THE EFFECT OF NITRITE SOURCE AND PARTIAL SUBSTITUTION OF SODIUM CHLORIDE ON THE FUNCTIONALITY, QUALITY AND CONSUMER ACCEPTABILITY OF RESTRUCTURED HAMS

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Abstract – The effect of nitrite source and partial substitution of sodium chloride with potassium chloride on the functionality, quality, and consumer acceptability of restructured hams was determined. Cook yield, expressible moisture, purge during simulated retail display, colour (CIE *L*a*b values) and bind strength of ham slices were measured. Consumer (N=71) ratings of the appearance, flavour, saltiness, texture, aftertaste, and overall acceptability of hams was evaluated using 9-point hedonic scales. Generally, low salt (LS) hams were lighter, with poorer binding properties, compared to regular salt (RS) formulations. Loss of functionality due to the salt reduction in LS hams was partially overcome by processing with celery powder, which improved hydration properties and resulted in textural quality equivalent to RS hams containing sodium nitrite. Consumer ratings indicated no effect of nitrite source on hedonic ratings. However, salt reduction led to a decrease in the acceptability of flavour and aftertaste, suggesting substitution of sodium chloride with potassium chloride at this concentration may not be optimal.**

Key Words – Low salt, Celery powder, KCl

I. INTRODUCTION

Consumer demand for reduced sodium foods has increased since a link was made between dietary sodium intake and the development of hypertension. This, coupled with increased consumer concern about chemical additives in conventionally processed foods [1], has led to an elevated interest in the development of natural and health-promoting food products. The meat industry has addressed these consumer interests through the development of reduced salt, natural (nitrite-free) meat products. Reformulation of meat products to satisfy reduced sodium and nitrite-free criteria is difficult because these ingredients are present for both functional and food safety reasons.

Lowering salt levels in meat products to reduce dietary sodium intake necessitates stringent process control to avoid compromising the meat product during or after thermal processing. The addition of salt not only enhances the flavour of meat products but also affects functional characteristics such as water-holding capacity, product binding, product texture, and bacterial growth [2, 3].

The addition of nitrite or nitrate is not permitted in products that are marketed as "natural". Processed meat products made without nitrite can be susceptible to safety issues and the development of negative sensory attributes. Most of the new technologies for the development of nitrite-free products depend on the natural conversion of nitrate to nitrite by microbial reduction in products formulated with natural nitrate sources such as sea salt, vegetable juice powder (dried celery juice), or turbinado sugar [1]. The nitrite produced from this process is generally adequate to develop cured meat colour, however, colour stability of "naturally cured" products is limited, and their flavour is noticeably different from the traditionally cured products [4]. The objective of this study was to determine the effects of nitrite source and partial substitution of sodium chloride with potassium chloride on functionality, quality, and consumer acceptability of restructured ham.

II. MATERIALS AND METHODS

The study was set up as a completely randomized design with a 2 x 3 complete factorial arrangement of treatments. The main effects investigated were: curing agent source (N-sodium nitrite [Prague powder] or CP-celery juice powder) and salt treatment (RS- regular salt, LS-low salt, LS+PL-low salt with potassium lactate).

Six different ham formulations were processed: regular salt (RS-N) ham, low-salt (LS-N) ham and low-salt with potassium lactate (LS+PL-N) containing sodium nitrite (100 ppm) as a curing agent, and regular salt (RS-CP) ham, low-salt (LS-CP) ham and low-salt with potassium lactate (LS+PL-CP) containing celery powder (CP) as a curing agent (0.5% CP contained 100 ppm of sodium nitrite). The regular salt treatments contained 2.4% NaCl and LS hams contained 1.2% sodium chloride and 1.2% Low-So Salt Replacer (Nu-Tek modified potassium chloride, Nu-Tek Salt, LLC, Minnetonka, MN). LS+PL treatments additionally contained 2% potassium lactate. For each formulation, the brine (equivalent to 30% pump above green weight) also included 2.5% dextrose and 0.5% sugar.

For each of three replications, boneless, skinless pork inside rounds were ground in a grinder through a plate with kidney shaped orifices and then the meat and brine (total batch size of 10 kg) were tumbled under vacuum (-0.9 bar) for 60 min. Each treatment batch was stuffed into presoaked, fibrous casings (105 mm diameter, UniPac, Edmonton, AB). The product was thermally processed in a smokehouse to a final internal temperature of 71°C, cooled in running water for 30 min, and then stored at 2°C until use. Following overnight storage, one chub per formulation was prepared as 3 mm slices and vacuum packed (10 slices per package). The remainder was vacuum packaged whole and all samples were stored at 2°C until sampling for sensory and instrumental evaluations. The variables measured on restructured ham included: pH, cook yield (% of the raw stuffed weight), expressible moisture (EM), and purge throughout the simulated retail display. Bind strength was determined on 12.7 mm ham slices using an Instron texture analyser [5]. Colour of the meat gels was measured using a Konica CM-2500C spectrophotometer (illuminant D65) and expressed as CIE L* (lightness), a* (redness), and b* (yellowness) values. Using a fully randomized block design, consumer (N=71) ratings of ham appearance, colour, flavour, juiciness, firmness, texture, and overall acceptability were evaluated on 9-point hedonic scales.

