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Replacing Sodium in Processed Meats Using Traditionally Brewed Soy Sauce and Fermented Flavor Enhancer

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Abstract: Sodium chloride (NaCl) serves as a key ingredient in processed meats contributing to both quality and food safety. Continued interest exists in identifying NaCl replacement ingredients with saltiness potentiation while still preserving important functional properties. An approach to identify ingredients with sodium reduction potential is to first critically evaluate their efficacy in replacement studies followed by reduction investigation. The use of traditionally brewed soy sauce (SS) and fermented flavor enhancer (NFE) has previously shown potential as effective sodium replacement and reduction ingredients for frankfurters; however, their efficacy in other meat products having different sodium chloride needs is not well understood. In this study, 7 treatments [100% flake salt (FS) and 25, 50, and 75% SS or NFE replacement of the NaCl provided by FS] were investigated in bacon, beef jerky, summer sausage, and boneless ham to understand what impact SS or NFE had on sensory properties including salty taste, and product qualities such as color, purge, and texture profiles. Replacement levels of FS with either SS or NFE for bacon (50 and 75% SS or NFE), beef jerky (50 and 75% SS or NFE), and summer sausage (50% SS and 50% NFE) were identified that provided increases ($P < 0.05$) for saltiness sensory responses without negatively impacting sensory or quality attributes. For boneless ham, a replacement level that provided an increase for saltiness was not identified ($P > 0.05$). These results indicated that SS and NFE may be suitable ingredients to utilize in processed meat products to replace flake salt for sodium reduction strategies offering minimal negative impacts of quality and sensory attributes.

Keywords: fermented flavor enhancer, processed meats, sodium replacement, traditionally brewed soy sauce
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Introduction

Sodium chloride (NaCl; salt) is one of the oldest and most familiar ingredients known and plays an essential role in further processed meat products providing a number of important functionalities. NaCl is a critical component for providing meat products their characteristic flavor by enhancing existing meat flavors while interacting with newly created flavor profiles that exist in processed meats (Weiss et al., 2010). NaCl also plays a critical role in manufacturing processed meat products by the effect NaCl has on the solubility of the myofibrillar meat proteins actin and myosin impacting bind, texture, and water holding capacity. Further, NaCl provides antimicrobial effects in foods by exerting a drying phenomenon, drawing water out of cells of both food and microorganisms, through the process of osmosis (Doyle and Glass, 2010; Romans et al., 2001).

Despite the significant importance of NaCl use in meat products, there has been continued interest from consumers and human health organizations (Webster et al., 2011: WHO, 2012) to reduce the overall sodium intake in the human diet. As sodium reduction interests continue, there is a need to identify ingredients offering the capability of effectively replacing NaCl while also understanding the potential impact their use may have on the physiochemical and sensory properties of various meat and poultry product that rely on sodium chloride for distinctively different functional needs. If NaCl can be effectively replaced, the possibility of reduction, preserving important NaCl-related function while maintaining the characteristic salty taste, can then be pursued and potentially realized.

Soy sauce (SS) is comprised of water, NaCl, soybeans, and wheat. An ingredient comparable to SS, fermented flavor enhancer (NFE) is a product derived from a process similar to that used for the production of soy sauce but manufactured to possess less soy flavor and a lighter color while providing umami flavor amplification (McGough et al., 2012a; McGough et al., 2012b). Of particular interest for this research, SS and NFE are both ingredients that contain high levels of umami substances generated through a fermentation process, from identified contributing amino acids and peptides (Kremer et al., 2009; Wei Goh et al., 2011; Jiménez-Maroto et al., 2013; Kremer et al., 2013a; Kremer et al., 2013b; Shimojo et al., 2014), which have been demonstrated to enhance saltiness in foods (Mojet et al., 2004).

Previous research (McGough, 2011) has shown SS and NFE could be successfully included into frankfurters where sodium reductions of 20% singly or 35% in combination with potassium chloride were achieved without any negative impact on quality or consumer acceptance. However, the results of this research were limited to frankfurters and did not consider the levels and needs of salt in other processed meat products. Therefore, the objectives of this study were 1) to investigate the feasibility of adding SS and NFE to bacon, beef jerky, boneless ham, and summer sausage, and 2) to determine what salt enhancing ability and quality effects may exist from the inclusion of SS and NFE in these meat products.

Materials and Methods

Experimental design and data analysis

This study utilized varying levels of NaCl from flake salt (FS) and traditionally brewed SS or NFE sources in the manufacturing of bacon, beef jerky, boneless ham, and summer sausage to investigate the efficacy of using SS or NFE as a source of NaCl for replacement and sodium enhancement. A portion of the formulation flake salt from SS or NFE for each product investigated was replaced at three levels, 25, 50, and 75%, for the generation of a total of 7 treatments. Treatments for this experiment were as follows: 100FS (100% NaCl from flake salt); 75FS/25SS (75% NaCl from flake salt and 25% NaCl from SS); 50FS/50SS (50% NaCl from flake salt and 50% NaCl from SS); 25FS/75SS (25% NaCl from flake salt and 75% NaCl from SS); 75FS/25NFE (75% NaCl from flake salt and 25% NaCl from NFE); 50FS/50NFE (50% NaCl from flake salt and 50% NaCl from NFE); and 25FS/75NFE (25% NaCl from flake salt and 75% NaCl from NFE). The experimental design consisted of a randomized complete block using a mixed effects model. Statistical analysis was performed using JMP Pro (version 10.0, SAS Inst. Inc., Cary, NC) mixed model procedure. The model included the fixed main effects of the treatment and replication ($n = 2$) resulting in 14 observations. The random effect was the interaction of treatment × replication. All least significant differences were found using the Tukey-Kramer pairwise comparison method. Significance levels were determined at $P < 0.05$.

Soy sauce and fermented flavor enhancer preparation

Traditionally brewed soy sauce (Kikkoman Product Code 00050 and 00070; Kikkoman Foods Inc., Walworth, WI) contained the following ingredients: water, salt, wheat and soybeans. Previous research (McGough, 2011) revealed a residual protease was present in SS which can break down meat proteins and disrupt meat emulsions and affect the quality of meat products. In an effort to mitigate any potential effects, the SS was treated by cooking in a water bath in a sealed vessel at 75°C for 7 h to inactive protease then cooled and stored at 4°C until needed. NFE (Kikkoman Product Code 00619; Kikkoman Foods, Inc.) contains the same ingredients as SS but its manufacturing processes included a protease inactivation procedure; therefore, no protease inactivation prior to our use was necessary. SS used for all studies included 13.7% salt while NFE contained 12.1% salt.

Product manufacture

All products in this study were manufactured at the University of Wisconsin Meat Science and Muscle Biology Laboratory (Madison, WI) using good manufacturing practices and typical commercial formulations and manufacturing procedures. Separate lots of raw materials for each replication were procured from a local supplier (UW Provision, Middleton, WI). Each treatment included varying amounts of salt, water, and either SS or NFE with water adjustments made to compensate for the water contribution from SS and NFE. These prescribed salt and water concentrations for each treatment and for all product types investigated are outlined in Table 1.

Bacon. Bacon was manufactured by randomly assigning 2 fresh pork bellies to 1 of 7 treatments. All

Table 1. Salt levels and sources of NaCl in bacon, beef jerky, boneless ham, and summer sausage containing soy sauce (SS), fermented flavor enhancer (NFE) and no SS/NFE (100FS)

	Treatments[1]						
Products	100FS	75FS/25SS	50FS/50SS	25FS/75SS	75FS/25NFE	50FS/50NFE	25FS/75NFE
Bacon							
Formulation Salt Level, %[2]	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Salt from SS, %[3]	0	0.4	0.8	1.2	0	0	0
Salt from NFE, %[4]	0	0	0	0	0.4	0.8	1.2
Flake Salt Added. %[5]	1.6	1.2	0.8	0.4	1.2	0.8	0.4
Water Added, %[6]	9.5	7.24	4.97	2.73	6.90	4.30	1.72
Beef Jerky							
Formulation Salt Level, %[2]	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Salt from SS, %[3]	0	0.75	1.5	2.25	0	0	0
Salt from NFE, %[4]	0	0	0	0	0.75	1.5	2.25
Flake Salt Added, %[5]	3.0	2.25	1.5	0.75	2.25	1.5	0.75
Water Added, %[6]	12.66	9.01	5.35	1.69	8.46	4.26	0.05
Boneless Ham							
Formulation Salt Level, %[2]	2.25	2.25	2.25	2.25	2.25	2.25	2.25
Salt from SS, %[3]	0	0.56	1.13	1.69	0	0	0
Salt from NFE, %[4]	0	0	0	0	0.56	1.13	1.69
Flake Salt Added, %[5]	2.25	1.69	1.12	0.56	1.69	1.12	0.56
Water Added, %[6]	13.08	10.51	7.95	5.38	10.13	7.18	4.24
Summer Sausage							
Formulation Salt Level, %[2]	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Salt from SS, %[3]	0	0.63	1.25	1.88	0	0	0
Salt from NFE, %[4]	0	0	0	0	0.63	1.25	1.88
Flake Salt Added, %[5]	2.5	1.87	1.25	0.62	1.87	1.25	0.62
Water Added, %[6]	12.41	8.95	5.68	1.46	8.31	4.57	0.94

[1]Treatments: 100FS = 100% NaCl from flake salt; 75FS/25SS = 75% NaCl from flake salt and 25% NaCl from SS; 50FS/50SS = 50% NaCl from flake salt and 50% NaCl from SS; 25FS/75SS = 25% NaCl from flake salt and 75% NaCl from SS; 75FS/25NFE = 75% NaCl from flake salt and 25% NaCl from NFE; 50FS/50NFE = 50% NaCl from flake salt and 50% NaCl from NFE; 25FS/75NFE = 25% NaCl from flake salt and 75% NaCl from NFE.

[2]Formulation salt level includes salt from flake salt and salt from cure (93.75% salt).

[3]SS = Soy sauce, analyzed for salt content (13.7% NaCl w/w).

[4]NFE = Fermented flavor enhancer, analyzed for salt content (12.1% NaCl w/w).

[5]Typical flake salt used for meat processing.

[6]Water added (formulation basis) varied to account for water contribution from SS or NFE.

treatments in this study included, on a total formulation basis, 0.6% sugar, 0.4% sodium tripolyphosphates, and the treatment specified FS, water, SS or NFE (Table 1), in addition to 547 mg/kg sodium erythorbate and 120 mg/kg sodium nitrite, added on a meat block basis.

