Hardness (N) | Cohesiveness (%) | Springiness (mm) | Chewiness (N mm) |
|---|---|---|---|---|
| Without STP | | | | |
| Control | $20.69^{c}$ | $42.99^{a}$ | $8.13^{c}$ | $70.36^{b}$ |
| NaCl | $40.16^{a}$ | $38.23^{bc}$ | $10.17^{a}$ | $155.91^{a}$ |
| KCl | $35.99^{ab}$ | $38.13^{bc}$ | $10.01^{a}$ | $136.37^{a}$ |
| NTS | $30.34^{b}$ | $40.32^{ab}$ | $9.64^{b}$ | $115.29^{ab}$ |
| NTS/NaCl | $33.53^{ab}$ | $36.49^{c}$ | $10.18^{a}$ | $124.46^{a}$ |
| Mix | $30.54^{b}$ | $38.78^{bc}$ | $9.90^{ab}$ | $116.93^{a}$ |
| Mix/NaCl | $36.54^{ab}$ | $38.80^{bc}$ | $10.12^{a}$ | $141.72^{a}$ |
| With STP | | | | |
| Control | $25.09^{e}$ | 43.22 | $9.01^{d}$ | $99.27^{e}$ |
| NaCl | $69.54^{a}$ | 43.97 | $11.33^{a}$ | $349.32^{a}$ |
| KCl | $52.92^{bc}$ | 42.72 | $10.51^{c}$ | $240.78^{bc}$ |
| NTS | $47.79^{cd}$ | 41.53 | $10.42^{c}$ | $206.64^{cd}$ |
| NTS/NaCl | $56.15^{b}$ | 41.67 | $10.92^{b}$ | $255.91^{b}$ |
| Mix | $44.16^{d}$ | 41.30 | $10.35^{c}$ | $192.12^{d}$ |
| Mix/NaCl | $56.14^{b}$ | 42.90 | $11.04^{ab}$ | $265.28^{b}$ |
| SE | 4.01 | 1.40 | 0.02 | 22.72 |

The denotations are the same as in table 1.

Table 3 Raw color means with storage (0, 3 d) of uncured ground pork influenced by salts

| | Without STP | | With STP | |
|---|---|---|---|---|
| | 0 | 3 | 0 | 3 |
| CIE L* | | | | |
| Control | $52.20^{a}$ | $52.88^{a}$ | $48.44^{a}$ | $49.08^{a}$ |
| NaCl | $43.69^{d}$ | $44.05^{d}$ | $48.12^{ax}$ | $46.35^{bcy}$ |
| KCl | $44.62^{bcd}$ | $45.62^{bc}$ | $46.37^{b}$ | $45.52^{c}$ |
| NTS | $45.89^{b}$ | $46.55^{b}$ | $45.95^{bc}$ | $45.11^{c}$ |
| NTS/NaCl | $43.86^{d}$ | $45.30^{bcd}$ | $47.16^{ab}$ | $47.11^{b}$ |
| Mix | $45.66^{bc}$ | $45.23^{bcd}$ | $44.80^{c}$ | $45.95^{bc}$ |
| Mix/NaCl | $44.33^{cd}$ | $44.66^{cd}$ | $45.94^{bc}$ | $45.55^{c}$ |
| SE | | 0.72 | | |
| CIE a* | | | | |
| Control | $12.04^{ax}$ | $10.61^{ay}$ | $10.53^{cdx}$ | $9.80^{bcy}$ |
| NaCl | $10.84^{bx}$ | $10.04^{by}$ | $11.88^{ax}$ | $11.01^{ay}$ |
| KCl | $10.36^{bx}$ | $9.56^{bcy}$ | $10.94^{bcx}$ | $9.90^{by}$ |
| NTS | $10.48^{bx}$ | $9.46^{cy}$ | $10.64^{cdx}$ | $9.36^{cdy}$ |
| NTS/NaCl | $10.50^{bx}$ | $9.80^{bcy}$ | $11.34^{bx}$ | $10.59^{ay}$ |
| Mix | $10.65^{bx}$ | $9.55^{bcy}$ | $10.36^{dx}$ | $9.16^{dy}$ |
| Mix/NaCl | $10.87^{bx}$ | $9.68^{bcy}$ | $10.77^{cdx}$ | $9.81^{bcy}$ |
| SE | | 0.27 | | |

$^{xy}$Means with unlike superscript letters within a row and treatment (with or without STP) are different ($P < 0.05$). Other denotations are the same as in table 1.

In raw meat (Table 3), the addition of either chloride or phosphate salts decreased ($P < 0.05$) the lightness (CIE L*) compared to the control. Salts consistently reduced redness (CIE a*) of the raw meat without phosphate compared to the control ($P < 0.05$). However, in the presence of STP on day 3, NTS/NaCl and NaCl were more red ($P < 0.05$) than the control. Display of up to three days at 4 °C markedly decreased the redness of the meat mixes both with and without STP. In the cooked sausages (Table 4), the lightness was more affected by salts than redness with NaCl resulted in the lowest lightness while NTS and Mix when used alone produced products generally with the greatest lightness.