Statistical analyses were performed using SAS version 9.2. Data were analysed as a 2x3 factorial design with two nitrite sources (N, CP) and three salt treatments (RS, LS, LS+PL) as main factors. Fisher's LSD mean separation tests were used for post-hoc analyses (α=0.05).

III. RESULTS AND DISCUSSION

A partial substitution of sodium chloride with a salt replacer containing potassium chloride resulted in products with sodium contents below the Health Check™ Program limit for deli meats (i.e., 360 mg per 55 g serving). Substituting 50% salt with the replacer allowed for creation of products with a per serving sodium content approximately 23% lower than the Health Check™ Program limit.

The pH values of the cooked hams processed with CP were higher (pH 6.36) than those containing sodium nitrite (pH 6.05). The low salt hams had a slightly lower pH (6.17) compared to regular salt hams (6.24) but were not different than LS with potassium lactate added (6.20).

A partial replacement of sodium chloride with salt replacer resulted in lower cook yield but only in treatments produced with CP. Low salt treatments without addition of potassium lactate had significantly higher EM than did RS and LS+PL hams. The significant increase of expressible moisture (EM) in hams due to salt replacement was observed only in products without addition of CP (Fig. 1). As indicated by EM, salt substitution had no significant (P>0.05) effect on the water holding capacity of CP hams. This suggests that processing with addition of CP improved moisture retention of LS products and makes them equivalent to RS hams.

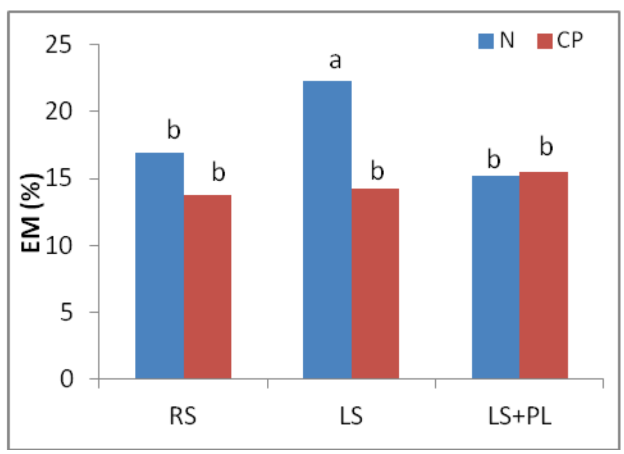

Figure 1. Effect of curing agent (sodium nitrite, N; celery powder, CP) and salt treatment (regular salt, RS; low salt, LS; low salt + potassium lactate; LS+PL) on expressible moisture (EM) from ham chubs.

In general, use of CP improved the hydration properties of hams, resulting in lower purge losses compared to samples with N. The improved water retention may partly reflect the higher pH of these hams because there is a clear tendency for water-holding capacity to increase with increasing pH [6].

Formulation treatments had a significant effect (P<0.05) on the bind strength of the ham slices (Fig. 2). The binding of processed meats, as related to both the adhesion of meat particles and water binding (holding) by meat proteins, relies on extraction of myofibrillar proteins from the meat [6].

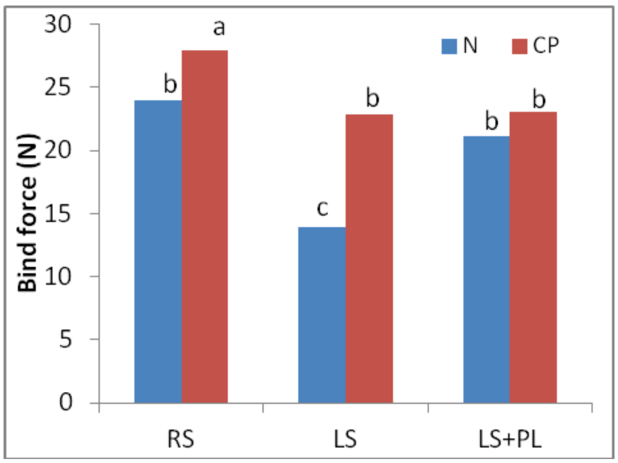

Figure 2. Effect of curing agent (sodium nitrite, N; celery powder, CP) and salt treatment (regular salt, RS; low salt, LS; low salt + potassium lactate; LS+PL) on bind force of ham slices.