The individual treatment brine solutions (n = 7) were manufactured by first dissolving the sodium tripolyphosphates in cold (4°C) water, followed by FS, sugar, sodium erythorbate, sodium nitrite, and either SS or NFE. Bellies were injected using a multi-needle injector (Fomaco Model FGM 20/20S, Food Machinery Company A/S, Copenhagen, Denmark) to 12% over non-injected weight. Each belly was weighed prior to injection and after injection to record brine pickup. After 12 h at 4°C, all treatments were thermal processed in a single truck oven (Alkar Model 450 MiniSmoker, Alkar Engineering Corp., Lodi, WI) using a common bacon thermal processing schedule consisting of an 8 h dry bulb/wet bulb ramping cook schedule beginning at 40.0°C and ending at 51.6°C until a final internal temperature of 53.9°C was reached. After thermal processing was complete, the bacon slabs were immediately chilled until the internal temperature was below 4.4°C. Before slicing, bacon slabs were tempered for 2 h at –20°C, sliced 2.5-mm thick with an automatic slicer (Bizerba A400FB, Bizerba GmbH & Co., Balingen, Germany), vacuum packaged, and stored at 4°C until sampling.

Beef jerky. Ready-to-eat, ground-and-formed beef jerky was manufactured utilizing beef cap-off inside rounds *(semimembranosus)* trimmed free of all exterior fat and connective tissue. The trimmed rounds were coarse ground through a grinder (Biro Model

6642, Biro Manufacturing Company, Marblehead, OH) using a 19.05 mm plate and were then re-ground through a 3.18 mm plate. The ground meat was then randomly separated into seven batches of 6.80 kg each and randomly assigned to 1 of 7 treatments. All beef jerky treatments included, on a total formulation basis, 84.22% beef inside rounds, 0.54% seasoning (ground black pepper, allspice, and garlic), and the treatment specified FS, water, SS, or NFE (Table 1) in addition to 547 mg/kg sodium erythorbate and 156 mg/kg sodium nitrite, added on a meat block basis.

To generate the beef jerky treatments, finely ground beef was first mixed with salt (FS or SS/NFE source) and sodium nitrite for 2 min in a double action paddle mixer (Leland Model 100DA, Leland Detroit Manufacturing Company, Detroit, MI) followed by the mixing of all spices, sodium erythorbate, water for an additional 3 min. The mixture was then transferred to a rotary-vane vacuum filler (Handtmann VF 608 Plus vacuum filler, Handtmann CNC Technologies Inc., Buffalo Grove, IL) and formed into strips using an extruder (Colosimo Model 200 sausage/jerky press, Colosimo's Original Sausage, Magna, UT) attachment with a 3 slot die (0.95 cm × 3.175 cm). Strips of beef jerky were then placed on a smokehouse rack and thermal processed in a single truck smokehouse using a standard beef jerky smokehouse consisting of a 3 h (< 50% RH) wet bulb/dry bulb ramping cooking schedule starting at 53.8°C and ending at 76.6°C until an internal temperature of 71.2°C was achieved and followed by drying at 76.6°C with 0% relative humidity until a water activity of 0.86 was reached in all treatments. After cooking and drying, the beef jerky was cut into 15.24 cm long strips, vacuum packaged (Ultravac 2100-C Vacuum Packager, Koch Equipment, Kansas City, MO) in vacuum pouches (3 mil high barrier EVOH pouches, Deli 1 material; oxygen transmission rate, 2.3 cm^3/cm^2; 24 h at 23°C; water transmission rate, 7.8 g/m^2; 24 h at 37.8°C; and 90% relative humidity; WinPak, Winnipeg, Manitoba, Canada), and stored at 4°C until testing.

Boneless ham. Ready-to-eat, boneless deli-style ham was manufactured with ham inside muscles (*semimembranosus*) trimmed of all exterior fat and connective tissue and the cap (*gracillis muscle*) removed. The trimmed inside ham muscles were ground through a kidney and were separated into 7 batches of 9.07 kg and randomly assigned to 1 of 7 treatments. All ham treatments included, on a total formulation basis, 83.33% pork inside ham muscles, 1.38% sugar, 0.33% sodium tripolyphosphate, and the treatment specified FS, water, SS or NFE (Table 1) in addition to 547 mg/kg sodium erythorbate and 200 mg/kg sodium nitrite, added on a meat block basis.

The individual treatment brine solutions (n = 7) were manufactured by first dissolving sodium tripolyphosphates in cold water, followed by flake salt, sugar, sodium erythorbate, sodium nitrite, and SS or NFE. Boneless ham was produced by tumbling (Lyco Model LT-40, Janesville, WI) coarse ground pork muscles and a pre-determined brine solution containing all non-meat ingredients under vacuum for 1 h at 18 rpm. After tumbling, the product was held for 12 h for cured-color development at 4°C. The ham mixture was then transferred to a rotary-vane vacuum filler and stuffed into 6.66 cm diameter fibrous casings (Vista International Packaging., Kenosha, WI) into individual chubs (2.27 kg). Boneless ham chubs were hung on a smokehouse truck and processed in the single truck smokehouse using a 5 step ramp-up steam cook process (100% relative humidity) starting at 60cC and finishing at 82.2°C (100% RH) with no external smoke application, to an internal temperature of 71.2°C. After cooking, the hams were cooled to less than 4.4°C, sliced to 3.2 mm thick on a manual deli slicer, vacuum packaged, and stored at 4°C until later sampling.

Summer Sausage. Ready-to-eat summer sausage was manufactured with ground (3.2 mm) beef chuck (80% lean/20% fat) separated into 7 batches of 9.07 kg and randomly assigned to 1 of 7 treatments. All treatments included, on a total formulation basis, 82.68% lean ground beef, 1.08% seasoning mix (coriander, black pepper, ground mustard, mustard seed, garlic powder, nutmeg, and allspice), 0.62% dextrose, 0.03% lactic acid starter culture (Saga 200, *Pediococcus* spp. Kerry Ingredients, Beloit WI), and the treatment specified FS, water, SS or NFE (Table 1) in addition to 547 mg/kg sodium erythorbate and 156 mg/kg sodium nitrite, added on a meat block basis.

Ground beef (80% lean/20% fat), salt (flake or SS/NFE source), and sodium nitrite were mixed in a double action paddle mixer for 2 min. Dextrose and spices were then added and mixed an additional 2 min followed by the lactic acid starter culture addition and 1 additional min of mixing. The mixture was then transferred to a rotary-vane vacuum filler stuffed into 6.35 cm diameter fibrous casings to a weight of 2.27 kg per chub. Thermal processing took place in a single truck smokehouse using a standard summer sausage smokehouse schedule fermenting to an internal pH of 4.8 at 40°C followed by cooking to an internal temperature of 71.2°C with a dry bulb/wet bulb ramp-up cook schedule starting at 54.4°C and ending at 76.6°C. After cooking, the summer sausage was placed in a 4°C cooler until the temperature was reduced to less than 4.4°C, sliced to 4.0 mm thickness on a manual deli slicer, vacuum packaged, and stored at 4°C until sampling.

Water activity

Water activity (a_w) was measured on beef jerky treatments with a water activity meter (AquaLab Model CX2, Decagon Devices Inc., Pullman, WA) to confirm the aw met the industry standard of no more than 0.86 used for food safety. For measurement of aw, strips of beef jerky were periodically removed from the smokehouse near the completion of drying to monitor aw status. The water activity machine was calibrated with water activity standards of 1.000 and 0.760 prior to analyzing samples and measurements were conducted in triplicate

Instrumental color measurements

Instrumental color was measured using a Minolta Colorimeter (Model CR-300, Minolta Camera Co., Ltd., Osaka, Japan; 1 cm aperture, illuminant D65, 2° observer angle). The colorimeter was standardized using the same packaging material that was used on the samples, placed over the white standardization tile. Values for the white standard tile were L^* = 97.06, a* = -0.14, b* = 1.93 (Y = 93.7, x = 0.3163, and y = 0.3324). Commission Internationale de l'Eclairage (CIE) L*(lightness), a*(redness), and b*(yellowness) external and internal color measurements were taken at 14 d post manufacture for each product (American Meat Science Association, 2012).

Color analysis for boneless ham and summer sausage consisted of cutting 3.00-cm sections lengthwise and placing them in a vacuum package. External and internal measurements were immediately taken at 2 randomly selected locations on all samples. After placing in a vacuum package, bacon sample measurements were conducted on lean and fat portions of the slices and both the lean and fat sides of the bacon slab. Beef jerky strips were sliced lengthwise to expose the internal surface for color measurement and placed in a vacuum package.

ph measurements

The pH levels were measured using methods described by Sebranek et al. (2001). The tip of the electrode was placed into the solution and pH was measured with a pH meter (Accumet Basic AB15 Plus pH Meter, Fisher Scientific, Fair Lawn, NJ) equipped with an electrode (Accument combination pH electrode with Ag/AgCl reference Model 13–620–285, Fisher Scientific, Fair Lawn, NJ) calibrated with 4.00 and 7.00 phosphate buffers. Measurements were made in triplicate for each treatment.

Purge level measurements

Purge levels were measured after 14 d of refrigerated 4°C storage when sensory evaluations occurred. Three packages from each treatment were weighed, drained, and then reweighed.

Cook yield measurements

Cook yields were determined for the products by taking a raw weight on each individual treatment batch prior to thermal processing and reweighing after completion of thermal processing and cooling.

Salt level determination

Salt levels were measured using methods described by Sebranek et al. (2001) to ensure product formulation goals were achieved and to confirm treatment salt levels were consistent with the controls. Percent NaCl was determined using Quantab strips (Quantab Titrators for Chloride, High Range Titrators– 300 to 6000 mg/kg Cl, Hach Company, Loveland, CO). All values were multiplied by 10 to account for the dilution factor to give the actual percentage of salt. Measurements were performed in duplicate for each treatment.

