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Influence of sodium chloride reduction and replacement with potassium chloride based salts on the sensory and physico-chemical characteristics of pork sausage patties

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ABSTRACT

This study evaluated the effects of sodium chloride reduction and replacement with potassium chloride or modified potassium chloride based salts using a weight or molar equivalent basis on the sensory and physico-chemical properties of pork sausage patties. Three independent replications of pork sausage patties were manufactured to compare five treatments: full sodium, reduced sodium, modified potassium chloride weight based replacement, modified potassium chloride molar based replacement, and standard potassium chloride weight based replacement. Salt replacement did not affect ($P > 0.05$) moisture, protein, fat, textural properties, lipid oxidation, or redness. Sausage patties with modified potassium chloride were more acceptable than those with standard potassium chloride ($P < 0.001$). Using modified potassium chloride replaced on a molar equivalent basis resulted in samples with more similar sensory characteristics to the full sodium control than replacement on a weight equivalent basis. The use of modified potassium chloride reduced sodium and improved sodium:potassium ratios while other changes in composition or physico-chemical characteristics were minimal.

1. Introduction

Excessive sodium intake has been associated with cardiovascular disease. The United States Department of Agriculture (USDA) and U.S. Department of Health and Human services (HHS) (2010) recommend daily sodium intake to be no > 2300 mg/day. An estimated 77% of daily sodium consumption comes from processed and restaurant foods (Mattes & Donnelly, 1991). Similarly, Anderson et al. (2010) reported 71% of sodium intake in the US is from processed foods but suggest that this likely underestimates the actual amount. Consequently, recent efforts have been made to reduce sodium content in foods and monitoring of commercially processed and restaurant foods has suggested that 43 of 73 sentinel food categories have had > 10% reduction in sodium (Ahuja et al., 2015).

One difficulty in achieving further reduction of sodium is the multitude of sodium containing functional ingredients. Simply removing or reducing these compounds can negatively impact product quality, acceptability and shelf life (Ruusunen & Puolanne, 2005). Sodium chloride is an important multifunctional ingredient in processed meats. In meat processing, sodium chloride is used to extract myofibrillar proteins which is important for product binding and texture (Bombrun, Gatellier, Carlier, & Kondjoyan, 2014; Desmond, 2006). The addition of sodium chloride provides a salty flavor and enhances the other flavors of the product (Aaslyng, Vestergaard, & Koch, 2014; Tobin, O'Sullivan, Hamill, & Kerry, 2012a, 2012b). Through adding sodium chloride to raw meat products, a shift in the microbial population (spoilage and pathogenic bacteria) and delay in the rate of growth of these organisms occur (Blickstad & Molin, 1983; Madril & Sofos, 1985; Whiting, Benedict, Kunsch, & Woychik, 1984). The addition of sodium chloride improves moisture retention in raw meat and during cooking (Horita, Messias, Morgano, Hayakawa, & Pollonio, 2014; Tobin et al., 2012a, 2012b; Xiong, Noel, & Moody, 1999). Due to these functions, reducing sodium is not as simple as just reducing the amount of sodium chloride added. Therefore much work has been conducted to identify ingredients and processing technologies to replace the functionality of sodium chloride.

Potassium chloride provides one of the most direct substitutions due to the similarity in molecular composition but its use can be limited due to negative sensory attributes. The chloride anion is responsible for myofibrillar protein extraction which helps with increased bind and emulsion stability. Protein extraction can be maintained with a 50% replacement of sodium chloride with potassium but this substitution amount also leads to reduced sensory attributes and overall acceptance by consumers (Horita et al., 2014). To achieve a similar perception of

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saltiness, 33% more potassium chloride than sodium chloride is required in an aqueous solution (Feltrin, de Souza, Saraiva, Nunes, & Pinheiro, 2015). Substituting sodium chloride with potassium chloride on a molar basis provides similar antimicrobial effectiveness against several pathogens: *A. hydrophila*, *E. sakazakii*, *S. Flexneri*, *Y. enterocolitica*, and three strains of *S. aureus* (Bidlas & Lambert, 2008).

Even with the efforts to reduce sodium content of processed foods, use of potassium chloride has been limited due to bitterness and off-flavors that can be associated with its use. A patented process to produce a potassium chloride based crystal (Chigurupati, 2011) has been developed with the potential to more closely mimic sodium flavor and reduce negative sensory attributes associated with using potassium chloride salts. In the modification process, the potassium chloride is treated with citric acid and mixed with a maltodextrin carrier before being spray dried. One study investigated this modified potassium chloride based salt and summarized that sodium chloride could be partially replaced with the modified potassium chloride without negatively impacting protein extraction, yield, or texture of cooked sausages (Zhao & Claus, 2013). The previous study, like most others, has investigated substitution of sodium chloride with potassium chloride on a weight equivalent basis. The objective of this study was to evaluate sodium chloride reduction and replacement with potassium chloride based salts on a weight or molar basis on the sensory and physicochemical and sensory properties of pork sausage patties.

