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Technological, sensory and microbiological impacts of sodium reduction in frankfurters

Suzana E. Yotsuyanagi [a], Carmen J. Contreras-Castillo [a,*], Marcia M.H. Haguiwara [b], Kátia M.V.A.B. Cipolli [b], Ana L.S.C. Lemos [b], Marcelo A. Morgano [b], Eunice A. Yamada [b]

[a] Universidade de São Paulo, Escola Superior de Agricultura "Luiz de Queiroz", Departamento de Agroindústria, Alimentos e Nutrição, Piracicaba, Brasil
[b] Instituto de Tecnologia de Alimentos, Campinas, Brasil

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ABSTRACT

Initially, meat emulsions were studied in a model system to optimize phosphate and potassium chloride concentrations. In the second step, frankfurters containing 1.00%, 1.30% and 1.75% sodium chloride (NaCl) were processed and their stability was monitored over 56 days. In the emulsion tests, the best levels in relation to shear force found in model system were 0.85% and 0.25% of potassium chloride and phosphate, respectively. In the second step, treatments with 1.30% and 1.75% NaCl performed better in most of the analysis, particularly the sensory analysis. Consumers could identify the levels of salt, but this was not the factor that determined the overall acceptability. In some technological parameters, frankfurters with 1.30% NaCl were better than those with 1.75%. This represents a reduction of approximately 25% sodium chloride, or 18% reduction in sodium (916 mg/100 g to 750 mg/100 g), and it appears to be feasible from a technological, microbiological and sensory point of view.

1. Introduction

Excessive sodium intake has been associated with hypertension and leads to an increased risk of strokes and fatal vascular diseases (He & MacGregor, 2010). In addition, it has been associated with other health problems, such as stomach cancer and kidney diseases (Sloan, 2010).

It has been established that the consumption of more than 6 g NaCl/day/person is associated with increased blood pressure with increasing age. Therefore, it is recommended that the total amount of salt (sodium chloride) should be approximately 5 to 6 g/day. Genetically, salt-sensitive and hypertensive individuals would benefit from a diet that is low in sodium, with a sodium chloride content of 1 to 3 g/day (Ruusunen & Puolanne, 2005).

Salt is one of the most commonly used ingredients in processed meat products. Salt impacts a number of functional properties in meat products: it activates proteins to increase hydration and water-binding capacity, it decreases fluids loss in vacuum-packaged products that has been thermally processed; it increases the water and fat binding properties of proteins resulting in the formation of a desirable gel texture upon cooking, it increases the viscosity of meat batters, facilitating the incorporation of fat to form stable batters; it is essential for flavor and is a bacteriostatic at relatively high levels (Terrel, 1983).

Decreasing salt content, therefore, has many implications for muscle food products. The product implications include textural changes, flavor differences, decreased moisture retention (yield) and product appearance (Collins, 1997). Sodium chloride is inhibitory against many spoilage and pathogenic microorganisms in meat because of its ability to reduce water activity. It is expected that reducing NaCl levels below those typically used, without other preservative measures, would result in shortened product shelf-life and reduced safety (Sofos, 1986).

Apart from lowering the level of sodium chloride (NaCl) added to products (Aaslyng, Vestergaard, & Koch, 2014; Tobin, O'Sullivan, Hamill, & Kerry, 2012), there are several approaches for reducing the sodium content in processed meats replacing all or part of the NaCl: (1) with other chloride salts (KCl, $CaCl_2$ and $MgCl_2$) (De Almeida et al., 2015; Horita, Morgano, Celeghini, & Pollonio, 2011); (2) with non-chloride salts, such as phosphates (Ruusunen, Särkkä-Tirkkonen, & Puolanne, 1999; Marchetti, Argel, Andrés, & Califani, 2015); (3) with various ingredients (Ruusunen et al., 2003; Choi et al. (2014); McGough, Sato, Rankin, & Sindelar, 2012; Colmenero, Ayo, & Carballo, 2005; Jiménez-Colmenero et al., 2010); (4) with new processing techniques or process modifications (Kang et al., 2014; Grossi, Søltoft-Jensen, Knudsen, Christensen, & Orlien, 2012); and (5) combinations of any of the above approach.

