EFFECTS OF TUMBLING SPEED AND CUMULATIVE REVOLUTIONS ON RESTRUCTURED HAM

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SUMMARY: Effects of tumbling speed (15 or 25 rpm) and cumulative revolutions of the tumbler (3000, 6000 or 9000) on the production of low sodium restructured ham were investigated. Products processed at 25 rpm and 3,000 revolutions were significantly harder, gummier, and chewier than other treatments.However, these variables had no significant effect on shrinkage and water holding capacity. The hams processed at 25 rpm were significantly darker and chewier; whereas those processed at 3,000 or 9,000 revolutions were the most tender as perceived by the taste panelists. Overall, all the processing schedules resulted in acceptable products as judged by the sensory panel.

INTRODUCTION: Adequate tumbling is an important factor in restructuring products. It affects the texture as well as the appearance of product. Too little tumbling/mixing results in a product that is crumbly with a soft texture. On the other hand, too much mixing, or over-extraction of myofibrillar proteins, results in a rubbery product with a tough skin. Adequate mixing is difficult to achieve, in part due to the differences in protein extractability from muscle to muscle, and in part because of the lack of understanding of the binding mechanism. Thus, the objective of this study was to investigate the effects of tumbling speeds and cumulative revolutions of the tumbler on the qualities of low sodium restructured ham.

MATERIALS AND METHODS: A 2 x 3 x 2 factorial randomized block design involving two replications was used to study the effects of tumbling speed (SPEED = 15 and 25 rpm) and cumulative revolutions (REV = 3000, 6000, and 9000 revolutions) on a (2% NaCl) restructured ham.

Tumbling schedule composed of 3 stages: first tumbling, resting, and second tumbling. Table 1 showed the tumbling cycle and time used in various treatments. The second tumbling time and the overall tumbling time were held constant, for all the treatments, at 1.5 h and 12 h, respectively.

Fresh boneless pork muscles were ground through a kidney plate, and pork fat was ground through a 3.2 cm plate. The ground pork was mixed in a paddle-type mixer for 15 min to ensure raw material homogeneity. The lean pork composition was 72.7% moisture, 22.6% protein, 5.1% fat, and 1.1% ash. Pork fat contained 80.9% fat, 15.6% moisture, 4.4% protein, and 0.1% ash. The meat and fat were packaged in polyethylene bags and frozen (-20°C) for up to 4 weeks. The meat was thawed for 2 days at 2°C and the fat was taken out and reground, while still partially frozen, once through a 5 mm plate to obtain small fat particles. Each treatment was formulated to contain 10% fat (2.2 kg lean

Table 1. - Tumbling cycle and time required in different treatments

Treatment	Tumbling time (min)					
	First Cycle	Rest	Second Cycle	Total time in 12 h	Tumbling rpm	REV
1	110	520	90	200	15	3000
2	310	320	90	400	15	6000
3	510	120	90	600	15	9000
4	30	600	90	120	25	3000
5	150	480	90	240	25	6000
6	270	360	90	360	25	9000

REV= cumulative revolutions of the tumbler

pork and 153.2 g fat). The curing solution (15%) was based on the meat block mass and contained 2% NaCl, 0.33% sugar, 0.25% sodium tripolyphosphate, 0.15% black pepper, 0.04% nutmeg, 0.012% sodium nitrite, and 0.055% sodium erythorbate.

All the raw materials were placed in a Table Top Tumbler under vacuum (68 kPa abs.) and tumbled intermittently at 2°C. The tumbled meat was stuffed into two 76 mm diameter Teepak fibrous, coated with plastic, casings using a hand operated stuffer. The stuffed hams were cooked in a steam jacket maintained at 75 ± 2°C until an internal temperature of 70 ± 1°C was reached. After cooking, hams were cooled in an iced water bath for 30 min and then stored in a cooler (2°C) for 10-12 h prior to further analysis.

Shrinkage (SH) After cooling, the cooked ham rolls were sliced in half to allow the draining of retained juice for 45 min. Shrinkage was calculated by:

[1 - (mass after cooking / mass before cooking)] x 100

Color ("L", "a", and "b") A Spectroguard color system was used to measure the color of four freshly cut surfaces from each cooked ham. The Hunter Color Lab. scale parameters of "L" (surface reflectance, degree of whiteness), "a" (intensity of the red color), and "b" (intensity of the yellow color) were determined.

Water Holding Capacity (WHC) The centrifugal method of Bouton et al. (1971) was used to determine WHC. Six replications per treatment were used for each of the cooked products.