2. Materials and methods

2.1. Materials and treatments

Boneless pork shoulder butts, USDA (2014) IMPS# 406A, were purchased from a regional distributor and stored frozen until product manufacture. All non-meat ingredients were provided by NuTek Food Science LLC (Minnetonka, MN). All products were formulated (Table 1) to contain 94.79% boneless pork shoulder butts, 1.14% breakfast sausage seasoning (BFSTK-BREAKTRAD-no salt, International Spices, Fremont, NE), and 0.02% rosemary oleoresin (5XT-W Herbalox Brand Rosemary Oleoresin Kalsec Inc. Kalamazoo, MI). Modified potassium chloride based salt (NTS; NuTek Salt 15,000, NuTek Food Science, LLC, Minnetonka, MN) contains 85% potassium chloride. The amount of sodium chloride and potassium chloride salts varied between treatment and water was adjusted to maintain equal batch weights. On a raw meat basis, all reduced sodium treatments contained 37.05% less sodium chloride. Treatments included: Control = sodium chloride (1.7%) control; Reduced sodium negative control (RS Control) = reduced sodium chloride (1.07%); NTS 1.2 = reduced sodium chloride (1.07%) with NTS (0.75%), weight replacement basis; NTS 1.5 = reduced sodium chloride (1.07%) with NTS (0.94%), molar replacement basis; KCl 1.0 = reduced sodium chloride (1.07%) with potassium chloride (0.63%). As the NTS 15000 modified potassium chloride contains 85% potassium chloride, the NTS 1.2 treatment represents sodium chloride being replaced with potassium chloride on a weight equivalent basis whereas NTS 1.5 represents sodium chloride being replaced on a molar equivalent basis.

2.2. Product manufacture and handling

Three independent replications were manufactured on separate days. For each replication, pork was allowed to temper at 1–2 °C for three days prior to manufacture. Boneless pork shoulder butts were course ground through a plate with 9.25 mm holes (4734, Hobart Manufacturing Co., Troy, OH). All meat (21.55 kg) and non-meat ingredients and 5% dry ice were added and mixed in a dual action mixer (100DA70, Leland Southwest, Fort Worth, TX) for 90 s. As the control treatment was used for sensory panel evaluations, two 21.55 kg batches were mixed for the control per replication to ensure sufficient quantity of patties. After mixing, the two control mixing batches were commingled during grinding. The sausage mixture was reground through a plate with 4.76 mm holes. A patty maker (Protégé, Patty-O-Matic, Farmingdale, NJ) was used to from 76 g patties that were 9.25 mm thick and 98 mm in diameter. Patties were placed on Styrofoam trays and overwrapped in oxygen permeable polyvinyl chloride film to be placed in simulated retail display. Patties were removed from retail display and vacuum packaged on the appropriate day of sampling and were stored frozen (− 80 °C) until analysis for lipid oxidation. All remaining patties were stacked, crust frozen, and placed in a 1.5 mil polyethylene bag lined box and were kept in frozen storage (− 20 °C) until evaluation. For evaluations that were conducted on cooked samples, patties were tempered for 24 h in a 1–2 °C cooler and cooked on a 190 °C gas heated flat top griddle (HG4, Hobart Corp., Troy, OH). Patties were cooked for 2.5 min on one side, turned, and cooked for 2.5 min on the other side. Internal temperature was measured at the end of cooking with a T-type thermocouple and product temperature ranged from 73.9 °C to 79.4 °C.

2.3. Proximate composition, sodium, potassium, and pH analysis

Proximate composition, sodium and potassium content, and pH were evaluated on both raw and cooked sausage patties. Moisture and ash content were measured using a LECO thermogravimetric analyzer (TGA 701, LECO Corporation, St. Joseph, MI). Total fat was determined as outlined by the AOAC method 960.39 (AOAC, 1990b) using the Soxhlet extraction procedure. Protein was measured using a LECO

Table 1
Pork sausage formulations.

Treatment[1]	Boneless pork shoulder butts	Water	Spice blend[2]	Salt (sodium chloride)	Modified potassium chloride based salt (ModKCl)[3]	Standard potassium chloride (StdKCl)	Rosemary oleoresin[4]
Control	94.79%	2.35%	1.14%	1.70%	0.00%	0.00%	0.02%
RS control	94.79%	2.98%	1.14%	1.07%	0.00%	0.00%	0.02%
NTS 1.2 (1 sodium chloride:1.2 ModKCl wt:wt salt replacement)	94.79%	2.23%	1.14%	1.07%	0.75%	0.00%	0.02%
NTS 1.5 (1 sodium chloride: 1.5 ModKCl wt:wt salt replacement)	94.79%	2.04%	1.14%	1.07%	0.94%	0.00%	0.02%
KCl 1.0 (1 salt: 1 StdKCl: 1 sodium chloride wt:wt salt replacement)	94.79%	2.35%	1.14%	1.07%	0.00%	0.63%	0.02%

[1]Control = full sodium control; RS control = 37.05% reduced sodium negative chloride control; NTS 1.2 = 37.05% reduced sodium chloride with 1:1.2 (wt:wt) sodium chloride: modified potassium chloride based salt (ModKCl) replacement ratio; NTS 1.5 = 37.05% reduced sodium chloride with 1:1.5 (wt:wt) sodium chloride:modified potassium chloride based salt (ModKCl) replacement ratio; KCl 1.0 = 37.05% reduced sodium chloride with 1:1 (wt:wt) sodium chloride:Standard potassium chloride (StdKCl) replacement ratio.
[2]Spice Blend (BFSTK-BREAKTRAD-no salt, International Spices, Fremont, NE).
[3]NuTek Salt 15,000 contains 85% potassium chloride; NuTek Food Science, LLC, Minnetonka, MN.
[4]XT-W Herbalox Brand Rosemary Oleoresin (Kalsec Inc. Kalamazoo, MI).