* Corresponding author.
E-mail address: ccastill@usp.br (C.J. Contreras-Castillo).

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Aaslyng et al. (2014) reported that salt reduction from 2.2% to 1.7% did not alter the sensory properties in sausages. According to (Ruusunen & Puolanne, 2005), the sodium chloride content in sausages phosphate free can be reduced to 1.5–1.7%, while adding phosphate to 1.4%, without a loss of quality in terms of technology and yield. These authors related that there are cooked sausages made with salt mixtures on the Finland market where the salt content based on sodium chloride content is 1.2% or lower.

Using other types of salts is one way of reducing NaCl levels. The synergistic effect between sodium chloride and phosphates is well known in the meat industry. Xiong and Mikel (2001) reported that phosphate (at levels above 0.5%) is used in meat products to improve their water holding capacity by increasing the swelling of fibers and the solubilization of proteins. Phosphates function to bind water and improve texture through changes in protein coagulation and fat emulsification (Collins, 1997). Barbut, Maurer, and Lindsay (1988) reported that phosphates significantly improved the texture and acceptability of loss salt (1.5%) in turkey frankfurters. This additive may help to stabilize the flavor and color of the final product by sequestering metallic ions (iron and copper), thereby reducing oxidation.

Potassium chloride (KCl) can be used to replace sodium chloride, despite the lower extraction capacity of myofibrillar proteins, when compared to sodium chloride (Munasinghe & Sakai, 2003). Potassium chloride is probably the most common salt used as a substitute in foods with reduced sodium content. However, at blends of more than 50:50 sodium chloride/potassium chloride solution, a significant increase in bitterness (and loss of saltiness) is observed (Desmond, 2006).

The aim of the present study was to assess the technological, sensory and microbiological impacts of reducing the sodium content, while adding phosphate and potassium chloride, on the storage of frankfurters processed with beef and pork meat. These salts were used as sodium substitutes by their properties to improve product characteristics relating to flavor, texture and water binding that could be impacted by sodium reduction. Thus, this study intends to expand the technological knowledge regarding the reduction of sodium levels, contributing to the meat industry and providing new, healthy options for consumers.

2. Materials and methods

The present study consisted of two steps:

The first step involved the preparation and analysis (emulsion-forming ability and shear force) of meat emulsions in a model system, using various phosphate, potassium chloride and sodium chloride levels.

The second step involved the preparation of frankfurters with the phosphate and potassium chloride levels selected in the first stage of the study. Sodium chloride remained the target of study, by varying the levels added. At this stage, chemical, microbiological, physical and sensory analysis was carried out during storage for 56 days at 4 °C. The storage temperature was consistent with other studies (Aaslyng et al., 2014) using sausages.

In order to choose the salt contents for this test, a preliminary survey of the sodium content in 13 retail frankfurters on the south Brazilian market was carried out. The average of sodium content was 987 mg Na/100 g (corresponding to 2.5% NaCl). The levels of sodium chloride added in the present study were 1%, 1.3% and 1.75%, (corresponding to 1.5%, 1.91% and 2.33% NaCl respectively) which already represents a reduction compared to commercial products.

2.1. Meat emulsion in a model system

In the first step, the technique of factorial central composite rotational design (CCRD) was used to optimize the process, based on response surface methodology. In the model system used, emulsion was obtained using a mini-cutter and all of the ingredients usually used to obtain a frankfurter, with varying levels of phosphate, salt (NaCl) and potassium chloride (KCl) (Table 1). The goal of the first step was to optimize the levels of potassium chloride and phosphate in relation to emulsion-forming ability and shear force. Although the levels of sodium chloride were variable, the objective of the second phase was to determine the influence of NaCl levels.