Texture Profile Analysis (TPA) The Instron Universal Testing Machine (model 4204) was used to determine the texture profiles of the samples with 1 kN load cell (Bourne, 1978). Samples (20 mm in diameter and 15 mm in height) were compressed twice to 75% of their height. Cross head and chart speeds were 20 mm/min and 100 mm/min, respectively. The following parameters were calculated: hardness (HARD, N/cm^2), cohesiveness (COH, ratio), elasticity (ELAST, cm), gumminess (GUM, N/cm^2), and chewiness (CHEW, N/cm). Eight replications were used. Samples were evaluated 12 h after cooking.

Warner Bratzler Shear (WBS) A single blade WBS was used to measure the maximum force (g) required to shear the cooked samples (Voisey and Larmond, 1974) using the same dimension as used for the TPA test.

Sensory Evaluation The taste panel was composed of 13 semi-trained judges. Sensory evaluations were carried out by graduate students of the Food Science Department, who had broad experience in sensory evaluation of food products and were also trained to evaluate the restructured ham product. The evaluation took place in a room equipped with individual booths under a daylight atmosphere. Water was available for the individual judges to rinse their mouth. Round ham samples (4 mm thick) were placed on a white paper plate and coded with a randomized three digit number. Each judge evaluated the color intensity (1 = very pale, 15 = very dark), tenderness (1 = tough, 15 = tender), juiciness (1 = dry, 15 = juicy), chewiness (1 = chewy, 15 = not chewy), off-flavor (1 = pronounce off-flavor, 15 = no off-flavor), and overall acceptability (1 = dislike, 15 = like) of the product. The ballot used consisted of 15 cm long horizontal lines (Stone et al., 1974). Each panelists marked the scale between these two endpoints. Results were obtained by measuring the distance from the left side of the scale to the judge's rating in cm.

Statistical analyses were conducted using the SAS-Statistical Analysis System (SAS, 1985) on an IBM 3081D mainframe computer. Analysis of variance (ANOVA) was used to test the effects of 6 treatments, tumbling speed (SPEED) and cumulative revolutions (REV). If ANOVA showed a significant difference, means were separated by using Duncan's test.

RESULTS AND DISCUSSION

Proximate Composition: The ANOVA and Duncan's tests indicated no effect of any variable on proximate composition - moisture, ash, protein and fat contents.

Shrinkage (SH) and Water Holding Capacity: The ANOVA and Duncan's tests showed that speed, REV, and speed x REV interaction had no

Table 2. Duncan's test results for different textural and sensory parameters w.r.t. treatments

Treatment	'L'	'a'	Hardness, N/cm^2	Gumminess, N/cm^2	Chewiness, N/cm	Sensory		
						Colour	Tender ness	Off flavour
1	59ab	11.1ab	47ab	11.6abc	6.2bc	6.7bc	6.9cd	8.8b
2	69ab	9.7b	41c	10.3bc	5.1c	5.6d	7.9abc	9.4ab
3	60ab	12.1a	39c	9.2c	4.8c	6.3cd	7.5bcd	9.5ab
4	58b	10.6ab	52a	14.3a	8.8a	7.6ab	8.2ab	9.0ab
5	60ab	10.1b	49a	13.1ab	7.7ab	8.0a	6.6d	9.0ab
6	62a	9.6b	43bc	9.8c	5.5c	5.3d	8.7a	10.3a

means with identical letters in the same columns are not significanthly different at 5% level.
'L'=reflectance, and 'a'=redness.

significant effect on SH and WHC. Overall, 15 rpm and 3,000 REV were sufficient to achieve the optimum shrinkage and WHC in the restructured ham. The correlations suggested that as shrinkage increased, water holding capacity decreased, which confirmed the findings of Rejt et al. (1978) for massaged and nonmassaged meat.

Hunter Color Parameters : Treatment means comparison (Table 2) indicated that the treatments significantly affected surface reflectance (L) only in treatments 4 (25 rpm and 3000 REV) and 6 (25 rpm and 6000 REV). Treatment 3 had the highest redness ('a'), and treatments 2, 5 and 6 had lower values. This suggested that low speed (15 rpm) with 9000 REV resulted in more red color intensity compared to other treatments.

Warner Bratzler Shear (WBS) and Texture Profile Analysis (TPA) The ANOVA showed that speed, REV, and speed x REV interaction did not significantly affect WBS. The ANOVA showed that cohesiveness (COH) was the only parameter that was not significantly affected by speed, REV, and speed x REV interaction. The speed significantly affected hardness, elasticity, gumminess, and chewiness. The REV significantly affected hardness, gumminess and chewiness. There was no significant effect of speed x REV interaction on any of the TPA parameters. The Duncan's test (Table 3) showed that 25 rpm treatment had significantly higher hardness, elasticity, gumminess and chewiness than those of 15 rpm treatment. This indicated that the use of higher speed (25