Instrumental texture measurements

Texture profile analysis (TPA) was conducted on all product types based on methods described by Wenther (2003) using an HDi Texture Analyzer (Texture Technologies Corp., Scarsdale, NY). The texture analyzer was equipped with a 25-mm diameter cylinder (TA-25), which was utilized in a 2-compression test for summer sausage and boneless ham. A compression plate surface was utilized for beef jerky texture profile analysis based on methods described by Thiagarajan (2008). Bacon texture analysis utilized the star probe puncture analysis test described by Wenther (2003). The HD*i* Texture Analyzer was equipped with a 50 kg load cell and was calibrated using a 10 kg weight for all products tested. TPA was conducted immediately after removing treatments from a 2.2°C cooler and all tests were performed at 1.7 mm/s for both a 2-cycle 50% compression and 2-cycle 72% compression.

For boneless ham and summer sausage, TPA was conducted using 2 randomly selected product pieces from which 4 cores (15 mm diameter, 20 mm high) were removed providing 8 texture samples. For beef jerky, TPA was conducted on eight randomly selected strips. Puncture analysis was also conducted on bacon treatments according to methods described previously

(Wenther, 2003). Star probe texture analysis was conducted on the fat and lean sides of an approximately 4 cm long section removed from the blade end of each belly to determine fat and lean firmness. A TA-HD*i* Texture Analyzer, equipped with a 50 kg load cell and a 2-mm diameter puncture probe, was programmed to penetrate a distance equal to 40% of the sample height into the sample after detecting the surface at 50 g of resistance. The puncture penetration rate was 1.7 mm/s. For each treatment, 8 measurements were collected per sample and 2 samples were measured, resulting in 16 measurements per treatment.

Descriptive sensory analysis

The appearance, texture, and flavor attributes of all the product types were evaluated by a trained sensory panel of the University of Wisconsin-Madison Sensory Analysis Laboratory (Madison, WI) under the supervision of the sensory analysis manager. The 13-member panel (7 females, 6 males) received a minimum of 40 h of training and practice on using Quantitative Descriptive Analysis and Spectrum evaluation of basic tastes, flavor profiles, and solid food texture before the beginning of this study (American Meat Science Association, 2016). The panelists received an additional 20 h of training on evaluating meat products over the course of the 14 d preceding the evaluation of each meat product. In total, 118 references were utilized for training on 35 different attributes.

Lexicon development (Table 2) occurred concurrently with the training, with the panelists collectively developing and refining the lexicon including product specific attributes for each of the evaluated product types (Civille and Lyon, 1996; American Meat Science Association, 2016). Bacon specific attributes consisted of phosphate, caramelized, pork cured, pork fatty, smoked, cohesiveness, chewiness, and crispiness. Beef jerky specific attributes consisted of beef cured, black pepper, first chew hardness, cohesiveness, and chewiness. Boneless ham specific attributes consisted of phosphate, pink color intensity, hammy, caramelized, brothy, hand firmness, tear, first chew hardness, cohesiveness, chewiness, and breakdown mass. Summer sausage specific attributes consisted of black pepper, coriander, garlic, mustard, hand firmness, first chew hardness, and cohesiveness. All products also included questions about the intensity of soy sauce flavor. References for the sensory attributes selected were identified from commercial meat products, which were made available to panelists during evaluation sessions.

Bacon was prepared by cooking slices in a convection oven (Hobart combi oven model 120, Hobart Corporation, Troy, OH) operating at 190°C for 13 min. After cooking, bacon slices were cut in half (mid-section) and served to the panelists. Beef jerky samples were sliced into 7.6 cm strips and stored at 4°C until served to each panelist. Boneless ham and summer sausage were stored pre-sliced at 4°C until serving to each panelist.

Thirteen trained panelists conducted 6 sensory sessions (2 per replication, resulting in 26 sample evaluations) per product for a total of 78 sample points for each treatment. Panelists were provided water and unsalted crackers to cleanse their palates between samples and were given access to reference standards and product specific standards throughout sensory evaluation of each product type. Samples were coded with a random 3-digit number and presented in a randomized monadic order. Responses were recorded on a 0 to 15 scale based on the intensity of the attribute evaluated (0 = no detection, 15 = extreme detection). Responses were collected using paper ballots for the boneless ham and summer sausage samples, and using FIZZ sensory software (FIZZ version 2.47B, Biosystemes, Couternon, France) for the beef jerky and bacon samples. Each sample was evaluated in duplicate during independent sensory sessions.

Results and Discussion

Bacon

Instrumental color measurements. External lean color values for CIE L^*, a^*, and b^* ranged from 34.4 to 39.0, 13.4 to 16.5 and 14.2 to 18.4, respectively (data not shown) and were not affected ($P > 0.05$) by the addition of SS and NFE (Table 3). Internal lean color values for CIE L^* and a^* ranged from 47.4 to 55.5 and 8.6 to 11.7, respectively (data not shown) with no differences ($P > 0.05$) among any treatment; however, b^* values were higher ($P < 0.05$) for all SS and NFE treatments compared to 100FS. This indicates that the use of SS and NFE at any level may result in a more yellowish bacon slice.

External fat color measurements for CIE a^*, and b^* were also affected by the addition of SS and NFE. L^* values were lower ($P < 0.05$) for 50FS/50NFE as compared to 100FS while all other treatments showed no differences ($P > 0.05$). External fat a^* and b^* values were higher ($P < 0.05$) for 50FS/50SS, 25FS/75SS, and 50FS/50NFE compared to 100FS which suggests an increase in the reddish and yellowish appearances existed in some treatments with addition of SS and NFE. Internal CIE L^*, a^*, and b^* fat color values were also observed to be affected by addition

Table 2. Descriptive sensory analysis lexicon attribute list for bacon, beef jerky, boneless ham, and summer sausage containing soy sauce (SS), fermented flavor enhancer (NFE) and no SS/NFE (100FS)

Attribute	Descriptor[1]
Acid[2]	Basic taste sensation elicited by acids.
Bitter[2]	Basic taste sensation elicited by bitter compounds, perceived as unpleasant.
Salt[2]	Basic taste sensation elicited by salt.
Sweet[2]	Basic taste sensation elicited by sugars.
Umami[2]	Basic taste sensation elicited by amino acids and nucleotides. Appetitive tastes, savoriness. Induces salivation and furriness sensation on tongue, throat, roof, and back of mouth.
Meat Specific Attributes	
Beef Cured[4]	Aromatic associated with cooked beef muscle meat. Combination of beefy and brothy/broth-like.
Black Pepper[4,6]	Spicy pungent aromatic characteristic of freshly ground black pepper.
Brothy[5]	Flavor associated with boiled meat, soup stock.
Caramelized[3,5]	Sweet aromatic characteristic of browned sugars.
Color[5]	Color of meat product from light (0) to dark (15).
Coriander[6]	The sweet, citrus/lemony, almost minty and musty aroma characteristic of the spice coriander.
Garlic[6]	Aromatic associated with garlic.
Hammy[5]	Flavor characteristic of ham, roasted ham.
Mustard[6]	Aromatic and heat associated with mustard.
Phosphate[3,5]	Aromatic taste of bitter, metallic, chemical associated with processed meats.
Pork Cured[3]	Aromatic associated with cured lean pork, lean smoked cured pork.
Pork Fatty[3]	The flavor of fatty pork (coating of inside of mouth).
Smoked[3,4,5]	Perception of any type of smoke flavor, may be phenol like.
Soy Sauce[2]	Aromatic note peculiar of soy sauce.
Texture Attributes	
Breakdown Mass[5]	Chew sample fifteen times, evaluate smoothness or roughness of particulates in mouth.
Chewiness[3,4,5]	Number of chews to prepare for swallowing/expectoration.
Cohesiveness[2]	Chew sample seven times, bring particles to center of mouth and observe how much the product stuck together or broke apart.
Crispiness[3]	The degree of sound made by chewing a sample.
First Chew Hardness[4,5,6]	Using incisors measure the amount of energy required to bite through a cube of product.
Hand Firmness[5,6]	Strength required to compress a cube 30%.
Tear[5]	The amount of energy needed to tear a 7.62 cm diameter x 3.2 mm slice of ham.
Chemical Feeling Factors	
Astringent[2]	Puckering, drying associated with tannins or alum.
Burn[2]	High concentration of irritants of the mucous membranes of the mouth.
Metallic[2]	Flat chemical feeling factor stimulated on the tongue.

[1]Descriptors adapted from Civille and Lyon, 1996.

[2]Attribute used in descriptive sensory of all products (bacon, beef jerky, boneless ham, summer sausage).

[3]Attribute used only in descriptive sensory analysis of bacon.

[4]Attribute used only in descriptive sensory analysis of beef jerky.

[5]Attribute used only in descriptive sensory analysis of boneless ham.

[6]Attribute used only in descriptive sensory analysis of summer sausage.

of SS and NFE. Internal fat L^* was lower ($P < 0.05$) in treatments 75FS/25SS, 50FS/50SS, 25FS/75SS, 50FS/50NFE, and 25FS/75NFE compared to 100FS which suggests adding SS and NFE can darken the color of the fat. Internal a^* fat values were higher ($P < 0.05$) in 75FS/25NFE compared to 100FS indicating an increase in reddish appearance of the fat. Internal fat b^* values revealed increases ($P < 0.05$) for all SS and NFE treatments compared to 100FS indicating that addition of SS and NFE will increase the yellowish appearance of internal fat color. Overall, the use of SS and NFE, regardless of addition level, was found to affect the external fat color and the internal fat and lean colors of bacon; however, addition of smoke during thermal processing could be used to negate the external color impact observed.

ph measurements. The pH level of 75FS/25NFE was reported higher ($P < 0.05$) than all other treatments (Table 3). This was not expected as SS and NFE have a pH of 4.6 and 5.3, respectively and this differ-

Table 3. Least squares means for instrumental external and internal color, pH, and texture analysis for bacon containing soy sauce (SS), fermented flavor enhancer (NFE) and no SS/NFE (100FS)

	Internal lean[2]	External fat[2]			Internal fat[2]						
Treatments[1]	b*	L*	a*	b*	L*	a*	b*	pH[3]	Lean peak force, N[4]	Lean total energy, N × s[5]	Fat total energy, N × s[5]
100FS	6.3[c]	69.8[a]	7.3[d]	28.6[b]	82.7[a]	4.6[b]	8.6[b]	6.12[b]	2.9[abc]	5.8[b]	4.1[ab]
75FS/25SS	13.3[ab]	65.6[ab]	10.4[bcd]	31.9[ab]	74.7[vb]	5.9[ab]	18.3[a]	6.31[b]	2.3[c]	5.1[b]	3.5[ab]
50FS/50SS	13.8[ab]	63.9[ab]	11.2[abc]	33.4[a]	75.9[b]	7.0[ab]	16.4[a]	6.24[b]	3.7[a]	8.3[a]	4.5[a]
25FS/75SS	15.4[a]	63.9[ab]	13.3[ab]	34.5[a]	74.9[b]	5.6[ab]	17.7[a]	6.17[b]	3.0[abc]	5.9[b]	2.6[b]
75FS/25NFE	10.9[b]	67.5[ab]	8.7[cd]	29.9[ab]	77.9[ab]	7.4[a]	14.0[a]	6.54[a]	3.2[ab]	6.6[ab]	3.8[ab]
50FS/50NFE	11.8[ab]	63.2[b]	14.4[a]	33.8[a]	77.4[b]	5.9[ab]	17.3[a]	6.22[b]	3.2[ab]	6.5[ab]	4.6[a]
25FS/75NFE	12.4[ab]	65.3[ab]	10.1[bcd]	31.2[ab]	73.9[b]	4.9[ab]	16.4[a]	6.30[b]	2.8[bc]	5.5[b]	3.3[ab]
SEM[6]	0.53	0.62	0.47	0.48	0.59	0.26	0.62	0.03	0.09	0.22	0.16

[a–d]Means within same column with different superscripts are different ($P < 0.05$).