Nitrogen/Protein analyzer (FP-528, LECO Corporation, St. Joseph, MI) using 6.25 as a conversion factor (AOAC, 1990a). Measures for moisture, ash, and protein content were conducted in duplicate and fat content was conducted in triplicate. Samples were stored frozen for up to 166 days prior to analysis.

To determine sodium and potassium content, samples were first ashed. Samples were dried at 100 °C in a drying oven for at least 30 min before being moved to an ashing oven maintained at 350 to 400 °C. After 15 min, the temperature increased to 520 °C and samples were allowed to ash for at least 2 h. Ash was dissolved and diluted to 50 ml. Dilutions of at least 5 mg/L ash in 0.1% nitric acid in water were prepared. Samples were analyzed by atomic absorption for sodium and potassium content using an external standard (0.1 to 10 mg/l sodium or potassium). Sodium:potassium ratios were calculated based on measured values. Samples were measured in triplicate. Samples were stored frozen for up to 49 days prior to analysis.

Sample pH was measured using a calibrated pH meter (Orion 410APlus; ThermoFisher Scientific, Waltham, MA) in a 10 g sample and 90 ml distilled water slurry. Measurements were conducted in duplicate.

2.4. Sensory analysis

Sensory analysis was conducted by The Pennsylvania State University Center for Food Innovation. For sensory analysis, sausage patties were tempered overnight in a walk-in cooler (1–2 °C) and were cooked as described above on a gas fired flat top griddle (Model 260L-48, Vulcan-Hart, Louisville, KY). Panelists were in individual booths with white lighting. Panelists received hot patties (immediately after cooking) one at a time and in a random order. Samples were evaluated for overall appearance, sausage flavor, spiciness, saltiness, aftertaste, overall acceptability, overall texture, and overall liking using the following nine-point hedonic scale: 1 = Dislike Extremely 2 = Dislike very much 3 = Dislike moderately 4 = Dislike slightly 5 = Neither like nor dislike 6 = Like slightly 7 = Like moderately 8 = Like very much 9 = Like Extremely. Spiciness level and saltiness level were evaluated using the following five point just about right scale: 1 = Not Spicy/Salty, 2 = Slightly not Spicy/Salty, 3 = Just about Right, 4 = Slightly too Spicy/Salty, or 5 = Too Spicy/Salty. At the conclusion of the panel, panelists were asked to rank samples in order of preference from most preferred to least preferred.

Two separate sensory comparisons were conducted to limit panelist fatigue during sampling. The first set of sensory panels compared control, NTS 1.2, and KCl 1.0 samples to compare modified and standard potassium chloride replacement of sodium chloride on a weight equivalent basis to full sodium sausage patties. The second set of panels compared control, RS control, NTS 1.2, and NTS 1.5 samples to evaluate the impact of sodium chloride reduction and replacement with modified potassium chloride on a weight or molar basis in sausage patties. Both sensory comparisons were conducted on each of the three replications. Patties were kept in frozen storage for between 21 and 63 days for the first sensory comparison and between 9 and 24 days for the second sensory comparison. The first sensory comparison (control, NTS 1.2, and KCL 1.0) had a total of 317 panelists (Gender: male = 56.8%, female = 43.2%; Age: 18–24 = 14.1%, 25–34 = 35.0%, 35–44 = 13.2%, 45–54 = 21.5%, 55–60 = 18.0%). The second sensory comparison (control, RS control, NTS 1.2, and NTS 1.5) had a total of 276 panelists (Gender: male = 52.2%, female = 47.8%; Age: 18–24 = 13.4%, 25–34 = 34.4%, 35–44 = 10.9%, 45–54 = 22.8%, 55–60 = 18.5%).

2.5. Lee-Kramer shear

Five cooked pork sausage patties from each treatment and replication were allowed to cool to room temperature. A 40 mm × 40 mm square shaped sample was removed from each patty, weighed (wt. range from 24.29 g to 33.59 g, average wt. 28.93 g), and sheared using a Lee-Kramer Shear cell. An Instron (Model 55R1123, Norwood, MA) with a 2500 kg load cell was equipped with a 10 blade shear cell with a cross head speed of 100 mm/min. The blades cleared the bottom plate to allow the force to return to baseline. Shear force (N; peak force) and total energy (J) were determined using the associated software (Bluehill Version 2.19, Instron, Norwood, MA). Shear force/g (N/g) and total energy/g (J/g) were calculated. Within each treatment and replication, the 5 measures were averaged for each trait. Samples were stored frozen for up to 72 days prior to analysis.