The experimental design consisted of 20 trials that were performed in random sequence, thereby enabling the acquisition of mathematical models with linear and quadratic parameters (multiple regression) of the variables studied. In the proposed design (CCRD with three variables), the first eight trials refer to all factorial design with levels −1 and +1, the function of which was to provide the linear parameters (L) of the regression model. The next six trials refer to the axial points (levels: −α; 0 and +α), the function of which was to provide the quadratic (Q) regression model parameters. The last six trials (level 0) were replicates at the central point. The responses studied were emulsion-forming ability and shear force.

The phosphate levels recorded were 0% (−α), 0.1% (−1), 0.25% (0) 0.4% (+1) and 0.5% (+α). The NaCl concentrations were 1% (−α), 1.3% (−1), 1.75% (0) 2.2 (+1) and 2.5% (+α). The KCl levels were 0.2% (−α), 0.46% (−1) % 0.85 (0) 1.24 (+1) and 1.5% (+α).

The basic meat emulsion formulation was composed of the following ingredients: 10% beef shoulder, 37% pork shoulder, 18% pork back fat, 3% textured soy protein, 2% cassava starch, 0.05% sodium erythorbate, 0.02% sodium nitrite, 0.25% seasoning unsalted, 0.75% yeast extract, 1% sodium lactate and 0.07% liquid smoke. Twenty different treatments were obtained by varying the amount of sodium chloride, potassium chloride and phosphate added, while the water amount (26%–24.3%) was adjusted so that the sum totaled 100%.

The following specifications for ingredients and additives were used in the preparation of meat emulsions and second stage: phosphate (in 100 g: 19.1 g of phosphorus, 2.3 g of sodium e 45.6 g of potassium) (Budenheim, Abastol 452, Germany), potassium chloride (in 100 g: 0.98 mg of phosphorus, 32.5 mg of sodium e 44.5 g of potassium) (Nu-tek, 15,000, Minnetonka, United States), salt-free seasonings for frankfurters (Kraki, Santo André, Brazil), cassava starch (Amafil, Cianorte, Brazil), textured soy protein (Solae, Centex 4010, St. Louis, United States), 65% sodium lactate (Corbion), yeast extract, sodium erythorbate (Kraki, Santo André, Brazil), sodium nitrite (Kraki, Santo André, Brazil) and liquid smoke (Ibrac, Aroma Flavor Smoke # 50C, São Paulo, Brazil).

Raw meat (kept at −17 °C), beef, pork and pork back fat were coarsely ground (Hermann, 106, São Paulo, Brazil) using a 12 mm plate in order to obtain meat emulsions in a mini-cutter (Skymsen, Brusque, Brazil). The beef and pork (except back fat) were placed in a mini-cutter, before adding NaCl, KCl, nitrite, phosphate, seasoning, yeast extract, sodium lactate, liquid smoke, half amount of water/ice and comminuting for two minutes. Then, fat and the remaining water/ice were added and chopped for 2 min. Sodium erythorbate, textured soy protein and cassava starch were added and comminuted for 1 min.

2.1.1. Emulsion-forming ability measurements

This test was performed as described by Parks and Carpenter (1987): 45 to 50 g of newly processed batter was placed in bag of nylon/polyethylene film, which was sealed without vacuum and heated for 1 h in water at 70 °C. After cooling the samples, they were removed from the package and weighed. The liquid volume exudates were calculated as a percentage loss in relation of the initial sample weight.

2.1.2. Shear force

A texture analyzer (Stable Micro Systems, TA XT-2i, Surrey, England), coupled to a Warner Bratzler device (3 mm), was used to shear the heat-treated emulsions. The equipment was calibrated with a 5 kg weight and a 25 kg load cell was used for the test. The speed of the test was 0.8 mm per second. Five units of heat-treated emulsions per treatment were cut into 2 cm (length) × 2 cm (width) × 1 cm (height) pieces, after 24 h storage at 4 °C.