[1]Treatments: 100FS = 100% NaCl from flake salt; 75FS/25SS = 75% NaCl from flake salt and 25% NaCl from SS; 50FS/50SS = 50% NaCl from flake salt and 50% NaCl from SS; 25FS/75SS = 25% NaCl from flake salt and 75% NaCl from SS; 75FS/25NFE = 75% NaCl from flake salt and 25% NaCl from NFE; 50FS/50NFE = 50% NaCl from flake salt and 50% NaCl from NFE; 25FS/75NFE = 25% NaCl from flake salt and 75% NaCl from NFE.

[2]Commission Internationale de l'Eclairage (CIE) *L*a*b**, where *L** = lightness or darkness on a 0 (black) to 100 (white) scale, *a** = redness (positive value) or greenness (negative value), or *b** = yellowness (positive value) or blueness (negative value).

[3]pH of bacon after thermal processing.

[4]Peak force = Maximum force during puncture of sample measured from.

[5]Total energy = Total energy during puncture of lean or fat sides of bacon slab section sample (area under the curve).

[6]SEM = Standard error of the means.

ence is likely explained by inherent pH variation of the raw bellies used for the study.

Purge and cook yield measurements. No differences ($P > 0.05$) were found between any treatments for purge loss, with values ranging from 0.78 to 0.80% (data not shown). Cook yield measurements ranged from 84.9 to 87.2% (data not shown), and no differences ($P > 0.05$) were observed between the treatments. Since ingoing NaCl remained constant between treatments, it was not expected to see changes in cook yield and purge level.

Salt level measurements. Salt concentration ranged from 1.96 to 2.03% (data not shown) revealing no significant changes ($P > 0.05$) among all treatments and was expected since all treatments for each product type contained the same concentration of salt.

Instrumental texture measurements. Both TPA and puncture measurements were conducted for bacon. The TPA testing identified no differences among any treatments ($P > 0.05$) for hardness, cohesiveness, springiness, and chewiness with least squares means ranging from 55 to 59, 42 to 53, 5.7 to 6.2 and 143 to 180, respectively (data not shown). Based on the results from TPA, no effects in texture properties were observed when adding SS and NFE at any inclusion level to bacon.

Puncture analysis (Table 3) conducted on the exterior lean and fat sides of the bacon slab sections showed no differences ($P > 0.05$) for lean peak force between any treatments but some differences ($P < 0.05$) were observed in lean total energy required to puncture the bacon in the 100FS,75FS/25SS, 25SS/75SS, and 25FS/75NFE compared to 50FS/50SS. The differences reported could be attributed to thickness of lean (from normal compositional variation from belly to belly) present in the sampling location. No differences ($P > 0.05$) were found for the peak force for fat, values ranging between 1.6 and 2.4 (data not shown), for any treatments; whereas, 25FS/75SS was numerically lower ($P > 0.05$) for fat total energy than all other treatments while being lower ($P < 0.05$) than 50FS/50SS and 50FS/50NFE treatments. These results show that adding SS and NFE to replace NaCl from flake salt does not contribute to an effect on textural properties of bacon.

Descriptive sensory analysis. Basic flavors including acid, bitter, salt, sweet, and umami showed mixed results with treatment inclusion of SS and NFE. Perceived saltiness increased ($P < 0.05$) in 50FS/50SS and 50FS/50NFE as compared to 100FS while no differences ($P > 0.05$) existed between any other treatments, although all were numerically higher than the 100FS (Table 4). These results are consistent with those found by Kremer et al. (2009) as they discovered the inclusion of SS in salad dressings, tomato soup, and stir-fried pork could lead to an increase in perceived salty taste. McGough et al. (2012a, 2012b) reported similar findings where an increased saltiness perception existed with inclusion of SS and NFE in frankfurters. Further, our study showed umami flavor increased ($P < 0.05$) in 50FS/50NFE while all other SS and NFE treatments were numerically

Table 4. Least squares means for descriptive sensory analysis[1] for bacon containing soy sauce (SS), fermented flavor enhancer (NFE) and no SS/NFE (100FS)

	Treatments[3]							
Attributes[2]	100FS	75FS/25SS	50FS/50SS	25FS/75SS	75SS/25NFE	50FS/50NFE	25FS/75NFE	SEM[4]
Basic Flavors								
Acid	0.5	0.5	0.5	0.7	0.5	0.4	0.5	0.04
Bitter	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.02
Salt	8.0[b]	8.9[ab]	9.0[a]	8.4[ab]	8.7[ab]	8.9[a]	8.4[ab]	0.11
Sweet	0.8	0.9	0.9	1.0	0.8	0.8	0.8	0.04
Umami	6.7[b]	7.1[ab]	7.3[ab]	7.0[ab]	7.0[ab]	7.4[a]	6.9[ab]	0.10
Bacon Specific Attributes								
Caramelized	0.9	1.1	1.4	1.3	1.2	1.1	1.3	0.09
Phosphate	1.2	1.2	1.5	1.0	1.3	1.1	1.3	0.06
Pork Cured	6.1[a]	5.4[b]	5.5[ab]	5.4[ab]	5.8[ab]	5.7[ab]	5.5[ab]	0.11
Pork Fatty	5.4[a]	4.9[ab]	4.0[c]	4.4[bc]	4.7[abc]	4.3[bc]	4.0[c]	0.10
Smoked	2.2	2.3	2.2	2.2	2.2	2.3	2.0	0.08
Soy Sauce	0.1[d]	0.7[bcd]	1.4[a]	1.5[a]	0.5[cd]	1.0[abc]	1.2[ab]	0.07
Texture Attributes								
Cohesiveness	6.0	6.0	5.6	5.8	5.6	5.6	5.7	0.15
Chewiness	5.1[ab]	5.0[ab]	5.0[ab]	5.0[ab]	4.9[ab]	5.2[a]	4.5[b]	0.09
Crispiness	4.1	4.9	5.1	5.0	4.9	4.7	5.1	0.14
Chemical Feeling Factors								
Astringent	2.0	2.2	2.5	2.2	2.4	2.3	2.2	0.10
Burn	0.5[b]	0.9[ab]	1.3[a]	0.9[b]	0.8[b]	0.8[b]	0.8[b]	0.06
Metallic	0.9	1.0	1.0	1.1	1.0	0.9	1.00	0.06

[a–d]Means within the same row with different superscripts are significantly different (P < 0.05).1Descriptive sensory analysis ranked using FIZZ sensory software with responses recorded on a 0–15 scale based on the intensity of the attribute evaluated (0 = no detection, 15 = extreme detection).

[2]Attributes as defined in Table 2.

[3]Treatments: 100FS = 100% NaCl from flake salt; 75FS/25SS = 75% NaCl from flake salt and 25% NaCl from SS; 50FS/50SS = 50% NaCl from flake salt and 50% NaCl from SS; 25FS/75SS = 25% NaCl from flake salt and 75% NaCl from SS; 75FS/25NFE = 75% NaCl from flake salt and 25% NaCl from NFE; 50FS/50NFE = 50% NaCl from flake salt and 50% NaCl from NFE; 25FS/75NFE = 25% NaCl from flake salt and 75% NaCl from NFE.

[4]SEM = standard error of the means.

higher than 100FS. The higher umami and salty sensory responses reported for SS and NFE containing treatments (both SS and NFE are known to contribute umami containing substances) are supported by the idea that umami substances have the ability to increase perceived saltiness (Fuke and Ueda, 1996; Keast and Breslin, 2002; McGough et al., 2012a, 2012b). Panel responses for acid, bitter, and sweet flavor attributes showed no differences ($P > 0.05$) between any treatments.

Specific bacon attribute sensory responses identified that adding SS and NFE had an effect on some flavors but no effect on others. Pork fatty flavor was numerically lower for all SS and NFE treatments when compared to 100FS and lower ($P < 0.05$) in treatments 50FS/50SS, 25FS/75SS, 50FS/50NFE, and 25FS/75NFE suggesting that higher inclusion levels of SS and NFE offer a masking effect of the characteristic fatty flavor of bacon. Soy sauce flavor increased ($P < 0.05$) in treatments 50FS/50SS, 25FS/75SS, 50FS/50NFE, and 25FS/75NFE compared with the 100FS treatment, with soy sauce ratings increasing as levels of SS or NFE increased. Pork cured flavor was found lower ($P < 0.05$) for 75FS/25SS when compared to 100FS but not different for any other treatment. Finally, caramelized, phosphate, and smoked attributes presented no change ($P > 0.05$) with addition of SS and NFE at any level.

Texture attributes of bacon through sensory analysis offered no differences ($P > 0.05$) in cohesiveness and crispiness (Table 4). Chemical feeling factor attributes had some effects with added SS and NFE; whereas specifically, burn perception revealed a higher ($P < 0.05$) score for 50FS/50SS compared to 100FS. Finally, no differences were observed ($P > 0.05$) for astringent and metallic attributes between all treatments.

