THE ROLE OF VARIOUS PROCESSES IN MANUFACTURING A LOW SODIUM RESTRUCTURED HAM

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INTRODUCTION

Sodium chloride (NaCl) is an essential ingredient in processed meat products, since it can contribute to: (i) solubilization of meat proteins responsible for the binding and texture of the cooked product (ii) providing the typical salty flavour and (iii) control microbial grwoth. However, sodium reduction, in the Western diet, is currently recommended as a means of decreasing hypertension and subsequent cardiovascular diseases. Growing consumer demand for low salt products has resulted in extensive research aimed to reduce the sodium levels in processed meat products. Some of the ways that have been suggested to do so, without adversely affecting the quality of the meat products include: slight NaCl reduction, replacing NaCl with non-chloride salts, the use of phosphates, altering processing methods (i.e., vacuum tumbling, massaging, use of pre-rigor meat) and/or various combinations of the above.

Among the non-chloride salts potassium chloride (KCl) has been indicated as the most suitable substitute for NaCl. However, due to off-flavour problems only partial substitution with KCl is recommended (Barbut and Findlay, 1989). Phosphate addition can further reduce the amount of NaCl required (Ockerman et al., 1978). The advantages of using mechanical action basically include improvement in tenderness, increasing colour and texture uniformity, and reducing processig time (Pearson and Tauber, 1984).

This paper describes the effects of tumbling parameters and KCl substitution on the quality of reduced sodium restructured ham.

METHODS AND MATERIALS

Experimental design

A rotatable central composite design was used with three variables: (i) tumbling time (6, 8.4, 12, 15.6, and 18 hr) (X1), (ii) tumbling speed (7, 11, 17, 23 and 27 rpm) (X2), and (iii) % KCl substitution (0, 15.2, 37.5, 60 and 75) (X3). This design consisted of 6 central, 6 star and 2^3=(8) factorial experiments i.e. 20 treatments. Tumbling was performed using intermittent cycling (25 min/hr). The minimum and maximum number of cumulative revolutions were 1050 and 12150, respectively. Percent KCl substitution was based on producing an equivalent ionic strength of 2% NaCl (i.e., equivalent ionic strength of 0.342).

Ham preparation

Boneless pork muscles (semi membranosus, adductor, biceps femoris and semi tendinosus) were ground through a kidney plate (Hobart, Don Mills, Ontario), and pork fat was ground three times through a 3.2 cm plate. Lean pork contained 73.3% moisture, 21.5% protein, 4.2% fat and 1.1% ash; and pork fat contained 59.7% fat, 37.3% moisture, 3.1% protein and 0.1% ash. Hams (3.0 kg/treatment) were formulated to contain 10% fat. The raw meat was stored at -20°C until needed and then thawed for 2 days at 2°C.

The total mass of the curing solution in each treatment was equivalent to 15% of the total raw material. Its composition was: 0.012% sodium nitrite, 0.055% sodium erythorbate, 0.25% sodium tripolyphosphate, 0.33% sugar, 0.04% nutmeg and 0.15% black pepper. The variables were NaCl, KCl and water. The raw meat was tumbled under vacuum (67.7 KPa) intermittently (25 min/hr) in a table-top tumbler (Lyco, model 40, Columbus, WI) at 2 C.

Cured meat was stuffed into 60 mm diameter moisture-proof casings (Teepak, Oak Brook, Il) using a hand stuffer (A.M.B., Bologna, Italy). Ham rolls were cooked in a steam jacketed kettle at 73-77°C until an internal temperature of 69-71°C was reached. Cooked ham was cooled in an ice water bath for 30 min, and stored at 2°C.

Quality measurement
Cooking yield (CY) was calculated by dividing the cooked ham mass by the uncooked ham mass. To measure shrinkage (SH), each ham roll was sliced in half to allow the draining of retained juice for 45 min. The shrinkage was computed as the ratio of the change in the ham mass before and after cooking.

A Spectroguard Color System (Pacific Scientific Co., Model 96, Silver Spring, MD) was used to measure the cooked ham colour. The Hunter Color lab scale parameters of 'L', 'a' and 'b' were measured. The centrifugal method of Bouton et al. (1971) was used to determine water holding capacity (WHC).