2.6. Simulated retail display, objective color, and discoloration

To evaluate shelf life of raw pork sausage, patties were placed under simulated retail display held at 1–2 °C with 1000 to 1800 lx warm fluorescence lighting (Philips F32T8/TL741 Alto 700 series, Royal Philips Electronics, Amsterdam, Netherlands). Patties were randomly located and rearranged daily in the simulated retail display. For discoloration evaluation, duplicate patties from each treatment were placed on a Styrofoam tray and overwrapped with oxygen permeable polyvinylchloride film (Prime Source PSM 18 #75003815, Bunzl Processors Division, North Kansas City, MO; oxygen transmission rate = 2.25 ml/cm^2/24 h at 23 °C and 0% relative humidity; water vapor transfer rate = 496 g/m^2/24 h at 37.8 °C and 90% relative humidity). A five person panel evaluated duplicate patties from each treatment for percentage discoloration daily for 15 days of simulated retail display storage. The experienced panelists were originally trained to evaluate discoloration in steaks using a pictorial reference of discoloration in 10% increments. The process was adapted to be used on ground patties. Each treatment was assigned a random 3 digit blinding code to minimize bias by the panelists. Objective color (CIE Commission Internationale de l'Eclairage L*, a*, b*) was measured using a Minolta colorimeter (CR-400, Konica Minolta, Inc., Tokyo, Japan) with a 2° standard observer and D65 illuminant daily for 15 days of simulated retail display. The colorimeter was calibrated daily using a standard white tile (according to manufacturer specifications) covered in the polyvinylchloride film described above. Calculations for a/b ratio (a*/b*), hue angle [(b*/a*) $\tan^{-1}$], and chroma [$(a^{*2} + b^{*2})^{1/2}$] were calculated according to guidelines of the American Meat Science Association (2012). Five additional patties from each treatment were placed on single patty Styrofoam trays and overwrapped with oxygen permeable polyvinylchloride film. One patty was removed from each treatment and replication on days 3, 6, 9, 12, and 15 to evaluate for lipid oxidation.

2.7. Lipid oxidation

Lipid oxidation was measured on pork sausage patties with 0, 3, 6, 9, 12, 15 days of simulated retail display. Patties were removed from simulated retail display, vacuum packaged, and stored in a − 80° F freezer for up to 95 days until analysis. Pork sausage patties were homogenized with a waring blender (Model 51BL32, Waring Products Inc., Torrington, CT) in preparation for analysis. Thiobarbituric reactive substances (TBARS) were used to measure lipid oxidation (Buege & Aust, 1978) with modifications as described by Ahn et al. (1998). Samples were run in duplicate; measures within a treatment and replication were averaged.

2.8. Statistical analysis

The project was conducted as a completely randomized design for traits that were measured at a single time point and a completely randomized split plot design when patties were evaluated over time during simulated retail display. Three independent replicates were conducted. Data were analyzed as using the PROC GLIMMIX procedure of SAS (SAS Institute Inc. Cary, NC). For proximate composition, sodium and

Table 2
Effects of sodium chloride reduction and the addition of potassium chloride salts on proximate composition, mineral content, and pH of raw and cooked pork sausage patties.

Treatment[1]	Protein (%)	Moisture (%)	Fat (%)	Ash (%)	Sodium (mg/100 g)	Potassium (mg/100 g)	Sodium: potassium ratio	pH
Raw sausage patties								
Control	15.07	62.79	17.18	2.49[a]	701.7[a]	312.4[b]	2.54[a]	6.32
RS control	15.52	63.40	17.12	1.86[b]	450.2[b]	376.4[b]	1.27[b]	6.29
NTS 1.2	15.07	62.81	17.19	2.44[a]	485.9[b]	624.8[a]	0.78[b]	6.31
NTS 1.5	15.72	62.83	17.10	2.49[a]	485.5[b]	722.0[a]	0.67[b]	6.33
KCl 1.0	15.52	63.86	16.16	2.53[a]	460.5[b]	614.9[a]	0.75[b]	6.29
SE[2]	0.36	0.84	1.04	0.07	20.4	31.2	0.25	0.02
P - value	0.891	0.853	0.939	0.001	< 0.001	< 0.001	0.003	0.698
Cooked sausage patties								
Control	20.57	55.90	17.64	3.11[a]	908.8[a]	278.3[c]	3.30[a]	6.41
RS Control	21.23	54.65	17.78	2.63[b]	597.3[b]	326.9[c]	1.84[b]	6.40
NTS 1.2	20.65	55.92	16.94	3.26[a]	606.8[b]	766.0[b]	0.80[c]	6.43
NTS 1.5	20.73	56.93	16.22	3.35[a]	608.7[b]	890.9[a]	0.69[c]	6.43
KCl 1.0	20.49	56.81	17.19	3.25[a]	609.4[b]	773.6[b]	0.79[c]	6.42
SE[2]	0.28	0.78	0.68	0.08	20.3	21.9	0.09	0.03
P – value	0.638	0.343	0.543	0.001	< 0.001	< 0.001	< 0.001	0.842