Beef jerky

Instrumental color measurements. Addition of either SS or NFE resulted in no changes ($P > 0.05$) for external L^* values which ranged from 25.5 to

28.1 (data not shown) among the treatments (Table 5). However, all treatments had lower external *a** values than the 100FS while 75FS/25SS, 50FS/50SS, 25FS/75SS, 75FS/25NFE, and 50FS/50NFE treatments were lower ($P < 0.05$), suggesting a decrease in reddish external appearance resulted due to SS and NFE inclusion. Lower External *b** values were also observed ($P < 0.05$) for 75FS/25SS, 50FS/50SS, and 25FS/75SS treatments compared to 100FS indicating a decrease in yellow appearance had occurred.

Results for the internal color values for CIE *L**, *a**, and *b** showed both SS and NFE had an effect on the internal color of beef jerky. Internal *L** values were higher ($P < 0.05$) for 50FS/50SS, 75FS/25NFE, 50FS/50NFE, and 25FS/75NFE treatments than 100FS, while a decrease ($P < 0.05$) in *L** values from the 100FS treatment was observed in 75FS/25SS and 25FS/75SS. Differences among the treatments *L** suggest that addition of SS has a darkening impact while addition of NFE has a lightening effect as compared to the 100FS treatment. Internal *a** values were lower ($P < 0.05$) for all SS and NFE containing treatments compared to 100FS. Internal *b** color values, for some treatments (50FS/50NFE and 75FS/25NFE), were higher ($P < 0.05$) yet lower ($P < 0.05$) for other treatments (75FS/25SS, 25FS/75SS, 50SS/50NFE, and 25FS/75NFE) than the 100FS with little known reason other than a possible relationship to *L** changes. These results suggest that SS and NFE can have an effect on external and internal color of beef jerky, however, just as with bacon, the addition of smoke during thermal processing may offer a negating color impact by masking or minimizing color effects on exterior of the beef jerky. The impact on internal color differences is not well understood and likely has little to no practical implication.

ph measurements. The pH levels were lower ($P < 0.05$) than 100FS for all SS containing treatments and not different ($P > 0.05$) from all NFE containing treatments (Table 5). The decrease in pH for SS containing treatments was expected as the pH of SS was 4.59 and would lower the overall meat system pH; however, a decrease of pH was not expected in treatments containing NFE since the pH of NFE was 5.26 and the magnitude of difference between the meat and NFE pH was less than that of SS.

Water activity and cook yield measurements. No significant differences ($P > 0.05$) were found between any treatments for both water activity and cook yield. Water activity ranged from 0.82 to 0.84 (data not shown) confirming shelf stable and commercially typical treatments were produced. Cook yields ranged from 53.2 to 56.0% (data not shown). The low cook yields were expected since jerky is a dry product and no differ-

Table 5. Least squares means for instrumental external and internal color, texture profile analysis, pH, and salt % for beef jerky containing soy sauce (SS), fermented flavor enhancer (NFE) and no SS/NFE (100FS)

	Color analysis[2]					Texture profile analysis				
	External		Internal							
Treatments[1]	a*	b*	L*	a*	b*	Hardness, N[3]	Chewiness, N × mm[4]	Gumminess, N[5]	pH[6]	Salt, %[7]
100FS	10.3[a]	7.0[ab]	25.8[d]	10.50[a]	48.4[b]	60.9[b]	49.2[ab]	48.4[b]	5.49[a]	7.36[a]
75FS/25SS	7.2[bc]	5.6[bcd]	23.6[e]	8.38[d]	28.9[c]	36.8[c]	29.5[b]	28.9[c]	5.38[bc]	7.26[ab]
50FS/50SS	5.4[c]	5.1[d]	26.5[c]	6.78[e]	55.7[a]	71.7[ab]	82.9[a]	55.7[ab]	5.33[c]	7.11[ab]
25FS/75SS	5.5[c]	5.3[cd]	22.3[f]	6.44[f]	26.6[c]	33.1[c]	27.6[b]	26.6[c]	5.32[c]	6.56[abc]
75FS/25NFE	8.3[b]	6.5[abcd]	28.2[a]	9.12[c]	61.9[a]	78.3[a]	65.4[ab]	61.9[a]	5.47[a]	6.22[c]
50FS/50NFE	8.1[b]	6.7[abc]	28.4[a]	9.32[b]	32.3[c]	40.5[c]	33.9[b]	32.3[c]	5.47[a]	6.27[c]
25FS/75NFE	8.4[ab]	7.3[a]	27.5[b]	9.43[b]	28.4[c]	34.1[c]	29.2[b]	28.4[c]	5.43[ab]	6.47[bc]
SEM[8]	0.29	0.18	0.34	0.21	1.65	2.08	4.04	1.65	0.01	0.10

[a–f]Means within the same column with different superscripts are different ($P < 0.05$).

[1]Treatments: 100FS = 100% NaCl from flake salt; 75FS/25SS = 75% NaCl from flake salt and 25% NaCl from SS; 50FS/50SS = 50% NaCl from flake salt and 50% NaCl from SS; 25FS/75SS = 25% NaCl from flake salt and 75% NaCl from SS; 75FS/25NFE = 75% NaCl from flake salt and 25% NaCl from NFE; 50FS/50NFE = 50% NaCl from flake salt and 50% NaCl from NFE; 25FS/75NFE = 25% NaCl from flake salt and 75% NaCl from NFE.

[2]Commission Internationale de l'Eclairage (CIE) *L*a*b**, where *L** = lightness or darkness on a 0 (black) to 100 (white) scale, *a** = redness (positive value) or greenness (negative value), or *b** = yellowness (positive value) or blueness (negative value).

[3]Hardness = The peak force during the first compression.

[4]Chewiness = The product of (hardness × cohesiveness × springiness).

[5]Gumminess = Calculated as (cohesiveness/hardness).

[6]pH of beef jerky after thermal processing.

[7]Percentage of salt in beef jerky.

[8]SEM = Standard error of the means.

ences ($P > 0.05$) suggests little variation existed among the treatments as a result of cooking and drying.

Salt level measurements. Salt values were lower ($P < 0.05$) in 75FS/25NFE, 50FS/50NFE, and 25FS/75NFE compared to 100FS (Table 5). Reasons for salt level variation in the NFE containing treatments could be due to sampling variations and the salt level measurement method utilized. Due to the higher salt content associated with jerky and the potential for non-uniform salt distribution, areas of slightly higher and lower salt concentration within a jerky strip could impact salt measurements. Further, the salt concentrations measured were reaching the upper level of detection for the method used thus unforeseen sampling error may also have been experimentally induced.

Instrumental texture measurements. TPA results reported no differences ($P > 0.05$) for cohesiveness and springiness with ranges of 77.1 to 84.0 and 1.02 to 1.40, respectively (data not shown; Table 5). However, 75FS/25SS, 25FS/75SS, 50FS/50NFE, and 25FS/75NFE treatments had lower ($P < 0.05$) hardness scores than the 100FS which could be attributed to a tenderizing effect from SS and NFE meat as illustrated from work by Kim et al. (2013) whereas SS was added in a marination of *biceps femoris* and resulted in lower shear force. No treatments were observed ($P > 0.05$) different for chewiness when compared to 100FS but some differences ($P < 0.05$) did exist among SS and NFE containing treatments. Gumminess values provided similar results as hardness, with lower ($P < 0.05$) values for 75FS/25SS, 25FS/75SS, 50FS/50NFE, and 25FS/75NFE and a higher ($P < 0.05$) value for 75FS/25NFE compared to the 100FS treatment value. Overall, these results show that the texture can be affected by the addition of SS and NFE; however, it is unclear if this is due to the drying process itself, a possible tenderizing effect of SS or NFE, or even normally existing piece to piece variation found in beef jerky.

Descriptive sensory analysis. For basic flavors, perceived saltiness increased ($P < 0.05$) in 75FS/25SS compared to 100FS whereas all other treatments were not different ($P > 0.05$; Table 6). The lack of change in saltiness perception was not expected and could be a result of the relatively high salt content found in beef jerky and a diminishing effect created as a threshold of salt detection and saltiness perception may have been approached. Observed increases in saltiness perception shown by previous research studies (McGough et al., 2012a, 2012b; Kremer et al., 2009) were based on meat products with lower salt concentrations. As a result, the salt enhancing effect of SS and NFE may not have been amplified in meat products with relatively high salt contents. Umami perception also reported increases ($P < 0.05$) in 75FS/25SS, 25FS/75SS, 75FS/25NFE, and 25FS/75NFE compared to100FS. Acid, bitter, and sweet flavor attributes showed no significant changes ($P > 0.05$) between all treatments.

Beef jerky specific attributes presented mixed effects from the inclusion of SS and NFE. Compared to 100FS, beef cured flavor increased ($P < 0.05$) for 50FS/50SS but was lower ($P > 0.05$) for any other treatment. These results demonstrated that despite high levels of SS and NFE, neither ingredient had an effect on the cured beef flavor. Black pepper did not change ($P > 0.05$) among any treatment providing similar results to beef cured suggesting SS and NFE do not have a masking effect for black pepper flavor. Smoked flavor responses were lower ($P < 0.05$) in 50FS/50NFE and 25FS/75NFE than 100FS. The decrease in smoke flavor could be attributed to the addition of high levels of SS and NFE where flavor masking of the smoke flavor may have existed. Compared to 100FS, soy sauce flavor increased ($P < 0.05$) in all SS and NFE containing treatments except 75FS/25NFE (which had the lowest level of NFE) and may be explained by the lower flavor contribution impact from NFE.

Texture attributes for beef jerky identified differences in all attributes investigated. Cohesiveness was lower ($P < 0.05$) for 25FS/75SS compared to 100FS, and a decrease in both chewiness and hardness ($P < 0.05$) was also observed for 75FS/25SS, 25FS/75SS, 75FS/25NFE, 50FS/50NFE, and 25FS/75NFE treatments. In addition to treatment effects, textural differences noted in our experiments could also be partially explained by uneven drying during jerky manufacturing. Chemical feeling factors attributes were higher ($P < 0.05$) in astringency for 75FS/25SS, 50FS/50SS, 25FS/75SS, 75FS/25NFE, and 25FS/75NFE compared to 100FS. This could be attributed to relatively higher salt levels found in jerky and the panelist response to the relatively high salt content. A higher score for burn ($P < 0.05$) existed for 75FS/25SS and 25FS/75NFE compared to 100FS.