The Instron Universal Testing Machine (Model 4204) was used to measure the texture profile analysis (TPA) parameters (Bourne, 1978). Each sample (2 cm in dia. and 1.5 cm in height) was compressed twice to 75% of its original height. Cross head and chart speeds were 20 mm/min and 100 mm/min, respectively. TPA parameters included hardness (HARD), cohesiveness (COH), elasticity (ELAS), gumminess (GUM) and chewiness (CHEW). Warner-Bratzler Shear (WBS) was determined by measuring the maximum force (kg) required to shear the cooked samples. Samples' dimensions were similar to the TPA.

The taste panel consisted of 12 to 20 semi-trained judges. They evaluated the colour (COL), tenderness (TEND), juiciness (JUIC), saltiness (SALT), off flavour (OF) and overall acceptability (OA) of the products. The ballot used consisted of 15 cm long horizontal lines (Stone et al., 1974) where the most desirable attribute was at the far right side. Results were obtained by measuring the distance from the left side of the scale in cm.

For statistical analysis, the Statistical Analysis System (SAS 1982) was used.

RESULTS AND DISCUSSION
Regression models were obtained without the intercept term. This was based on the assumption that when tumbling time (X1), tumbling speed (X2), and % KCl substitution (X3) all equal zero, the product can not be prepared. The following models were selected based on the tests of hypothesis concerning the individual parameters in the second order model. The significance of each term in the model met the 20% level. However, individual terms (X1, X2, X3) were added if their interaction terms were significant at 20% level.

Textural parameters

$$\text{WBS (g)} = 114.1\ X1 + 79.8\ X2 + 14.5\ X3 - 5.4\ X1.X3 - 0.97\ X1.X3 \qquad (1)$$
$$R^2 = 0.985,\ \text{MSE} = 62676 \text{ at } 15 \text{ df.}$$

Where R^2 is coefficient of determination, MSE is mean sum of squares of error, and df is degree of freedom for error.

$$\text{HARD (N/cm}^2) = 5.91\ X1 + 2.44\ X2 - 0.17\ X3 - 0.14\ X1^2 - 0.003\ X3^2 - 0.22\ X1.X2 + 0.035\ X1.X3 \qquad (2)$$
$$R^2 = 0.996,\ MSE = 16.1 \text{ at } 13 \text{ df.}$$

$$\text{COH} = 0.028\ X1 + 0.012\ X2 - 0.001\ X3 - 0.001\ X1^2 - 0.001\ X1.X2 + 7E\text{-}5\ X1.X3 \qquad (3)$$
$$R^2 = 0.997,\ MSE = 2.57E\text{-}5 \text{ at } 14 \text{ df.}$$

$$\text{ELAS (cm)} = 0.066\ X1 + 0.018\ X2 + 0.003\ X3 - 0.002\ X1^2 - 3.9\ E\text{-}5\ X3^2 - 0.001\ X1.X2 \qquad (4)$$
$$R^2 = 0.996,\ MSE = 1.8E\text{-}3 \text{ at } 14 \text{ df.}$$

$$\text{GUM (N/cm}^2) = 1.007\ X1 + 1.024\ X2 - 0.078\ X3 - 0.001\ X3^2 - 0.089\ X1.X2 + 0.014\ X1.X3 \qquad (5)$$
$$R^2 = 0.991,\ MSE = 2.18 \text{ at } 14 \text{ df.}$$

$$\text{CHEW (N/cm)} = 0.904\ X1 + 0.484\ X2 - 0.055\ X3 - 0.024\ X1^2 - 9.94E\text{-}4\ X3^2 - 0.042\ X1.X2 + 0.011\ X1.X3 \qquad (6)$$
$$R^2 = 0.992,\ MSE = 1E\text{-}4 \text{ at } 13 \text{ df.}$$

