Meat Science 137 (2018) 191–200

Contents lists available at ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

The effects of sodium chloride and PSE meat on restructured cured-smoked pork loin quality: A response surface methodology study

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ARTICLE INFO

Keywords:
Meat product
Water losses
Texture analysis
Saltiness
Sodium content

ABSTRACT

The effects of the PSE meat proportion (0 to 100%) and sodium chloride contents (0 to 2%) on technological and saltiness of restructured cured-smoked pork loins were investigated by using response surface methodology (RSM). Lipid oxidation, pH values and reheating loss of the products were most affected by the proportion of PSE meat, while the salt concentration mainly affected the water activity, expressible moisture values, hardness, chewiness and sliceability of the products. Perception of the salt flavor increased with the addition of salt and proportion of PSE meat in the elaborated products, where the addition of 0.5% salt was considered as ideal by consumers. It was concluded that an amount close to 0.8% salt is required for satisfactory maintenance of the technological characteristics of the restructured cured-smoked pork loins, especially when PSE meat is used in the formulation.

1. Introduction

Pale, soft and exudative meats (PSE) are an anomaly of high incidence in pork, which causes great harm to the meat industry. Generated by a rapid drop in pH post-mortem, in conjunction with elevation of the animal's body temperature, a portion of the proteins in this meat are denatured which affects their capacity for water retention, bonding and emulsification of fat, and consequently the yield and texture of the products in which it is used (Barbut et al., 2008). Therefore, the persistent incidence (between 10.1% and 43.4%) of this type of meat in Brazilian slaughterhouses (Cazedey, Torres Filho, Fontes, Ramos, & Ramos, 2016) has generated the need to use this meat in processed products.

The mixture of normal meats with PSE meats (up to 25%), especially with the use of additives and ingredients (tripolyphosphate, sodium caseinate, whey protein isolate, soy protein concentrate, modified food starch, carageenan etc) with potential to improve the water retention capacity, has been suggested to overcome the defects generated by PSE meat processing, helping to maintain the quality of the product (Kuo & Chu, 2003; Lee & Chin, 2011; Motzer, Carpenter, Reynolds, & Lyon, 1998; Pyrcz, Kowalski, Danyluk, Bilska, & Uchman, 2009; Schilling et al., 2004). However, the most efficient combination to reduce the difference between normal and PSE pork is to use higher salt (sodium chloride, NaCl) and phosphate additions (Torley, D'Arcy, & Trout, 2000). Increasing the sodium chloride concentration increases salt-soluble protein extraction, resulting in increased amounts of fat and water that can be bound (Ruusunen & Puolanne, 2005), which affects the binding and textural characteristics of meat products.

In addition to the technical advantages, salt attributes the salty taste and contributes to conservation of the product, being the ingredient most used by the meat industry. Furthermore, the saltiness elicited by sodium chloride enhances the perception of meat flavor, which is an important factor in the overall acceptability of meat products (Desmond, 2006). However, excessive intake of sodium has been associated with increased blood pressure (hypertension), one of the major risk factors for cardiovascular diseases such as coronary heart disease and stroke, as well as other health problems such as stomach cancer and renal diseases (WHO, 2010). Health agencies of several countries have regulated the total sodium content of processed foods and requested their reduction. Because it is the main source of sodium found in foods, several studies have been carried out to evaluate the effects of salt reduction in processed meat products (Inguglia, Zhang, Tiwari, Kerry, & Burgess, 2017).

Much has been studied on the reduction of salt and the use of PSE meat in meat products, however no studies were found in literature in which these factors were evaluated together. Considering the constant use of PSE meat in meat products and the need to reduce the amount of sodium they contain, this work was carried out with the objective of

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https://doi.org/10.1016/j.meatsci.2017.11.030
Received 22 June 2017; Received in revised form 22 November 2017; Accepted 23 November 2017
Available online 24 November 2017

Table 1
Experimental values of response variables for central composite rotatable design.

Trial	Coded levels		Uncoded levels	
	X_1	X_2	PSE meat (%)	Salt (%)
1	− 1	− 1	14.5	0.3
2	1	− 1	85.5	0.3
3	-1	1	14.5	1.7
4	1	1	85.5	1.7
5	− 1.41	0	0	1
6	1.41	0	100	1
7	0	− 1.41	50	0
8	0	1.41	50	2
9 to 11	0	0	50	1

evaluating the effects of these variables on the technological and sensorial quality of restructured cured-smoked pork loins in order to optimize the use of PSE meats and salt in the formulation of commercial cooked meat products.

2. Material and methods

2.1. Experimental design

The main effects of the formulation variables (PSE meat, X_1; sodium chloride, X_2) on technological and sensorial quality of restructured cured-smoked pork loin were investigated using the response surface methodology (RSM). A central composite rotatable design (CCRD) was used with a total of 11 different formulations (trials) consisting of 3 central points and 4 axial points in a 2^2 full factorial design in random order (Table 1). Two replicates were performed for this study.