Table 3.- Duncan's test results for textural and sensory parameters w.r.t. speed

Speed rpm	Hardness N/cm^2	Elasticity cm	Gumminess N/cm^2	Chewiness N/cm	Sensory Colour	Sensory Chewiness
15	42.6b	0.52b	10.4b	5.4b	6.2b	6.7b
25	47.8a	0.58a	12.4a	7.3a	7.0a	7.6a

Means with identical letters in the same columns are not significantly different at 5% level.

rpm) contributed to the firmness (higher hardness) and elasticity of the product. This would be expected since vigorous tumbling at 25 rpm caused an increase in cell disruption and extraction of more myofibrillar proteins. Upon heating, these myofibrillar proteins are coagulated and contributed to a rigid and firm cooked product structure. Gumminess and chewiness are directly related to hardness and elasticity, therefore these were also significantly affected by tumbling speed.

All REV levels significantly affected hardness (Table 4). Hams processed at 9,000 REV had significantly lower gumminess and chewiness than those processed at 3,000 and 6,000 REV. These results suggested that as REV increased above 6,000; hardness, gumminess and chewiness decreased. The correlations indicated that products with higher texture profile parameters (except elasticity) were rated higher in color intensity by the panel. Furthermore, products having lower cohesiveness and gumminess were got higher flavor scores by the panel.

Sensory Evaluation: The ANOVA showed that speed, REV, speed x REV interaction did not significantly affect off-flavor and overall acceptability. Furthermore, the Duncan's test demonstrated that all the 6 treatments were equally acceptable by the semi-trained sensory panelists. The Pearson correlation indicated that overall acceptance was significantly correlated with sensory color intensity ($r = -0.60$), sensory tenderness ($r = 0.64$), and off-flavor ($r = 0.82$). These correlations suggested that products which were paler in color, higher in tenderness, and with low off-flavor were most preferred by the panelists.

The ANOVA showed that speed, REV, and speed x REV interaction significantly affected color. The Duncan's test (Table 3) showed that ham tumbled at 25 rpm had significantly darker color than that at 15 rpm. The darker color at 25 rpm was probably due to more mechanical agitation which accelerated the distribution of cure ingredients uniformly throughout the product. The Duncan's test (Table 4) showed that ham processed at 9,000 REV had significantly lower color intensity than those at 3000 and 6000 REV.

Table 4.- Duncan's test results for textural and sensory parameters w.r.t. cumulative revolutions

Revolutions Number	Hardness N/cm^2	Gumminess N/cm^2	Chewiness N/cm^2	Sensory Colour	Sensory Tenderness
3000	49.4a	13.0a	7.5a	7.2a	7.6ab
6000	45.2b	11.7a	6.4a	6.8a	7.2b
9000	41.0c	9.5b	5.2b	5.8b	8.1a

means with the identical letters in the same columns are not significantly different at 5% level.

In addition, the Duncan's test (Table 2) indicated that treatment 5 (25 rpm and 6,000 REV) had the highest color intensity. This suggested that total tumbling revolutions above 6,000 REV decreased color intensity.

Tumbling speed did not significantly affect tenderness. The Duncan's test showed that the tenderness at both tumbling speeds (15 and 25 rpm) were not significantly different. The tenderness was significantly affected by REV and speed x REV interaction. Table 4 showed that there was a significant difference in tenderness for products processed at 6,000 and 9,000 REV. Hams processed at 9,000 REV were the most tender. The Duncan's test (Table 2) indicated that treatment 6 (25 rpm and 9,000 REV) was the most tender in comparison to some other treatments.

Speed significantly affected sensory chewiness. It did not significantly correlate with TPA-chewiness. This could be due to the different interpretation of chewiness by instrument and sensory evaluation. The Duncan's test showed that the two tumbling speeds (15 and 25 rpm) were not significantly different in juiciness. Overall, products tumbled at 25 rpm were significantly less chewy than that at 15 rpm.

Conclusions: Restructured hams processed at 25 rpm and 3000 total revolutions of the tumbler were significantly harder, gummier and chewier. The hams processed at 25 rpm were significantly darker and chewier and hams processed at 9000 revolutions were the least gummier and chewier.

REFERENCES:

Bourne, M. C.(1978). Food Technology 32(7): 62.

Bouton, P.E., Harris, P.V. and Shorthouse, W.R. (1971). J. Food Sci. 36: 435.

Rejt, J., Kubicka, H. and Pisula, A. (1978). Meat Sci. 2: 145.

SAS. 1985. SAS User's Guide: Statistics. Statistical Analysis System Institute, Inc. Cary, N.C.

Stone, H., Sidel, J., Oliver, S., Woolsey, A. and Singleton, R.C. (1974). Food Technology 28 (11): 24.

Voisey, P.W. and Larmond, E. (1974). J. Can. Inst. Food. Sci. Technology. 7 (4): 243.