Evaluation of storage condition and phosphate addition on the physicochemical properties and textural characteristics of model lamb sausages

Chin, K.B [1*], Kim, Y.H.B [2] and Rosenvold, K [2]

[1] Department Animal Science, Chonnam National University, Gwangju, South Korea
[2] Agresearch Ltd. Ruakura Research Centre, Hamilton, New Zealand

Abstract— **This study was performed to evaluate the physicochemical properties and textural characteristics of model lamb sausages with different storage conditions, and salt and phosphate combinations. Lamb loins were stored for either 9 weeks at -1.5°C (fully-aged) or for 8 weeks at -1.5°C followed by 1 week at -18°C (aged-frozen). The aged-frozen treatment had higher pH, but lower hunter a (redness) and b (yellowness) values than those with the fully-aged treatment. The lamb loins were minced and mixed with sodium chloride (1.5%) alone or in combined with sodium tripolyphosphate (STPP 0.4%). After mixing, the meat batters were packed into 50-mL tubes and cooked to an internal temperature of 72°C. Since no interactions between storage condition and STPP addition were observed ($P > 0.05$), data were pooled and separated out by storage condition and STPP addition. The aged-frozen treatment was lighter and redder color, and lower cooking loss and expressible moisture ($P < 0.05$) than those with fully-aged ones. However, STPP addition reduced hunter redness, cooking loss and expressible moisture, regardless of storage condition. Furthermore, textural hardness was improved with the addition of 0.4% STPP. These results indicated that the aged-frozen treatment affected hunter color values and water-holding capacity. The addition of STPP reduced the redness, but improved water-holding capacity and textural characteristics, regardless of storage condition.**

Keywords— **storage condition, phosphate addition, physicochemical and textural properties, model lamb sausages**

I. INTRODUCTION

New Zealand is the largest lamb exporter in the world. For conventional frozen products for export, New Zealand lamb carcass was electrically stimulated and conditioned for 10 hr at 6°C and frozen within 48 hr of slaughter following the Accelerated Conditioning and Ageing process [1]. However, unfrozen chilled lamb meats have been produced with improved quality, resulting in the higher price than the frozen counterpart [2]. During long–time transportation, the chilling condition is critical for the lamb quality. Kim et al. [3] reported that aging prior to freezing provided equivalent tenderness and colour stability, and better lipid oxidation stability compared to the aged-only loins under high oxygen modified atmosphere. Thus, the aged-frozen treatment might provide positive effects on processed meat quality. This study was performed to evaluate the processing properties of lamb loin aged at -1.5°C for 9 weeks, or for 8 weeks at -1.5°C followed by 1 week at -18°C as affected by NaCl and phosphate.

III. MATERIALS AND METHODS

A. Preparation of model lamb sausage

Aged lamb loins (two loins from three animals) aged for either 9 week at -1.5°C (fully-aged) or 8-week storage at -1.5°C followed by 1-week storage at -18°C (aged-frozen) were thawed overnight by placing meat at a refrigerator (3°C), pH and colour values were measured. Then, the meats were ground and mixed with sodium chloride (NaCl) alone or in combined with sodium tripolyphosphate (STPP) for 3 min along with sodium nitrite as shown in Table 1. Then, approximately 40 g of meat batter was stuffed into 50-mL centrifuge tubes (4 tubes of each treatment; the model sausages) and cooked at 75°C for 30 min until the internal temperature reached to 72°C. The model sausages were then cooled and stored at 4°C until analyzed.

B. pH and Hunter color measurement

pH was measured using a calibrated pH probe (Testo 205 pH meter, Lenzkirch, Germany) calibrated with buffers (pH 4 and 7). Hunter L (lightness), a (redness) and b (yellowness) values were measured in

triplicates on the model sausages using a Hunter Lab Miniscan XE Plus Colour Meter (D65, 1cm diameter, 10º standard observer; Hunter Associates Laboratory, Inc. Reston, VA, USA).

Table 1. Formulation of lamb model sausage

Ingredients (g)	Fully-aged		Aged-frozen	
	NaCl	NaCl+STPP	NaCl	NaCl+STPP
Ground lamb	350	350	350	350
Water	142.4	142.4	142.4	142.4
Salt	7.5	7.5	7.5	7.5
STPP	0	2.0	0	2.0
Sodium nitrite	0.075	0.075	0.075	0.075

C. Cooking loss (%) and Expressible moisture (%)

Cooking loss was measured by weighing before and after cooking. To measure the expressible moisture contents, approximately 1.5 g of sausage samples was weighed and wrapped with filter paper (Whatmann #3), and then centrifuged at 3,000 rpm for 15 min according to the modified method of Jauregui et al. [4]. Expressible moisture contents were calculated as below:

Expressible moisture (EM, %) = (weight of expressed water in filter paper / weight of sample) x 100

D. Textural hardness

Textural hardness was performed using a Texture Analyzer (TA-XT2, Stable Micro System, Haslemere, England) according to the texture profile analysis (TPA) method of Bourne [5]. The sausage samples (12.5 mm in diameter x 1.2 cm length) was compressed twice to 75% of their original height with a 50 kg load cell at a cross speed of 300 mm/min. Textural hardness was expressed as hardness (gf) of the model sausage samples.