Boneless ham

Instrumental color measurements. Compared to the 100FS, external L^* values were lower ($P < 0.05$) for 50FS/50SS, 25FS/75SS, and 25FS/75NFEtreatments while no differences existed ($P > 0.05$) for 75FS/25SS, 75FS/25NFE, and 50SS/50NFE treatments (Table 7). These results suggest that low levels of SS and NFE, present in 75FS/25SS, 75FS/25NFE, and 50FS/50NFE treatments, may not provide a darkening effect for boneless ham. Further, external a^* values were lower ($P < 0.05$) for redness for 50FS/50SS, 25FS/75SS,

Table 6. Least squares means for descriptive sensory analysis[1] for beef jerky containing soy sauce (SS), fermented flavor enhancer (NFE) and no SS/NFE (100FS)

Attributes[2]	Treatments[3]							SEM[4]
	100FS	75FS/25SS	50FS/50SS	25FS/75SS	75SS/25NFE	50FS/50NFE	25FS/75NFE	
Basic Flavors								
Acid	1.1	1.1	1.1	1.1	1.1	1.1	1.2	0.06
Bitter	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.08
Salt	8.6[b]	9.4[a]	8.5[b]	8.7[b]	8.8[b]	8.7[b]	8.9[ab]	0.14
Sweet	1.2[b]	1.1[b]	1.1[b]	1.1[b]	1.0[b]	1.1[b]	1.0[b]	0.11
Umami	5.7[gc]	6.6[a]	6.0[bc]	6.2[ab]	6.2[ab]	6.0[bc]	6.5[a]	0.11
Beef Jerky Specific Attributes								
Beef Cured	4.6[b]	4.6[b]	4.7[a]	4.4[b]	4.2[b]	4.4[b]	4.4[b]	0.09
Black Pepper	3.2	3.3	3.4	3.4	3.3	3.4	3.1	0.09
Smoked	4.3[a]	4.1[a]	4.2[a]	4.1[a]	4.1[ab]	3.8[b]	3.8[b]	0.11
Soy Sauce	0.7[c]	1.2[b]	1.4[b]	1.4[ab]	1.0[bc]	1.2[b]	1.9[e]	0.10
Texture Attributes								
Cohesiveness	4.2[ab]	5.4[a]	3.1[bc]	2.7[c]	3.7[bc]	3.6[bc]	3.5[ab]	0.17
Chewiness	10.3[a]	6.9[c]	9.6[ab]	8.6[b]	8.8[b]	8.8[b]	8.4[b]	0.16
Hardness	12.1[a]	9.2[d]	11.5[ab]	10.6[bc]	10.2[cd]	10.7[bc]	10.3[c]	0.13
Chemical Feeling Factors								
Astringent	1.7[b]	2.0[a]	1.8[a]	2.0[a]	1.8[a]	1.7[b]	1.8[a]	0.07
Burn	3.3[c]	4.2[a]	3.7[bc]	3.7[bc]	3.7[bc]	3.6[bc]	3.9[b]	0.09
Metallic	3.2	3.6	3.3	3.5	3.5	3.5	3.4	0.11

[a–d]Means within the same row with different superscripts are significantly different ($P < 0.05$).1Descriptive sensory analysis ranked using FIZZ software with responses recorded on a 0–15 scale based on the intensity of the attribute evaluated (0 = no detection, 15 = extreme detection).

[2]Attributes as defined in Table 2.

[3]Treatments: 100FS = 100% NaCl from flake salt; 75FS/25SS = 75% NaCl from flake salt and 25% NaCl from SS; 50FS/50SS = 50% NaCl from flake salt and 50% NaCl from SS; 25FS/75SS = 25% NaCl from flake salt and 75% NaCl from SS; 75FS/25NFE = 75% NaCl from flake salt and 25% NaCl from NFE; 50FS/50NFE = 50% NaCl from flake salt and 50% NaCl from NFE; 25FS/75NFE = 25% NaCl from flake salt and 75% NaCl from NFE.

[4]SEM = standard error of the means.

50FS/50NFE, and 25FS/75NFE compared to 100FS. External b^* values were higher ($P < 0.05$) for yellowness in all SS and NFE containing treatments compared to 100FS. The results of the external objective color analysis suggested SS and NFE had a notable impact on the external color of boneless ham. However, in this study, the boneless ham treatments did not receive an external smoke application during the thermal process which, for other product types, was suggested to provide a color negating effect.

Internal CIE L^*, a^*, and b^* color values showed that SS and NFE also affected the internal appearance of boneless ham (Table 7). Internal L^* values were lower ($P < 0.05$) for 25FS/75SS and 25FS/75NFE compared to 100FS. These treatments contained the highest concentrations of SS and NFE inclusion which likely explain the observed darkening effect. Internal a^* levels revealed the 25FS/75SS treatment was less red ($P < 0.05$) compared to 100FS while no other differences ($P > 0.05$) were observed for any other treatments. Internal b^* color scores followed a similar trend as the external b^* levels whereas increases ($P <$ 0.05) in yellowness, compared to 100FS, were noted for all SS and NFE treatments and as levels increased.

ph measurements. Only the pH for 25FS/75NFE was lower ($P < 0.05$) than the 100FS treatment (Table 7). The use of phosphates in the manufacture of boneless ham for raising the meat system pH and provide buffering ability likely mitigated any SS (pH = 4.59) or NFE (pH = 5.26) induced pH changes in all other treatments. The lower pH found in 25FS/75NFE treatment can likely be attributed to the high addition level of NFE likely exceeded the buffering ability of the added phosphates.

Purge and cook yield measurements. No significant differences ($P > 0.05$) were observed between any treatments for purge loss (14 d) or cook yield measurements. Purge loss ranged between 2.82 and 3.40% (data not shown) while cook yields ranged between 96.0 and 95.2% (data not shown). These results confirm NaCl from SS and NFE can provide equivalent function regarding moisture control in boneless ham.

Salt level measurements. The salt concentration for 25FS/75NFE was higher ($P < 0.05$) than all other treatments (Table 7) and although not expected, this could be

Table 7. Least squares means for instrumental external and internal color, texture profile analysis, pH, and salt % for boneless ham containing soy sauce (SS), fermented flavor enhancer (NFE) and no SS/NFE (100FS)

	Color analysis[2]						Texture profile analysis			
	External			Internal						
Treatments[1]	L*	a*	b*	L*	a*	b*	Hardness, N[3]	Chewiness, N × mm[4]	pH[5]	Salt, %[6]
100FS	70.0^{a}	8.3^{a}	5.1^{e}	66.9^{ab}	9.3^{a}	4.8^{e}	54.6^{a}	155.7^{ab}	6.34^{a}	2.56^{b}
75FS/25SS	69.7^{ab}	7.7^{ab}	9.1^{c}	68.6^{a}	8.1^{ab}	8.9^{c}	52.9^{ab}	177.5^{ab}	6.28^{ab}	2.60^{b}
50FS/50SS	67.3^{cd}	7.5^{bc}	11.6^{b}	67.2^{ab}	8.3^{ab}	11.2^{ab}	39.9^{cd}	126.8^{abc}	6.30^{ab}	2.44^{b}
25FS/75SS	66.1^{d}	7.3^{bc}	13.7^{a}	64.7^{c}	8.5^{b}	12.6^{a}	46.8^{abc}	150.8^{ab}	6.30^{ab}	2.40^{b}
75FS/25NFE	69.3^{ab}	7.6^{abc}	7.2^{d}	67.7^{ab}	8.5^{ab}	6.7^{d}	41.3^{bcd}	116.6^{bc}	6.26^{ab}	2.63^{b}
50FS/50NFE	69.1^{ab}	7.5^{bc}	9.5^{c}	67.9^{ab}	8.5^{ab}	8.9^{c}	34.8^{d}	108.9^{bc}	6.28^{ab}	2.43^{b}
25FS/75NFE	68.3^{bc}	6.9^{c}	11.5^{b}	65.7^{c}	8.5^{ab}	10.1^{bc}	35.5^{cd}	85.9^{c}	6.23^{c}	2.99^{a}
SEM[7]	0.22	0.08	0.31	0.26	0.12	0.31	1.38	6.17	0.01	0.10

[a–e]Means within the same column with different superscripts are different ($P < 0.05$).

[1]Treatments: 100FS = 100% NaCl from flake salt; 75FS/25SS = 75% NaCl from flake salt and 25% NaCl from SS; 50FS/50SS = 50% NaCl from flake salt and 50% NaCl from SS; 25FS/75SS = 25% NaCl from flake salt and 75% NaCl from SS; 75FS/25NFE = 75% NaCl from flake salt and 25% NaCl from NFE; 50FS/50NFE = 50% NaCl from flake salt and 50% NaCl from NFE; 25FS/75NFE = 25% NaCl from flake salt and 75% NaCl from NFE.

[2]Commission Internationale de l'Eclairage (CIE) $L^*a^*b^*$, where L^* = lightness or darkness on a 0 (black) to 100 (white) scale, a^* = redness (positive value) or greenness (negative value), or b^* = yellowness (positive value) or blueness (negative value).

[3]Hardness = The peak force during the first compression.

[4]Chewiness = The product of (hardness × cohesiveness × springiness).

[5]pH of boneless ham after thermal processing.

[6]Percentage of salt in boneless ham.

[7]SEM = Standard error of the means.

explained by selection of samples containing a higher salt concentration or induced error in the testing method.

Instrumental texture measurements. The TPA results reported lower ($P < 0.05$) hardness values for 50FS/50SS, 75FS/25NFE, 50FS/50NFE, and 25FS/75NFE treatments compared to the 100FS treatment (Table 7). Although differences weren't expected, the variations in hardness could be attributed to the muscle orientation in the sample cores. Due to the chunked and formed boneless ham manufacturing process, random orientation of meat pieces can be expected impacting cores used for texture measurements. Cohesiveness and springiness (data not shown) values were not different ($P > 0.05$) among any treatments with ranges of 44.2 to 54.0% and 5.5 to 6.3 mm, respectively. Chewiness values were lower ($P < 0.05$) for 75FS/25NFE, 50FS/50NFE, and 25FS/75NFE compared to 100FS. These results show that adding SS and NFE does not contribute to changes in cohesiveness and springiness, however may have an effect on hardness and chewiness.

