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Reducing sodium levels in frankfurters using naturally brewed soy sauce

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ABSTRACT

Sodium chloride (NaCl; salt) serves important functions in processed meats, contributing to desirable quality and food safety characteristics; however, renewed interest exists in reducing sodium in the human diet despite sodium being a required component of the diet for physiological regulation. This study investigated consumer sensory and quality impacts from replacement of normally added NaCl (flake salt) with naturally brewed soy sauce (SS). Varying levels of SS were used with NaCl and/or potassium chloride (KCl) to comprise treatments (TRT) which investigated flake salt replacement (Phase I) and sodium reduction (Phases II and III). Phase I identified a 50% replacement of NaCl with SS as the baseline for subsequent phases. Phase II indicated that the inclusion of SS could allow for a 20% NaCl reduction without adverse effects on quality or sensory attributes. Phase III results demonstrated that it was feasible to reduce NaCl by 35% via the inclusion of KCl in SS containing frankfurters without major quality or sensory changes.

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1. Introduction

Sodium chloride (NaCl; salt) is one of the oldest and most familiar food ingredients known to man. Salt is especially important in processed meats, contributing to desirable food quality and food safety characteristics (Man, 2007). The role of salt in processed meat products can be placed in three broad categories: processing characteristics, preservation, and sensory attributes (Hutton, 2002; Rust, 1987). However, despite the importance of salt in producing food of high quality and safety, there has been a great deal of interest in reducing sodium intake in the human diet. Sodium reduction efforts stem from reports that over-consumption of sodium has the propensity to lead to hypertension and cardiovascular disease, among other ailments (Hazen, 2010). Lately, there has been a shift in consumer food purchasing habits as health-related and driven interests are commonly influencing what foods consumers buy (Resurreccion, 2003).

The current recommendation for human sodium intake from the World Health Organization (WHO) is 2000 mg per day (WHO, 2007). As of June 2010, it has been suggested that the recommended dietary allowance (RDA) of sodium, supplied by the Dietary Guidelines Advisory Committee, in the United States be reduced from 2300 mg per day to 1500 mg per day (Soong, 2010; Wenther, 2010). The Dietary Guidelines Advisory Committee have also suggested setting a legal limit on sodium in packaged foods, with gradual changes occurring to meet this limit (Wenther, 2010). Salt reduction initiatives, such as the National Salt Reduction Initiative (NSRI), aim to reduce salt in the American diet by 20% over a five year period, starting in 2010. Numerous meat processors and other food companies have joined in the efforts to decrease sodium intake across all food products, as approximately 75% of the daily dietary sodium is added to food before it ever reaches the consumer (Doyle & Glass, 2010).

Although several research studies have been conducted to examine sodium reduction and replacement in processed meats, there is still a need to develop novel approaches to reduce sodium without sacrificing product safety and quality. It is especially important to find methods that effectively maintain the salty taste that is traditionally associated with processed meats without introducing non-traditional flavors that are often associated with a decline in consumer acceptance (Sofos, 1983a). Limited research has been conducted on the usage of naturally brewed soy sauce and similar products as a means to replace and reduce sodium content via salt reduction in food products. Kremer, Mojet, and Shimojo (2009) examined the use of naturally brewed soy sauce in salad dressings, tomato soup, and uncured stir-fried pork with their research suggesting that it was feasible to reduce salt content in the products up to 50%, 17%, and 29%, respectively. Other research has validated the ability of umami containing substances, such as naturally brewed soy sauce (Kremer et al., 2009), to enhance saltiness via both taste and odor. According to Djordjevic, Zatorre, and Jones-Gotman (2004), soy sauce has the ability to induce an enhanced perception of saltiness level through scent. Yamaguchi and Takahashi (1984), as well as Mojet, Heidema, and Christ-Hazelhof (2004) determined that umami containing substances appear to work in a compensative relationship with NaCl, demonstrating the ability of umami flavors to increase salty taste despite decreases in salt content. These authors

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also found that umami containing substances enhanced saltiness in broth samples. Despite the information regarding the saltiness enhancement abilities of umami substances, little is known as to the abilities umami containing substances may have on the quality and sensory characteristics of processed meats.

Therefore, the objectives of this study were threefold: first, to investigate the feasibility of using naturally brewed soy sauce (SS) to replace flake salt in frankfurters; second, to determine what salt enhancing ability and effects may exist from the inclusion of SS in frankfurters; and third, to determine the ability of SS to offer synergistic effects to maximize potassium chloride (KCl) usage capabilities or provide KCl bitterness masking effects.

2. Materials and methods

2.1. Experimental design and data analysis

This study utilized varying levels of SS, NaCl, and KCl in the manufacture of emulsified frankfurters in three separate phases of research to investigate the efficacy of replacing and/or reducing NaCl in frankfurters (Table 1). Four treatments (TRTs) and a control (C) were used in each phase. Statistical analysis was performed for all measurements using the Statistical Analysis System (version 9.2, SAS Institute Inc., Cary, NC) mixed model procedure (SAS Institute Inc., 2009). For each phase, the experimental design was a randomized complete block using a mixed effects model. The main plot consisted of 3 blocks (replication). The model included the fixed main effects of treatment (TRTs 1–4, C) and replication (n = 3) resulting in 15 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 $P<0.05$.