($P > 0.05$)
[1]Control = full sodium control; RS control = 37.05% reduced sodium negative chloride; NTS 1.2 = 37.05% reduced sodium chloride with 1:1.2 (wt:wt) sodium chloride: modified potassium chloride based salt replacement ratio; NTS 1.5 = 37.05% reduced sodium chloride with 1:1.5 (wt:wt) sodium chloride:modified potassium chloride based salt replacement ratio; KCl 1.0 = 37.05% reduced sodium chloride with 1:1 (wt:wt) sodium chloride:standard potassium chloride replacement ratio.
[2]SE = standard error of means.
[a–c]Within raw or cooked patties, means within a column with a common superscript are similar.

potassium content, and Lee-Kramer shear force, the effect of treatment was considered a main effect. For sensory analysis, treatment was considered a main effect and panelist a random variable. For color measures and lipid oxidation, the main effects of treatment and storage time and their interaction were evaluated. Storage time was considered a repeated measure using an autoregressive covariance structure. Means separation ($P \leq 0.05$) was conducted using Tukey's multiple pairwise comparison adjustment.

3. Results

Product composition results can be found in Table 2. As expected due to sausage formulation, the control samples had the greatest ($P < 0.001$) sodium content and all other samples were similar in both raw and cooked sausage patties. In regards to potassium content, the control and RS control samples had lower potassium content ($P < 0.001$) than any treatment with potassium chloride salts (NTS 1.2, NTS 1.5, KCl 1.0). For cooked sausage patties, NTS 1.5 samples had the greatest amount of potassium ($P < 0.001$), followed by NTS 1.2 and KCl 1.0 samples, and both controls had the least amount of potassium. The ratio of sodium:potassium follows similar trends. In raw sausage patties, the control had a greater ratio ($P = 0.003$) than all other treatments which were similar. In cooked patties, the ratio was the greatest ($P < 0.001$) for control patties and followed by RS control patties. All patties with potassium chloride salts were similar and had the lowest sodium:potassium ratio. Related to the differences in sodium and potassium content, ash content varied among treatments. In both raw and cooked sausage patties, RS control treatments had less ash content ($P = 0.001$) than all other treatments which were similar. No differences existed ($P > 0.34$) for protein, moisture, or fat content among treatments in raw or cooked sausage patties. No treatment effects on pH were identified ($P = 0.698$).

Results of the sensory comparison of the full sodium chloride control to samples containing modified potassium chloride (NTS 1.2) or standard potassium chloride (KCl 1.0) can be found in Fig. 1. Significant treatment differences were found for all traits evaluated ($P \leq 0.041$). The control samples received among the highest ratings and were significantly higher than the standard potassium chloride samples for all traits measures ($P < 0.05$). However, both treatments with potassium chloride salts received ratings closer to "just about right" for saltiness level. The modified potassium chloride treatment (NTS 1.2) received intermediate values for all traits. It was similar ($P > 0.05$) to the control for liking of overall appearance, flavor, aftertaste, overall texture, and overall liking and was similar ($P > 0.05$) to the standard potassium chloride treatment for spiciness, spiciness level, saltiness, saltiness level, and overall texture. For overall acceptability and relative ranking, the NTS 1.2 treatment was intermediate and different ($P \leq 0.05$) than both the control and standard potassium chloride treatments.

The second sensory comparison was conducted to evaluate the impact reducing sodium chloride and replacing it with modified potassium chloride on a weight or molar equivalent basis (Fig. 2). Significant treatment effects ($P \leq 0.024$) were identified for all sensory traits except overall appearance ($P = 0.738$). As with the first set of sensory comparisons, the control samples received among the highest sensory ratings for all traits. The control sample ratings were greater ($P \leq 0.05$) than the reduced sodium negative control for all sensory traits except saltiness, overall appearance, overall texture, and ranking. Between the treatments with modified potassium chloride replacement of sodium chloride on a weight or molar equivalent basis, there were no significant differences ($P > 0.05$) however differences in relationship to the full sodium chloride or reduced sodium chloride control were identified. When modified potassium chloride replaced sodium chloride on a molar basis (NTS 1.5), samples were similar ($P > 0.05$) to the full sodium chloride control for flavor, spiciness, spiciness level, saltiness, saltiness level, aftertaste, overall texture, and ranking and were similar ($P > 0.05$) to the reduced sodium negative control for spiciness, saltiness, aftertaste, overall acceptability, overall texture, overall liking, and ranking. The weight equivalent replacement treatment (NTS 1.2) was only similar ($P > 0.05$) to the full sodium chloride control for spiciness level. It was similar ($P > 0.05$) to the reduced sodium chloride negative control for all traits except for saltiness level in which reduced sodium negative control received the poorest rating ($P < 0.05$).

No differences ($P \geq 0.487$) were found among treatments for Lee-Kramer shear measures of shear force or total energy (Table 3). Similarly, no differences ($P \geq 0.690$) were found for shear force or energy when calculated on a per gram of sample basis (Table 3).

For objective color measures, discoloration, and lipid oxidation, no significant treatment by days of simulated retail storage interactions ($P > 0.336$) were identified so main effects of treatment and days of simulated retail display were considered (Tables 4 & 5, respectively).