There was a significant interaction between curing agent source and salt treatment for binding strength of meat slices. LS hams processed with N required the least amount of force to break the slices, whereas the strongest bind was achieved in RS hams processed with the addition of CP. It is interesting to note that the bind strength of both reduced sodium treatments processed with CP was equivalent to that of regular salt processed with N.

Regardless of salt level, ham samples containing N were lighter (higher *L**), more red (larger a*, lower hue angle), and less yellow (lower b*) compared to treatments processed with CP.

RS samples were significantly ($P<0.05$) darker and less yellow compared to LS hams (LS, LS+PL). Hue angle of RS treatment was lower than LS+PL hams but equivalent to LS treatments.

Table 1. Effect of curing agent and salt treatment on colour characteristics of ham slices.

	L*	a*	b*	Hue
Curing agent				
N	67.6a	14.2a	6.1b	23.2b
CP	63.4b	13.4b	6.9a	27.1a
P	*0.00*	*0.02*	*0.00*	*0.00*
Salt treatment				
RS	64.5b	14.0	6.1b	23.7b
LS	66.1a	13.9	6.6a	25.5ab
LS+PL	65.9a	13.6	6.7a	26.2a
P	*0.02*	*0.42*	*0.04*	*0.03*

a, b, Means with different letters in the same column (within each main effect) are significantly different (LSD, $P<0.05$).
[x]N=Nitrite; CP=Celery powder; RS=Regular salt; LS=Low salt; LS+PL=Low salt with potassium lactate

Except for texture, consumer acceptability of ham sensory attributes were unaffected by source of curing agent (Table 2). Texture acceptability of low salt hams with sodium nitrite was lower than low salt counterparts produced with celery powder. Overall, 50% reduction of salt resulted in lower scores for appearance, flavour, aftertaste and overall acceptability compared to control. It is possible that the use of potassium chloride in LS treatments elicited levels of bitterness that led to significantly lower ratings for overall acceptability, flavour and aftertaste. In addition, saltiness acceptability was lowest for LS with PL suggesting that the addition of PL may alter the perceived saltiness of certain reduced sodium meat products. Further investigation of the impact of PL on reduced sodium meat products may be warranted.

IV. CONCLUSIONS

Overall, consumer sensory acceptability results indicate that the use of celery powder as a natural curing agent may be a promising approach towards the production of certain reduced sodium meat products. The use of potassium chloride as a salt replacer leads to a decrease in consumer acceptance of flavour and aftertaste compared to regular salt suggesting that, the use of this salt, at certain levels and in some meat products, remains problematic. Future work investigating the use of alternative strategies towards sodium reduction combined with the application of natural, nitrite-free curing in processed meat products is warranted.

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Table 2**.** Mean score and mean separation test results for main effects of curing agent and salt treatment on consumer acceptability (n=71) of ham slices.

Treatment		Hedonic scores[1]					
		Appearance	Flavour	Saltiness	Texture	Aftertaste	Overall
Curing agent							
N		6.4	6.1	5.9	6.0b	5.8	6.1
CP		6.4	6.3	6.2	6.6a	5.9	6.3
P-value		*0.95*	*0.20*	*0.08*	*0.00*	*0.40*	*0.06*
Salt treatment							
RS		6.7a	6.7a	6.3a	6.9a	6.3a	6.7 a
LS		6.3b	6.0b	6.1a	6.0b	5.8b	6.0 b
LS+PL		6.1b	5.9b	5.7b	6.0b	5.5b	6.0 b
P-value		*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Curing x salt							
N	RS	6.8a	6.7	6.2	6.8a	6.2	6.0bc
	LS	5.9c	5.8	5.9	5.3d	5.7	5.6c
	LS+PL	6.3bc	5.9	5.7	5.9c	5.5	6.0bc
CP	RS	6.6ab	6.8	6.5	7.0a	6.4	6.7a
	LS	6.6ab	6.3	6.4	6.6ab	5.8	6.3ab
	LS+PL	5.9c	6.0	5.7	6.2bc	5.5	6.0bc
P-value		*0.00*	*0.60*	*0.41*	*0.00*	*0.94*	*0.05*

[1]Rated on 9-point hedonic scales:1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much, 9=like extremely

a, b, Within a column and within a treatment effect, mean values followed by different letters are significantly different ($P \leq 0.05$)

[x]N=sodium nitrite; CP=celery powder; RS=regular salt; LS=low salt (50% sodium chloride, 50% potassium chloride); LS+PL=low salt with potassium lactate

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