E. Statistical analysis

The experiment was replicated twice, and the data were analyzed by two-way analysis of variance (ANOVA) using SPSS [6]. Duncan's multiple mean comparisons for each trait were performed ($P < 0.05$).

III. RESULTS AND DISCUSSION

After 9-week chilled storage at -1.5°C (Fully-aged) or 8-week chilled storage at -1.5°C and 1-week frozen (Aged-frozen) storage, pH and Hunter color values of lamb loins were evaluated. As shown in Table 2, the fully-aged lamb loins had higher Hunter a and b values, but lower pH and Hunter L values than the aged-frozen ones. The higher pH of aged-frozen lamb loin might have higher functional attributes, as compared to the fully-aged ones [6]. Zhang et al. [6] also reported that high pH meat had lower L*, a* and b* values than normal pH meat, which partially agreed with our results. These results confirm that the storage condition affected meat quality.

Table 2. Pooled mean of pH and Hunter color values of lamb loin as affected by different storage condition

	Storage condition	
	Fully-aged	Aged-frozen
pH	5.77B	5.91A
Hunter L	37.5B	35.6A
Hunter a	14.6 A	10.8B
Hunter b	17.4 A	14.7B

A, B mean with same letter in a same row are not different ($P > 0.05$)

Since no interaction between storage condition and ingredient (NaCl * STPP) was observed, data were pooled and separated by the storage condition and ingredient (Table 3). In the main effect, the storage

Table 3. Summary of interactions and main effects of meat and model sausage as affected by storage condition or ingredients

	Interactions	Main effect	
		Storage	Ingredient
pH	-	-	-
Hunter L	-	*	-
Hunter a	-	*	-
Hunter b	-	-	***
Cooking loss	-	*	***
WHC[1]	-	*	*
Hardness (gf)	-	-	***

Differences are significant at $P < 0.05$ (*); $P < 0.01$(**) and $P < 0.001$(***):
-: no significant
WHC[1]: water-holding capacity (expressible moisture %)

condition affected the Hunter L and a values, cooking loss and expressible moisture (WHC), but the ingredient combinations (NaCl alone or NaCl with STPP) affected the Hunter b value, cooking loss, textural hardness ($P < 0.001$) and expressible moisture (WHC) ($P < 0.05$). Thus, the storage conditions and ingredient affected the physicochemical and textural characteristics of the model lamb sausages.

As shown in Table 4, storage condition affected physicochemical properties of model lamb sausages. The model lamb sausages manufactured with the fully-aged lamb loins had higher Hunter a values, cooking loss and expressible moisture, but lower Hunter L values than those with the aged-frozen lamb loins ($P < 0.05$). Thus, the aged-frozen lamb sausages had higher water-holding capacity than those with fully-aged ones. Theses results were partially due to the loss of water from the meat during thawing, as compared to the fully-aged ones. However, no differences in pH, Hunter b values and textural hardness of the model lamb sausages were observed. The higher pH of the sausages containing aged-frozen loins was partially due to the higher pH of the raw lamb loins [7].

Table 4. Pooled mean of pH and physicochemical properties of lamb model sausages as affected by storage condition

	Storage condition	
	Fully-aged	Aged-frozen
pH	6.25A[a]	6.32A
Hunter L	63.3 B	66.5A
Hunter a	9.1 A	6.9B
Hunter b	10.1 A	10.0A
Cooking loss (%)	3.3A	1.8B
Expressible moisture (%)	28.3A	24.9B
Textural hardness (gf)	3842A	3725A

A, B mean with same letter in a same row are not different (P > 0.05); a: mean of duplicates

The effects of different ingredient combinations (NaCl alone or in combined with STPP) on pH, Hunter colour values, cooking loss, expressible moisture and textural hardness were observed (Table 5). The NaCl and STPP combination had higher Hunter L, but lower Hunter a values, cooking loss, expressible moisture and textural hardness than those with salt addition alone. Thus, the combination of NaCl with STPP increased water-holding capacity and textural hardness. Therefore, the combination of NaCl and STPP would be recommended to have better texture and water-holding capacity to manufacture processed meats. Chin et al. [8] produced low-fat meat products with konjac flour, carageenan and soy protein isolates to reduce the sodium chloride with hydrocolloids.

Table 5. Pooled mean of pH and physicochemical properties of lamb model sausages as affected by ingredient combinations

	Ingredient(s)	
	NaCl	NaCl+STPP
pH	6.23A[a]	6.34A
Hunter L	64.5 B	65.2A
Hunter a	9.8 A	6.2B
Hunter b	10.1 A	10.1A
Cooking loss (%)	4.7A	0.4B
Expressible moisture (%)	28.3A	24.8B
Textural hardness (gf)	2647B	4920A

A, B mean with same letter in a same row are not different (P > 0.05): a: mean of duplicates.

IV. CONCLUSIONS

The pH and color values of lamb loins were affected by the storage conditions. The model lamb sausages containing fully-aged lamb loins had lower water-holding capacity than those with the aged-frozen lamb loins (P < 0.05). The NaCl and STPP combination improved processing properties (better water-holding capacity and textural characteristics), as compared to the model lamb sausages with sodium chloride addition alone.

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