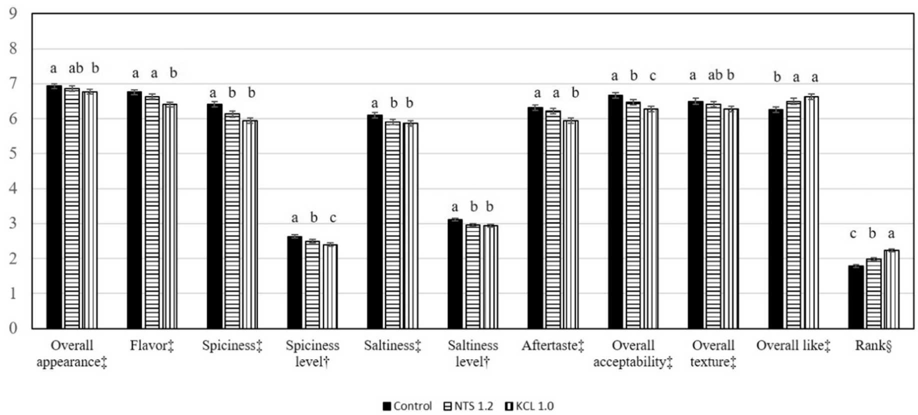

Fig. 1. Effect of sodium reduction and replacement with standard (KCl 1.0) or modified potassium chloride (NTS 1.2) on sensory characteristics of sausage patties. Error bars indicate standard error of means. ‡Evaluated on a 9 point hedonic scale with 1 = "dislike extremely" and 9 = "like extremely" used as anchors. †Evaluated on a 5 point JAR scale where 1 = "not spicy/salty", 3 = "just about right" and 5 = "too spicy/salty." § Ranking from most preferred to least preferred. [a–c]Means within a trait with a common superscript are similar ($P > 0.05$).

Significant treatment effects for product lightness (L*, $P = 0.029$) and yellowness (b*, $P = 0.037$) were identified. The reduced sodium control treatment was the lightest colored but L* values were only significantly greater than NTS 1.5 treatment. For yellowness, NTS 1.5 was the least yellow but b* values were only significantly less than KCl 1.0 treatment. No significant treatment effects were found for redness (a*), a/b ratio, hue angle, or chroma ($P > 0.07$). No significant treatment effects were identified for discoloration or lipid oxidation ($P > 0.68$). During simulated retail display, L*, a*, a/b ratio, and chroma decreased with increased days of retail display ($P > 0.001$) and b*, hue angle, discoloration, and lipid oxidation increased (Table 6) with days of retail display ($P > 0.001$).

4. Discussion

While the use of potassium chloride as a sodium chloride substitute/replacement is not a new concept, efforts to modify potassium chloride salts to negate sensory effects is relatively novel. It is expected that the formulations of pork sausage with reduced sodium chloride had lower sodium content and with the addition of potassium chloride salts, potassium content increased. This was identified in both raw and cooked pork sausage patties. Furthermore, these impacted the sodium:potassium ratios. It has been suggested that a total dietary sodium:potassium ratio should be < 1.0 and greater ratios can result in increased mortality (Yang, Liu, & Kuklina, 2011). The ratio of these molecules may be more indicative of mortality than either independently. All treatments containing potassium chloride salts had a sodium:potassium ratio meeting the recommendations (Table 2).

The overall proximate composition of these products only varied in ash content where the RS control product was lower than all other treatments. No differences were found in protein, moisture, or fat content. As this was found in both raw and cooked products, it suggests the treatment did not impact composition during cooking. This is supported by findings of no difference in cooking loss in pork patties with a potassium chloride replacing 40% of sodium chloride (Moon, Kim, Jin, & Kim, 2008). Others reported a reduction in cooking loss when using 1.0% potassium chloride but no differences when 0.5% or 1.5% potassium chloride was formulated in pork patties (Davaatseren, Chun, Cho, Min, & Choi, 2014).

The concern with potassium chloride inclusion is the reduction of product palatability. Partial replacement of sodium chloride with potassium chloride in pork patties has been shown to reduce relative ranking for sensory characteristics (Davaatseren et al., 2014). In comparing sausage patties with standard potassium chloride and modified potassium chloride, sausage patties with modified potassium chloride had improved sensory ratings for flavor, aftertaste, overall acceptability, and overall liking in the present study. Previous research using a different modified potassium chloride has indicated that replacement of

Table 3
Effects of sodium chloride reduction and the addition of potassium chloride salts on textural properties of cooked pork sausage patties.

Treatment[a]	Shear force (N)	Energy (J)	Shear force per gram (N/g)	Energy per gram (J/g)
Control	803.7	5.02	27.5	0.17
RS control	793.3	5.08	27.9	0.18
NTS 1.2	775.5	4.60	27.0	0.16
NTS 1.5	862.2	5.17	29.6	0.18
KCl 1.0	773.8	5.13	27.5	0.18
SE[b]	37.1	0.31	1.6	0.01
P - value	0.487	0.688	0.806	0.690

[1]Control = full sodium control; RS control = 37.05% reduced sodium negative chloride; NTS 1.2 = 37.05% reduced sodium chloride with 1:1.2 (wt:wt) sodium chloride: modified potassium chloride based salt replacement ratio; NTS 1.5 = 37.05% reduced sodium chloride with 1:1.5 (wt:wt) sodium chloride:modified potassium chloride based salt replacement ratio; KCl 1.0 = 37.05% reduced sodium chloride with 1:1 (wt:wt) sodium chloride:standard potassium chloride replacement ratio.
[2]SE = Standard Error of Means.