Table 4 Internal color means of cooked uncured pork sausage influenced by salts

| | CIE L* | CIE a* | Chroma C |
|---|---|---|---|
| Without STP | | | |
| Control | $73.47^{a}$ | $10.85^{a}$ | $15.58^{a}$ |
| NaCl | $67.46^{e}$ | $9.06^{b}$ | $12.10^{c}$ |
| KCl | $69.81^{cd}$ | $8.98^{b}$ | $12.83^{bc}$ |
| NTS | $71.48^{b}$ | $8.51^{b}$ | $12.88^{bc}$ |
| NTS/NaCl | $69.73^{cd}$ | $8.53^{b}$ | $12.45^{c}$ |
| Mix | $70.69^{bc}$ | $9.51^{b}$ | $13.50^{b}$ |
| Mix/NaCl | $68.95^{d}$ | $8.98^{b}$ | $12.62^{c}$ |
| With STP | | | |
| Control | $72.48^{a}$ | $10.35^{a}$ | $14.65^{a}$ |
| NaCl | $65.15^{d}$ | $8.63^{b}$ | $11.10^{d}$ |
| KCl | $66.83^{c}$ | $9.37^{ab}$ | $11.98^{bc}$ |
| NTS | $68.13^{b}$ | $9.17^{b}$ | $12.59^{b}$ |
| NTS/NaCl | $66.79^{c}$ | $8.94^{b}$ | $11.61^{cd}$ |
| Mix | $67.88^{b}$ | $9.36^{ab}$ | $12.56^{b}$ |
| Mix/NaCl | $66.06^{cd}$ | $8.59^{b}$ | $11.37^{cd}$ |
| SE | 0.65 | 0.58 | 0.38 |

The denotations are the same as in table 1.

Myofibrillar proteins are known to be responsible for water holding and the textural properties of processed meat products, the extraction of which is particularly important for holding water in meat [5]. From Figure 1, without STP the salts (at 2%) tested had an equivalent ($P > 0.05$) effect on protein extraction. In the presence of STP, NTS/NaCl significantly improved protein extractability to a level equal ($P > 0.05$) to NaCl and greater than KCl. Moreover, NTS/NaCl had greater ($P < 0.05$) protein extractability than Mix/NaCl suggesting the ingoing intact NTS crystal has superior properties when combined with NaCl. NTS and

Mix when used alone did not increase protein extractability when compared to meat mixed with STP only.

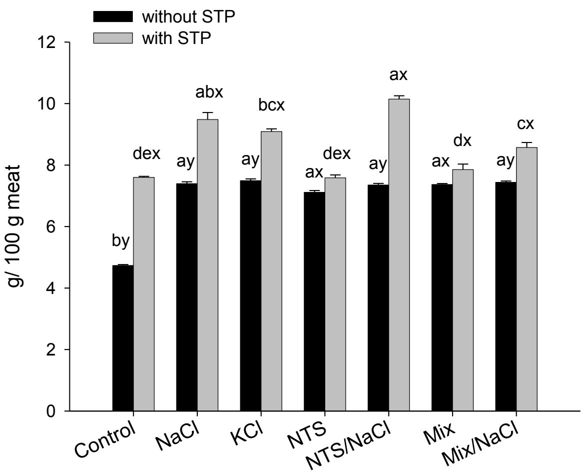


Figure 1. Protein extractability of various salts at 2% of meat weight. Treatment denotations are the same as in table 1. a-e: letters for comparison of the salt treatments within the same STP group. xy: letters for comparison of STP effect within the same salt treatment.

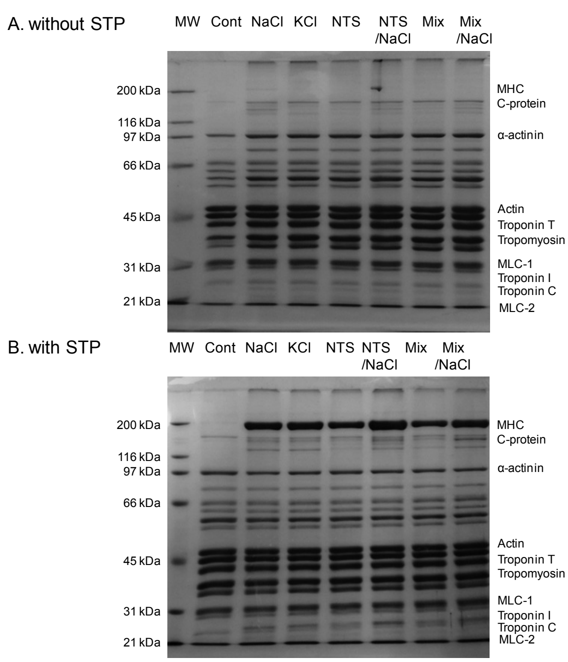


Figure 2. SDS-PAGE of extracted proteins by various salts at 2% of meat weight without (A) or with (B) 0.4% tripolyphosphate (STP). MW: molecular weight standards; Cont: no salt control; MHC: myosin heavy chain; MLC: myosin light chain.

The profile of extracted proteins are shown in Figure 2. With STP, a significant amount of myosin heavy chain (MHC) was extracted. The increased number and band density of the extracted proteins by NaCl and NTS/NaCl support the results in Figure 1.

## IV. CONCLUSION

Sodium could be effectively reduced by partial replacement of NaCl with alternative potassium chloride-based salt ingredients (NTS) without negatively affecting protein extraction, water holding, and texture development in cooked sausages.

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