Functional properties

$$\text{SH(5)} = 0.322\ X1 - 0.004\ X1^2 \qquad (7)$$
$$R^2 = 0.862,\ MSE = 1.88 \text{ at } 18 \text{ df.}$$

$$\text{CY} = 0.124\ X1 + 0.042\ X2 + 0.0004\ X3 - 0.003\ X1^2 - 0.003\ X1.X2 \qquad (8)$$
$$R^2 = 0.997,\ MSE = 0.005 \text{ at } 15 \text{ df.}$$

$$\text{WHC of raw ham (5)} = 8.06\ X1 + 4.00\ X2 - 0.18\ X1^2 - 0.06\ X2^2 - 0.17\ X1.X2 \qquad (9)$$
$$R^2 = 0.998,\ MSE = 21.2 \text{ at } 15 \text{ df.}$$

$$\text{WHC of cooked ham (\%)} = 3.84\ X1 + 3.90\ X2 + 0.47\ X3 - 0.05\ X2^2 - 0.16\ X1.X2 - 0.04\ X1.X3 \qquad (10)$$
$$R^2 = 0.997,\ MSE = 19.2 \text{ at } 14 \text{ df.}$$

$$\text{L (lightness)} = 5.85\ X1 + 2.90\ X2 - 0.16\ X1^2 - 0.04\ X2^2 - 0.12\ X1.X2 \qquad (11)$$
$$R^2 = 0.998,\ MSE = 7.13 \text{ at } 15 \text{ df.}$$

$$\text{a (redness)} = 0.114\ X1 + 1.076\ X2 - 0.030\ X2^2 \qquad (12)$$
$$R^2 = 0.990,\ MSE = 1.29 \text{ at } 17 \text{ df.}$$

$$\text{b (yellowness)} = 0.797\ X1 + 0.408\ X2 - 0.004\ X3 - 0.025\ X1^2 - 0.007\ X2^2 - 0.012\ X1.X2 \qquad (13)$$
$$R^2 = 0.998,\ MSE = 0.15 \text{ at } 14 \text{ df.}$$

Sensory attributes

$$\text{Colour} = 1.06\ X1 - 0.04\ X1^2 \qquad (14)$$
$$R^2 = 0.990,\ MSE = 0.46 \text{ at } 18 \text{ df.}$$

$$\text{Tenderness} = -0.575\ X1 + 0.971\ X2 + 0.164\ X3 + 0.054\ X1^2 - 0.016\ X2^2 - 0.002\ X3^2 - 0.037\ X1.X2 \qquad (15)$$
$$R^2 = 0.984,\ MSE = 1.57 \text{ at } 13 \text{ df.}$$

$$\text{Juiciness} = 0.65\ X1 + 0.48\ X2 - 0.04\ X1.X2 \qquad (16)$$
$$R^2 = 0.977,\ MSE = 1.70 \text{ at } 17 \text{ df.}$$

$$\text{Saltiness} = 1.194\,X1 + 0.229\,X2 - 0.088\,X3 - 0.029\,X1^2 + 0.002\,X3^2 - 0.018\,X1.X2 - 0.005\,X1.X3 \quad (17)$$

$R^2 = 0.995$, MSE = 0.47 at 13 df.

$$\text{Off-flavour} = -\,0.016\,X1 + 1.366\,X2 + 0.074\,X3 - 0.039\,X2^2 - 0.003\,X3^2 \quad (18)$$

$R^2 = 0.983$, MSE = 1.88 at 15 df.

$$\text{Overall acceptability} = 2.085\,X1 - 0.069\,X3 - 0.095\,X1^2 - 0.002\,X3^2 + 0.006\,X1.X3 \quad (19)$$

$R^2 = 0.992$, MSE = 0.67 at 15 df.

Process optimization

The above mentioned regression models provide response surfaces, and thus can be used to calculate optimum process conditions. Some of these models can be combined to form composite models. When combined, different weight can be given to the different attributes or parameters. For example, sensory attributes - (colour, tenderness, juiciness, off-flavour and overall acceptability - models) can be combined by giving equal weight to each attribute. The following composite model (SENS) was obtained: (equation 20)

$$SENS = 3.2037\,X1 + 2.8126\,X2 + 0.1686\,X3 - 0.0817\,X1^2 - 0.0554\,X2^2 - 0.0066\,X3^2 - 0.0762\,X1.X2 + 0.0059\,X1.X3$$

The model (20) was maximized using the optimization program of Mittal and Usborne (1986). The optimum process conditions were X1 = 12.4 hr, X2 = 16.8 rpm, and X3 = 18.3% KCl substitution and provided SENS = 45.1. Similar calculations can be performed for other models.

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