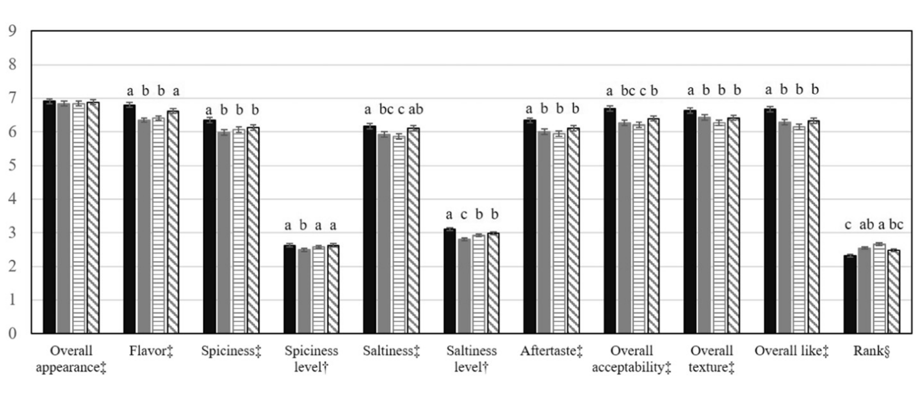

Fig. 2. Effect of sodium reduction and modified potassium chloride replacement on a weight (NTS 1.2) or molar (NTS 1.5) basis on sensory characteristics of sausage patties. Error bars indicate standard error of means. ‡ Evaluated on a 9 point hedonic scale with 1 = "dislike extremely" and 9 = "like extremely" used as anchors. † Evaluated on a 5 point JAR scale where 1 = "not spicy/salty", 3 = "just about right" and 5 = "too spicy/salty." § Ranking from most preferred to least preferred. [a-c] Means within a trait with a common superscript are similar ($P > 0.05$).

Table 4
Effects of sodium chloride reduction and the addition of potassium chloride salts on objective color, discoloration, and lipid oxidation of raw pork sausage patties in simulated retail display.

Treatment[1]	L*	a*	b*	a/b ratio	Hue angle	Chroma	Discoloration (%)	Lipid oxidation[2]
Control	51.88[ab]	8.66	12.05[ab]	0.74	54.79	15.07	54.31	1.26
RS control	53.41[a]	8.31	12.23[ab]	0.70	56.26	14.99	53.70	1.54
NTS 1.2	52.56[ab]	8.61	12.35[ab]	0.71	55.77	15.28	53.04	1.55
NTS 1.5	51.08[b]	8.57	11.72[b]	0.75	54.44	14.74	53.00	1.65
KCl 1.0	52.22[ab]	8.67	12.42[a]	0.72	55.58	15.39	54.72	1.66
SE[3]	0.56	0.31	0.19	0.03	1.21	0.20	3.99	0.30
P - value	0.029	0.767	0.037	0.448	0.583	0.071	0.990	0.689

[1]Control = full sodium control; RS control = 37.05% reduced sodium negative chloride; NTS 1.2 = 37.05% reduced sodium chloride with 1:1.2 (wt:wt) sodium chloride: modified potassium chloride based salt replacement ratio; NTS 1.5 = 37.05% reduced sodium chloride with 1:1.5 (wt:wt) sodium chloride:modified potassium chloride based salt replacement ratio; KCl 1.0 = 37.05% reduced sodium chloride with 1:1 (wt:wt) sodium chloride:standard potassium chloride replacement ratio.
[2]Greater color values indicate samples were: L* - lighter colored, a* - more red, b* - more yellow, a/b ratio – less discoloration, hue angle – less red color, chroma – more saturated color.
[3]Lipid oxidation is reported as TBARS values (mg malonaldehyde/kg of sample).
[4]SE = Standard Error of Means.
[a–b]Means within a column with a common superscript are similar ($P > 0.05$).

up to 75% of sodium chloride with modified potassium chloride in pork sausage resulted in no differences in degree of liking of product (Pasin et al., 1989). The use of modified potassium chloride can improve palatability in comparison to using standard potassium chloride in pork sausage.

When looking solely at molecular weights of sodium chloride (58.44) and potassium chloride (74.55), 27.5% more potassium chloride must be used to provide the same molar concentrations; however, all previous research on pork sausage has investigated equal replacement on a weight basis. In the current study, the comparison of replacing sodium chloride with modified potassium chloride on a weight or molar basis resulted in no significant differences between samples for sensory traits. However, samples formulated with replacement on a molar basis were more similar to the full sodium chloride control than those formulated weight based replacement ratio.