Descriptive sensory analysis. Basic flavors showed mixed results for inclusion of SS and NFE. Compared to the 100FS treatment, sweetness scores were lower ($P < 0.05$) for 50FS/50NFE and 25FS/75NFE and may be attributed to the lower flavor profile of NFE (Table 8). Umami scores were lower ($P < 0.05$) for 75FS/25SS compared to 100FS. Further, acid and bitter showed no significant changes ($P > 0.05$) between any treatments. For all other meat products types investigated in this study, saltiness increased with addition and increasing concentrations of SS and NFE. The lack of significance, may suggest, for this product type, saltiness perception is not a primary sensory response or was confounded with another attribute.

Boneless ham specific attributes had varying sensory responses when including SS and NFE. Hammy flavor was lower ($P < 0.05$) in 25FS/75SS (higher SS level) than 100FS (no inclusion of SS). Soy sauce flavor was higher ($P < 0.05$) for 50FS/50SS, 25FS/75SS, and 25FS/75NFE than the 100FS treatment which was expected considering the impact SS and NFE would have in a product having a more delicate flavor profile such as ham. Further, compared to 100FS, phosphate perception increased ($P < 0.05$) for 50FS/50SS, 75FS/25NFE, 50FS/50NFE, and 25FS/75NFE treatments. Color assessed by panelists was darker ($P < 0.05$) for 50FS/50SS, 25FS/75SS, 50FS/50NFE, and 25FS/75NFE than the 100FS treatment. This was expected as SS and NFE are both dark liquids which when added at medium and high levels of inclusion could physically alter the color of a product. Both brothy and caramelized attributes did not reveal any differences ($P > 0.05$) between any treatments.

Texture attributes including breakdown mass, chewiness, cohesiveness, firmness, first chew hard-

Table 8. Least squares means for descriptive sensory analysis[1] for boneless ham containing soy sauce (SS), fermented flavor enhancer (NFE) and no SS/NFE (100FS)

	Treatments[3]							
Attributes[2]	100FS	75FS/25SS	50FS/50SS	25FS/75SS	75SS/25NFE	50FS/50NFE	25FS/75NFE	SEM[4]
Acid	1.6	1.7	2.1	1.5	1.7	1.8	1.6	0.12
Bitter	0.3	0.2	0.3	0.3	0.3	0.2	0.4	0.05
Salt	5.5	5.5	5.6	5.9	5.7	5.7	5.8	0.18
Sweet	2.0^{a}	1.5^{ab}	1.7^{a}	1.9^{a}	1.9^{a}	1.4^{c}	1.5^{bc}	0.11
Umami	4.6^{a}	3.2^{b}	4.2^{a}	4.1^{a}	4.5^{a}	34.0^{a}	3.8^{a}	0.18
Boneless Ham Specific Attributes								
Brothy	2.6	2.6	2.8	3.2	2.6	2.6	3.3	0.17
Caramelized	2.4^{a}	2.1^{a}	2.2^{a}	2.3^{a}	2.1^{ab}	1.6^{b}	1.8^{ab}	0.14
Color	9.2^{b}	9.9^{b}	10.8^{a}	11.2^{a}	10.2^{b}	11.3^{a}	11.6^{a}	0.18
Hammy	7.1^{ab}	7.7^{a}	6.2^{bc}	5.8^{c}	7.2^{a}	5.8^{b}	5.3^{b}	0.24
Phosphate	1.0^{b}	1.5^{ab}	1.6^{a}	1.4^{ab}	1.4^{a}	1.4^{a}	1.5^{a}	0.13
Soy Sauce	0.6^{b}	1.0^{b}	2.4^{a}	3.0^{a}	1.9^{b}	2.2^{b}	3.0^{a}	0.17
Texture Attributes								
Breakdown Mass	9.5	9.7	9.7	10.0	10.0	9.9	9.2	0.17
Chewiness	7.3	7.8	7.5	7.7	7.7	7.5	7.8	0.16
Cohesiveness	7.3^{ab}	7.4^{ab}	6.9^{b}	7.9^{a}	7.2^{a}	7.3^{a}	7.1^{a}	0.18
Hand Firmness	9.9^{ab}	10.2^{a}	10.3^{a}	9.3^{b}	10.0^{a}	10.3^{a}	10.3^{a}	0.16
First Chew Hardness	6.3	6.2	6.4	6.1	6.3	6.5	6.4	0.15
Tear	7.3	7.5	7.7	7.3	8.3	8.5	9.0	0.18
Chemical Feeling Factors								
Astringent	1.5	1.7	1.3	1.6	1.4	2.1	1.4	0.13
Burn	0.7	0.7	1.1	1.0	1.1	0.1	1.2	0.12
Metallic	1.2	1.5	1.4	1.5	1.5	1.3	1.5	0.15

[a–c]Means within the same row with different superscripts are significantly different ($P < 0.05$).

[1]Descriptive sensory analysis using paper ballots with responses recorded on a 0–15 scale based on the intensity of the attribute evaluated (0 = no detection, 15 = extreme detection).

[2]Attributes as defined in Table 2.

[3]Treatments: 100FS = 100% NaCl from flake salt; 75FS/25SS = 75% NaCl from flake salt and 25% NaCl from SS; 50FS/50SS = 50% NaCl from flake salt and 50% NaCl from SS; 25FS/75SS = 25% NaCl from flake salt and 75% NaCl from SS; 75FS/25NFE = 75% NaCl from flake salt and 25% NaCl from NFE; 50FS/50NFE = 50% NaCl from flake salt and 50% NaCl from NFE; 25FS/75NFE = 25% NaCl from flake salt and 75% NaCl from NFE.

[4]SEM = standard error of the means.

ness, and tear were also evaluated. All of these attributes showed no significant changes ($P > 0.05$) between the treatments. The results demonstrated there was no effect from SS and NFE on the texture of boneless ham using sensory analysis. Finally, no changes ($P > 0.05$) in the chemical feeling factors of astringent, burn, and metallic existed among treatments.

Summer sausage

Instrumental color measurements. External L^* values were lower ($P < 0.05$) for 25FS/75SS compared to 100FS while no other differences existed amount (Table 9). External a^* values were also lower ($P < 0.05$) for redness for 75FS/25SS, 50FS/50SS, 25FS/75SS, 50FS/50NFE, and 25FS/75NFE compared to 100FS; however, the small numerical difference suggests minimal practical differences. External b^* values were higher ($P < 0.05$) for all treatments compared to 100FS. The results for external color indicate changes in yellowness and redness occurred with any amount of added SS and NFE; however, due to the small numeric differences, the true practical impact of these differences must be considered when interpreting the results.

For internal L^* values, no differences ($P > 0.05$) were observed between any SS and NFE treatments and the 100FS treatment; however, some differences did exist between certain SS and NFE treatments. Internal a^* values were lower ($P < 0.05$) for 50FS/50SS, 25FS/75SS, 50FS/50NFE, and 25FS/75NFE treatments compared to

Table 9. Least squares means for instrumental external and internal color, texture profile analysis, pH, and salt % for summer sausage containing soy sauce (SS), fermented flavor enhancer (NFE) and no SS/NFE (100FS)

	Color analysis[2]					Texture profile analysis					
	External			Internal							
Treatments[1]	L*	a*	b*	L*	a*	Hardness, N[3]	Cohesiveness, m %[4]	Springiness, mm[5]	Chewiness, N × mm[6]	pH[7]	Salt, %[8]
100FS	49.8[a]	15.4[a]	11.6[e]	40.6[ab]	17.4[a]	39.5[a]	48.0[ab]	6.22[a]	118.3[a]	4.52[bc]	2.82[ab]
75FS/25SS	48.7[ab]	14.3[bc]	12.7[d]	40.1[ab]	16.7[ab]	30.4[bc]	43.9[b]	6.12[ab]	81.5[bc]	4.50[c]	3.02[ab]
50FS/50SS	48.0[ab]	13.6[c]	14.1[b]	39.7[b]	15.8[b]	32.1[b]	51.2[a]	5.92[ab]	96.8[b]	4.54[b]	2.93[ab]
25FS/75SS	44.5[b]	14.2[bc]	14.7[a]	38.9[b]	15.9[b]	28.7[bc]	44.5[b]	6.00[ab]	75.9[c]	4.50[c]	2.61[b]
75FS/25NFE	49.1[a]	14.6[ab]	12.4[d]	42.2[a]	16.5[ab]	26.8[bc]	45.5[ab]	6.09[ab]	74.3[c]	4.51[c]	2.27[b]
50FS/50NFE	48.1[ab]	14.1[bc]	13.4[c]	39.4[b]	16.1[b]	25.8[c]	46.1[b]	5.81[b]	69.1[c]	4.59[a]	2.57[b]
25FS/75NFE	46.9[ab]	14.4[bc]	14.2[ab]	40.3[ab]	15.7[b]	25.0[c]	44.3[b]	6.07[ab]	67.3[c]	4.58[a]	2.70[b]
SEM[9]	0.42	0.10	0.12	0.21	0.13	0.80	0.58	0.03	2.85	0.01	0.06

[a–e]Means within the same column with different superscripts are different ($P < 0.05$).

[1]Treatments: 100FS = 100% NaCl from flake salt; 75FS/25SS = 75% NaCl from flake salt and 25% NaCl from SS; 50FS/50SS = 50% NaCl from flake salt and 50% NaCl from SS; 25FS/75SS = 25% NaCl from flake salt and 75% NaCl from SS; 75FS/25NFE = 75% NaCl from flake salt and 25% NaCl from NFE; 50FS/50NFE = 50% NaCl from flake salt and 50% NaCl from NFE; 25FS/75NFE = 25% NaCl from flake salt and 75% NaCl from NFE.

[2]Commission Internationale de l'Eclairage (CIE) $L^*a^*b^*$, where L^* = lightness or darkness on a 0 (black) to 100 (white) scale, a^* = redness (positive value) or greenness (negative value), or b^* = yellowness (positive value) or blueness (negative value).

[3]Hardness = The peak force during the first compression.

[4]Cohesiveness = The ratio of the positive force area during the second compression (50%) to that during the first compression (50%), calculated as [(Area 2/Area 1) × 100].

[5]Springiness = The height the sample recovered during the time that elapses between the end of the first compression and the start of the second compression.

[6]Chewiness = The product of (hardness × cohesiveness × springiness).

[7]pH of summer sausage after thermal processing.

[8]Percentage of salt in summer sausage.