2.2. Product manufacture

Ready-to-eat emulsified frankfurters were manufactured with 90% lean (10% fat) beef trimmings and 42% lean (58% fat) pork trimmings obtained from a local supplier. Raw materials were ordered separately for each research phase. The pork trimmings were coarse ground (Hobart Model 4732, Hobart Corporation, Troy, OH) using a 19.05 mm plate and the beef trimmings were coarse ground using a 9.53 mm plate. Coarse ground beef and pork were briefly mixed individually for uniformity, randomly separated into 4.54 kg batches, and vacuum packaged (Ultravac 2100-C, Ultravac Solutions LLC, Kansas City, MO; Flavorseal Vacuum Pouch, 3 mil, Carroll Manufacturing & Sales, Avon, OH). Vacuum packaged raw materials were stored under refrigeration at 2.2 °C for one to three days. Beef and pork packages were randomly assigned to treatments (TRT 1–4) and control (C). All formulations for each phase contained 4.54 kg of both pork trimmings and beef trimmings. Treatment combinations are listed in Table 1 and formulations are listed in Table 2. Sodium phosphates were not included in the formulation to better understand the functional limitations of SS and the TRT combinations.

Emulsions were produced using techniques described by Rust (1987). Frankfurters were manufactured using a bowl chopper (Krämer & Grebe 67–225, Krämer & Grebe GmbH & Co. KG., Biendenkopf-Wallau, Germany). The coarse ground beef was chopped with sodium nitrite, flake salt (Phase I), flake salt and/or SS (Phase II), flake salt and/or SS and/or KCl (Phase III), and half of the ice until a temperature of 2.2 °C was achieved. Coarse ground pork, spices, sodium erythorbate, and the remainder of the ice were added to the bowl chopper, and the mixture was chopped until a temperature of 14.4 °C was achieved. The emulsion was then transferred to a rotary-vane vacuum filler with a linking attachment (Handtmann VF 608 Plus vacuum filler, Handtmann CNC Technologies Inc., Buffalo Grove, IL) and stuffed into 27 mm cellulose casings (Viscofan USA Inc., Montgomery, AL) with 80 g per link.

Links from each treatment were hung on smokehouse sticks and were placed on a smokehouse truck and showered with cold water prior to the onset of cooking. Cooking was accomplished using a single truck thermal processing oven (Alkar Model 450 MiniSmoker, Alkar Engineering Corp., Lodi, WI) and a common frankfurter smokehouse schedule reaching an internal temperature of 71.1 °C was used. After the completion of thermal processing, the frankfurters were immediately chilled until the internal temperature was below 4.4 °C. After cooling, the cellulose casings were removed and frankfurters were placed in 3 mil nylon/polyethylene vacuum pouches (Flavorseal

Table 1
NaCl, SS, and KCl treatment combinations for frankfurter treatments (TRT) and control (C) used in research Phases I, II, and III.

TRT	NaCl from flake salt	% NaCl from SS	KCl	NaCl reduction	Formulated NaCl[a]
Phase I — NaCl replacement using SS					
C	100%	0%	–	–	2.5%
1	75%	25%	–	–	2.5%
2	50%	50%	–	–	2.5%
3	25%	75%	–	–	2.5%
4	0%	100%	–	–	2.5%
Phase II — NaCl reduction using SS					
C	100%	0%	–	–	2.5%
1	50%	50%	–	–	2.5%
2	40%	50%	–	10%	2.25%
3	30%	50%	–	20%	2.00%
4	20%	50%	–	30%	1.75%
Phase III — NaCl reduction using SS and KCl					
C	100%	0%	–	–	2.5%
1	50%	50%	–	–	2.5%
2	30%	50%	20%	20%	2.00%
3	15%	50%	35%	35%	1.63%
4	0%	50%	50%	50%	1.25%

[a] Formulated NaCl reported as ingoing levels based upon meat block weight.

Table 2
Frankfurter formulations[a] used for frankfurter treatments (TRT) 1 and control (C) in research phases I, II, and III.

TRT	Water	SS	Flake salt	KCl
Control formulation for Phases I, II, and III				
C	20.0%	–	2.50%	0%
Phase I TRT formulations				
TRT	Water	SS (16.0% NaCl)	Flake salt	KCl
1	16.75%	3.90%	1.86%	0%
2	13.45%	7.79%	1.25%	0%
3	10.20%	11.69%	0.62%	0%
4	6.90%	15.58%	0%	0%
Phase II TRT formulations				
TRT	Water	SS (13.7% NaCl)	Flake salt	KCl
1	12.15%	9.11%	1.25%	0%
2	12.15%	9.11%	1.00%	0%
3	12.15%	9.11%	0.75%	0%
4	12.15%	9.11%	0.50%	0%
Phase III TRT formulations				
TRT	Water	SS (13.7% NaCl)	Flake salt	KCl
1	12.15%	9.11%	1.25%	0%
2	12.15%	9.11%	0.75%	0.50%
3	12.15%	9.11%	0.37%	0.87%
4	12.15%	9.11%	0%	1.25%

[a] Water, SS, flake salt, and KCl are presented as calculated on a meat block basis. All formulations contained 0.81% sugar and 0.54% spices (based on total batch weight) and 156 mg/kg sodium nitrite and 547 mg/kg sodium erythorbate (based on meat block).