2.2. Porcine raw materials

Porcine loins (*Longissimus lumborum*) used in the present work were the same as described in a previous report (Cazedey et al., 2016). Briefly, samples from 60 pigs (commercial cross Large White x Landrace) weighing 105 ± 10 kg were obtained in a commercial facility, classified into different quality categories. For this study, normal (reddish-pink, firm and non-exudative; RFN) and PSE samples were selected according to the criteria of Torres Filho, Cazedey, Fontes, Ramos, and Ramos (2017): RFN samples were identified as having a lightness (CIE L^*) between 44 and 52 and a percentage drip loss (PDL), by bag method (Honikel, Kim, Hamm, & Roncales, 1986), between 2 and 6%; PSE samples were identified as having CIE $L^* > 53$ and PDL > 6%.

Selected RFN ($L^* = 49.6 \pm 2.27$ and PDL = 4.19 ± 0.11%) and PSE ($L^* = 57.52 \pm 3.91$ and PDL = 10.33 ± 0.98%) pork loins were vacuum-packaged, frozen (− 20 °C) and stored until their use.

2.3. Sample processing

Samples were processed according to the commercial formulations of products designated “lombo tipo Canadense” in Brazil. In these products, it is common to use additives and ingredients with potential to improve the functional characteristics of PSE meat, such as carrageenan, maltodextrin, and soy protein isolate (Motzer et al., 1998; Schilling et al., 2004). However in this study soy protein isolate was replaced by whey protein concentrate due to its good water binding and improved sensory quality (Hayes, Desmond, Troy, Buckley, & Mehra, 2006).

The basic formulation consisted of: 59% pork loins; 33% water; 2.0% salt; 2.0% whey protein concentrate (Gemacom Tech Indústria e Comércio Ltda., Juiz de Fora, MG, Brazil); 0.5% sodium tripolyphosphate; 0.5% maltodextrin (E-max 206; New Max Industrial Ltd., Americana, SP, Brazil); 0.5% carrageenan (CEAMGEL M-920; New Max Industrial Ltd., Americana, SP, Brazil); 0.3% monosodium glutamate; 150 ppm sodium nitrite; 540 ppm sodium erythorbate; 0.3% smoke powder (New Max Industrial Ltd., Americana, SP, Brazil); and 1.0% ham flavoring and seasonings (Condimento Califórnia; New Max Industrial Ltd., Americana, SP, Brazil). PSE meat and the salt concentration were incorporated in the formulation according to each treatment (Table 1), whereas the reduction in salt was accompanied by equal increase in meat content.

Pork loins were thawed in refrigerator (at 4 °C) for 24 h, ground (meat grinder Beccaro Ltda, Rio Claro, SP, Brazil) using a 20 mm plate and mixed (Lieme Indústria Metalúrgica Ltda., Caxias do Sul, RS, Brazil) with the ingredients for 15 min. The mixture was stuffed into 85 mm cellulose casings of approximately 400 g capacity and refrigerated (4 °C) for 16 h to cure. The next day, all products were processed in a smokehouse (Defumax Equipamentos e Produtos Ltda., São Paulo, SP, Brazil) for about 4 h, to an average internal temperature of 71 °C. The cured-smoked pork loins were immediately immersed in a cold (< 5 °C) water bath and then stored at 4 °C for 12 h prior to cooking loss determinations.

2.4. Physical and chemical analysis

The cured-smoked pork loins were submitted to proximate analyses of total moisture (AOAC 950.46B), fat (AOAC 960.39), protein (AOAC 981.10, using 6.25 as conversion factor) and ash (AOAC 950.46) contents using the Association of Official Analytical Chemists procedures (AOAC, 2005). Total carbohydrate was obtained by the difference (total weight minus moisture, protein, fat and ash). These analyses were conducted only to provide additional information regarding the chemical composition of the elaborated samples, and was not evaluated by the CCRD methodology.

In order to determine the sodium content in the formulated products, the analysis was conducted by flame photometer detection according to the AOAC methodology (AOAC, 2005). Average pH values were measured using a potentiometer (Digimed, modelo DM 20, São Paulo, Brasil) by inserting a combined penetration electrode into the product at three different points. Water activity was measured using an Aqualab® Water Activity Meter CX2 device (Decagon Devices Inc., WA, USA). The degree of lipid oxidation in the products was also evaluated by measuring the 2-thiobarbituric acid reactive substances (TBARS index) as described by Jo and Ahn (1998). The concentration of malonaldehyde (MDA; expressed as mg MDA/kg of sample) was determined using an analytical curve of 1.1.3.3-tetraethoxypropane (TEP).

2.5. Weight loss attributes evaluation

Cooking loss was estimated as the weight loss (%) that occurred during the smoking/cooking process.

The syneresis, fluid loss during sample storage, was determined by weighing together 10 cubes with 10 mm edge, that were vacuum-packed and stored (4 °C) for 7 days. Every two days the package was kept at room temperature for 2 h to simulate stress conditions in the product and then returned to the cooler. After 7 days of storage, the cubes were unpacked, cleaned with absorbent paper, reweighed and the weight loss (%) calculated.

Expressible moisture (EM) of the samples was determined according to modifications of the method described by Pietrasik and Li-Chan (2002). For each treatment, the EM was determined on 3 square sample cores with edge measuring 25 mm after equilibration at room temperature. Expressible fluid was measured gravimetrically after placing a pre-weighed core sample between two layers of filter paper and compressing the sample to 50% of the original height at a crosshead speed of 60 mm/min on a universal TA.XT2i Texture Analyzer (Stable Micro Systems Ltd., Surrey, England). Results are expressed as the percent