[9]SEM = Standard error of the means.

the 100FS treatment. This suggests addition of SS and NFE at and above 50% inclusion levels can result in a decrease in redness on the slice surface. Internal b^* values ranged from 16.0 to 16.1 (data not shown) with no ($P > 0.05$) differences between any of the treatments.

ph measurements. The pH levels were higher ($P < 0.05$) in 50FS/50NFE and 25FS/75NFE compared to the 100FS treatment, although the practical significance could be questioned since the difference was small (0.07 pH units; Table 9).

Purge and cook yield measurements. No differences ($P > 0.05$) were present between any of the treatments for purge loss (14 d) or cook yields. Purge losses ranged between 2.03 and 2.83% (data not shown) while cook yields ranged between 83.1 and 84.1% (data not shown). These results confirm NaCl from FS or from SS and NFE sources will perform similarly regarding important water-holding properties.

Salt level measurements. Salt values for all treatments reported no differences ($P > 0.05$) when compared to the 100FS treatment (Table 9). This was as expected as each product was formulated to match the 100FS salt concentration.

Instrumental texture measurements. Hardness and chewiness values were lower ($P < 0.05$) for all SS and NFE containing treatments compared to the 100FS treatment (Table 9) while no differences ($P > 0.05$) existed for cohesiveness between SS and NFE treatments and the 100FS treatment. Springiness for 50FS/50NFE was lower ($P < 0.05$) compared to 100FS with no other treatment differences reported.

Descriptive sensory analysis. Basic flavor scores revealed saltiness and umami attributes were affected by the addition of SS and NFE. All SS and NFE containing treatments were saltier ($P < 0.05$) than the 100FS treatment (Table 10). These results are consistent with previous work by Fuke and Ueda (1996) who identified SS as a possible salt enhancing tool. Further, umami flavor scores were higher ($P < 0.05$) in 75FS/25SS, 25FS/75SS, 50FS/50NFE, and 25FS/75NFE treatments compared to the 100FS treatment. With an increase in SS and NFE, the perceived increase in saltiness may be perpetuated by the addition of umami containing substances which may increase perceived saltiness (Fuke and Ueda, 1996; Keast and Breslin, 2002; McGough, 2011). Acid, bitter, and sweet attributes were not different ($P > 0.05$) for any SS or NFE containing treatment compared to the 100FS treatment.

Summer sausage specific attributes disclosed that black pepper levels were lower ($P < 0.05$) in 25FS/75SS,

Table 10. Least squares means for descriptive sensory analysis[1] for summer sausage containing soy sauce (SS), fermented flavor enhancer (NFE) and no SS/NFE (100FS)

	Treatments[3]							
Attributes[2]	100FS	75FS/25SS	50FS/50SS	25FS/75SS	75SS/25NFE	50FS/50NFE	25FS/75NFE	SEM[4]
Acid	4.9	5.2	4.9	5.0	4.9	5.1	5.1	0.12
Bitter	0.0[ab]	0.00[b]	0.0[b]	0.1[a]	0.0[ab]	0.0[ab]	0.1[a]	0.01
Salt	5.2[b]	6.0[a]	6.2[a]	6.4[a]	5.9[a]	6.2[a]	5.9[a]	0.11
Sweet	0.7	0.5	0.5	0.5	0.5	0.6	0.7	0.05
Umami	3.6[c]	4.3[ab]	4.1[ab]	4.7[a]	4.1[ab]	4.5[ab]	4.7[a]	0.11
Summer Sausage Specific Attributes								
Black Pepper	3.7[a]	3.4[ab]	3.4[ab]	3.0[b]	3.5[ab]	3.6[a]	3.5[a]	0.12
Coriander	4.7[a]	3.9[b]	4.3[ab]	4.5[ab]	4.5[a]	4.2[ab]	4.1[ab]	0.13
Garlic	4.5	4.8	4.6	4.4	4.9	4.3	4.7	0.12
Mustard	4.1	4.0	3.8	3.7	3.8	4.0	3.9	0.11
Smoked	4.1[a]	4.2[a]	4.0[a]	3.7[ab]	4.3[a]	3.5[b]	3.6[b]	0.13
Soy Sauce	0.1[c]	1.00[b]	1.3[b]	2.0[a]	0.9[c]	1.9[b]	2.9[a]	0.11
Texture Attributes								
Cohesiveness	6.8	6.9	6.9	6.6	7.1	6.8	7.2	0.12
Hand Firmness	10.2[a]	9.3[b]	10.0[a]	10.0[a]	9.1[b]	9.1[b]	9.5[b]	0.11
First Chew Hardness	5.1	5.0	5.2	5.0	4.8	4.9	4.7	0.06
Chemical Feeling Factors								
Astringent	1.9	1.9	1.8	1.7	1.8	1.9	1.8	0.051
Burn	2.6[b]	2.5[b]	2.9[ab]	2.8[a]	3.3[a]	3.1[ab]	3.1[ab]	0.108
Metallic	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.054

[a–c]Means within the same row with different superscripts are significantly different ($P < 0.05$).

[1]Descriptive sensory analysis ranked using paper ballots with responses recorded on a 0–15 scale based on the intensity of the attribute evaluated (0 = no detection, 15 = extreme detection).

[2]Attributes as defined in Table 2.

[3]Treatments: 100FS = 100% NaCl from flake salt; 75FS/25SS = 75% NaCl from flake salt and 25% NaCl from SS; 50FS/50SS = 50% NaCl from flake salt and 50% NaCl from SS; 25FS/75SS = 25% NaCl from flake salt and 75% NaCl from SS; 75FS/25NFE = 75% NaCl from flake salt and 25% NaCl from NFE; 50FS/50NFE = 50% NaCl from flake salt and 50% NaCl from NFE; 25FS/75NFE = 25% NaCl from flake salt and 75% NaCl from NFE.

[4]SEM = standard error of the means.

the highest SS level containing treatment, compared to 100FS, while coriander was also lower ($P < 0.05$) than 100FS in the 75FS/25SS treatment. Smoked perception sensory responses were also lower ($P < 0.05$) for 50FS/50NFE and 25FS/75NFE treatments than the 100FS treatment. Compared to the 100FS treatment, soy sauce flavor responses were higher ($P < 0.05$) for all SS and NFE containing treatments with exception of 75FS/25NFE (contained the lowest level of NFE at 25% inclusion level). This result may be due to NFE's lower soy sauce flavor coupled with the lower level found in this treatment providing minimizing flavor impact. Finally, increases ($P < 0.05$) for SS flavor were noted with each increased experimental inclusion level.

Texture attribute scores reported decreases ($P < 0.05$) in firmness for 75FS/25SS, 75FS/25NFE, 50FS/50NFE, and 25FS/75NFE compared to 100FS. Cohesiveness and first chew hardness scores were not different ($P > 0.05$) among any treatments. Chemical feeling factor scores for burn were higher ($P < 0.05$) for 25FS/75SS and 75FS/25NFE compared to 100FS while no differences ($P > 0.05$) for astringent and metallic were found amoung any of the treatments.

Formulations to further investigation or efficacy

The results from this experiment identified what the effects inclusion of different concentrations of SS and NFE had on a variety of quality and sensory attributes. In addition, results from this study can be utilized to help identify the levels of SS and NFE for potential sodium reduction strategies. Five specific factors from each descriptive sensory panel (2 basic flavors; salt and umami, 2 product specific attributes, and soy sauce flavor) from this study were considered important for identifying concentrations of SS and NFE in products for further investigation and promise of successful sodium reduction.

Bacon results suggested 4 treatments (50FS/50SS, 25FS/75SS, 50FS/50NFE, and 25FS/75NFE) could be considered for sodium reduction efficacy studies as all were found to provide minimal changes in quality characteristics and revealed sensory enhancing characteristics. All 4 treatments showed similar SS sensory responses and improvements for salt and umami sensory responses compared to the 100FS treatment. Product specific sensory attributes identified supporting this included pork cured and pork fatty whereas similar responses were noted regardless of SS or NFE treatment. As such, mid and higher level NFE/SS treatments would be expected to have the greatest potential for achieving sodium reduction goals in bacon.

Beef jerky treatments including 50FS/50SS, 25FS/75SS, 50FS/50NFE, and 25FS/75NFE were identified as optimum as these treatments showed increasing SS and NFE inclusion levels had minimal impact on product quality while maintaining and enhancing salt and umami sensory responses. Since jerky is a higher salt product, the importance for showing large increases for salt responses was not deemed critical yet the ability to reduce sodium (via flake salt) was of interest. Important beef jerky specific attributes included beef cured and black pepper and these sensory responses were found to be maintained or improved with the addition of SS or NFE.

Boneless ham results showed that the addition of SS and NFE had a much greater effect on quality and sensory properties likely due to the unique properties (delicate flavor profile, lighter color, etc.) ham possesses compared to the other processed meat products investigated. Although salt and umami sensory response values increased with increasing levels of SS and NFE, so did soy sauce responses and several quality factors; namely color. Key product specific sensory attributes utilized to help identify optimum levels of SS and NFE included caramelized and hammy attributes. The results suggested that boneless ham treatments 75FS/25SS and 50FS/50NFE could be successful for sodium reduction efficacy testing since noteworthy increases in soy sauce along with decreases in hammy sensory responses beyond 25% NFE and 50% SS inclusion levels did existed and as such established efficacy limits.

Two summer sausage treatments, 50FS/50SS and 50FS/50NFE were identified with sodium reduction potential as diminishing returns for salt sensory responses above 50% inclusion for both SS and NFE were noted while SS sensory scores were also noticeably higher above this inclusion level. Product specific attributes identified were black pepper and coriander and were either not different or higher than the 100FS treatment.

Conclusions

Across the product treatments investigated and as SS and NFE treatment concentrations increased, soy sauce sensory scores increased, saltiness sensory responses generally increased, and physiochemical attributes remain unchanged. The results of this study clearly show that the utilization of NaCl from SS and NFE is feasible in replacing a portion of the formulation flake salt while maintaining product quality. Some physiochemical texture and color differences were reported; however, use of other ingredients and processing adjustments (e.g., application of smoke) may mitigate the noticeable effects of adding SS and NFE. As such, balancing the various attributes impacted (both positively and negatively) by the addition of SS and NFE is key in their successful utilization.

Further research should be conducted on all 4 products to determine if sodium reductions are feasible when targeting specific reduction levels. Additional research may include the use of potassium chloride or other salt replacers in sodium reduction studies to evaluate the additive effect and possible interactions between SS, NFE, and other ingredients to even further sodium reduction opportunities.

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