While consumer panelists detected differences in overall texture, no differences were found in total compressive load or energy to shear sausage patties using a Lee-Kramer shear apparatus. Others have reported increased hardness during compression of pork patties containing 0.5% potassium chloride but not in patties formulated with 1.0% or 1.5% potassium chloride (Davaatseren et al., 2014). In cooked pork sausage links without sodium phosphates, no differences were reported in texture profile analysis measures between treatments containing only sodium chloride or a combination of sodium chloride and modified potassium chloride based salt (Zhao & Claus, 2013).

Raw pork sausage patties in simulated retail display had limited differences due to treatment. The reduced sodium chloride control treatment was lighter colored and the standard potassium chloride treatment was more yellow than treatments where modified potassium chloride salt replaced sodium chloride on a molar basis. No other differences in objective color measures or discoloration due to treatment were identified. Previous studies found no difference in lightness or redness of salted raw pork due replacing 50% of sodium chloride with a modified potassium chloride based salt (Zhao & Claus, 2013). Similarly, Moon et al. (2008) reported no differences in objective color measures when partially replacing sodium chloride with standard potassium chloride. In contrast, others have reported replacing sodium chloride with standard potassium chloride at greater amounts resulted in salted pork patties that were less red and less yellow in color (Cheng, Wang, & Ockerman, 2007). In the present study, lipid oxidation during simulated retail display was not different among treatments. This is in contrast findings in previous studies. Cheng et al. (2007) found less lipid oxidation when 50% of sodium chloride was replaced with potassium chloride and Moon et al. (2008) found less oxidation in treatments replacing 40% of sodium chloride with potassium chloride on days four and eight of storage. The differences in reported lipid oxidation may in part in part explained by the addition of oleoresin of rosemary as an antioxidant in the present study whereas the was no

Table 5
Effects of days of simulated retail display on objective color, discoloration, and lipid oxidation of cooked pork sausage patties.

Days of simulated retail display	L*	a*	b*	a/b ratio	Hue angle	Chroma	Discoloration (%)	Lipid oxidation[1]
0	56.68[a]	13.80[a]	11.88[cde]	1.16[a]	40.75[i]	18.21[a]	0.00[g]	0.53[b]
1	54.20[b]	12.82[b]	11.23[efg]	1.14[a]	41.22[i]	17.05[b]	0.07[g]	–
2	53.30[bc]	11.78[c]	11.09[fg]	1.06[b]	43.27[hi]	16.19[c]	0.82[g]	–
3	53.46[bc]	10.96[d]	10.88[g]	1.01[c]	44.80[h]	15.46[cd]	3.17[g]	0.63[b]
4	53.15[bcd]	10.03[e]	11.00[fg]	0.91[d]	47.69[g]	14.91[de]	7.81[g]	–
5	52.34[bcde]	9.57[ef]	11.57[defg]	0.83[e]	50.38[f]	15.03[de]	19.99[f]	–
6	52.62[bcd]	9.03[f]	11.74[cdef]	0.77[f]	52.51[e]	14.82[de]	33.96[e]	0.63[b]
7	52.51[bcd]	8.27[g]	11.79[cdef]	0.70[g]	54.95[d]	14.42[e]	49.93[d]	–
8	51.70[cdef]	7.88[g]	12.26[bcd]	0.64[h]	57.34[c]	14.59[de]	66.77[c]	–
9	52.29[bcde]	7.08[h]	12.44[abc]	0.57[i]	60.38[b]	14.33[e]	83.12[b]	1.14[b]
10	51.75[cdef]	6.25[hi]	12.97[ab]	0.48[j]	64.26[a]	14.41[e]	94.97[a]	–
11	51.72[cdef]	5.75[i]	13.13[a]	0.44[j]	66.26[a]	14.35[e]	99.49[a]	–
12	50.97[defg]	5.62[i]	13.04[ab]	0.44[j]	66.55[a]	14.22[e]	99.97[a]	1.92[b]
13	50.13[efg]	5.92[hi]	13.17[a]	0.45[j]	65.66[a]	14.46[e]	99.98[a]	–
14	49.48[gf]	6.10[hi]	13.11[a]	0.47[j]	64.95[a]	14.50[e]	100.00[a]	–
15	49.36[g]	6.14[hi]	13.15[a]	0.47[j]	64.90[a]	14.54[de]	100.00[a]	4.34[a]
SE[2]	0.67	0.30	0.24	0.03	1.01	0.27	3.25	0.50
P - value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

[a]Lipid oxidation is reported as TBARS values (mg malonaldehyde/kg of sample).
[b]SE = Standard Error of Means.
[a–j]Means within a column with a common superscript are similar ($P > 0.05$).

antioxidant as included in the other studies.

5. Conclusions

The findings of the present study suggest that the use of modified potassium chloride based salts can be used as a partial replacement for sodium chloride in pork sausage patties. Their use can reduce sodium content, increase potassium content, improve the sodium:potassium ratios, and have limited impact on other physico-chemical traits. The full sodium chloride control samples were among the highest rated samples for all sensory traits including overall acceptability and overall liking. However, consumer panelists indicated that the modified potassium chloride salts had improved palatability in comparison to standard potassium chloride and that using a molar equivalent replacement rate may result in samples more similar to full sodium chloride control.

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