J Food Sci Technol (July 2014) 51(7):1363–1369
DOI 10.1007/s13197-012-0644-9

ORIGINAL ARTICLE

Effect of meat chunk size, massaging time and cooking time on quality of restructured pork blocks

A. M. Gurikar · V. Lakshmanan · Y. P. Gadekar · B. D. Sharma · A. S. R. Anjaneyulu

Revised: 28 January 2012 / Accepted: 3 February 2012 / Published online: 18 February 2012

Abstract In the present study, effect of meat chunk size (2–3 and 4–5 cm), massaging time (6, 8 and 10 min) and cooking time (40, 45 and 50 min) on quality of restructured pork blocks was evaluated. Higher product yield (89.31%) was obtained with chunk size of 2–3 cm compared to blocks prepared from chunk size of 4–5 cm (85.12%). PH and shear force values were comparable. Among sensory attributes appearance and overall palatability was significantly higher for product prepared from chunk size of 2–3 cm. Increase in massage time from 6 min to 10 min resulted in improvement in product yield and reduction in shear force value. All the sensory attributes improved with the increasing massaging time except the flavour, which remained constant. Ten minutes of massaging time was found optimum due to higher product yield, significantly better appearance, texture and overall palatability than 6 and 8 min of massaging. In cooking time, it was found that product yield and shear force values were inversely proportional to the cooking time. Sensory attributes were comparable. Cooking time of 50 min was found optimum in view of better sensory attributes of the product than 40 and 45 min of cooking. From the present study it can be concluded that Meat chunk size of 2–3 cm, massaging time of 10 min and cooking time of 50 min was found optimum for making restructured pork blocks in the view of better sensory attributes of the product.

Keywords Restructured pork blocks · Cooking time · Massaging time and meat chunk size

A. M. Gurikar · V. Lakshmanan · Y. P. Gadekar · B. D. Sharma · A. S. R. Anjaneyulu
Division of Livestock Products Technology,
Indian Veterinary Research Institute,
Izatnagar,
Bareilly, UP 243 122, India

A. S. R. Anjaneyulu
National Research Centre on Meat,
Hyderabad, India

Y. P. Gadekar (✉)
Meat Science and Pelt Technology Section,
Central Sheep and Wool Research Institute, Avikanagar,
Malpura, Rajasthan, India
e-mail: yogirajlpt@gmail.com

Introduction

In view of the rapid increasing demand for meat products and changing trends to fast food consumption in cities, there is a need to develop low cost processed meats with higher health and nutritional values and also convenience at preparation. The meat industry has experienced numerous innovations in the processing of meat products. One such approach is the development of restructured meat products.

Restructuring is a method in which the meat is partially or completely disassembled and then reformed into same or a different form. Restructuring has the advantages of convenience in preparation and economy in the production due to which the restructured products are becoming important components of the processed meat industry. Restructured meat products are made by extraction of muscle proteins using salt and phosphate which forms a heat set protein gel upon subsequent cooking (Raharjo et al. 1994).

Restructured meat products are commonly prepared using different methods of size reduction viz. chunking and forming, flaking and forming, sectioning and forming or combination of the above methods. Finer the particle size, the larger is the surface area and greater, the release of muscle proteins. Fine flake size produced a more acceptable appearance, increased tenderness and decreased shear force

value (Berry et al. 1987). In restructuring, tumbling and massaging are the two techniques routinely used. Tumbling utilizes impact energy while massaging utilizes frictional energy. The basic aim of both these techniques is to extract enough salt soluble proteins to enhance the tenderness, juiciness and slicing characteristics.

Product yields are dependent on time, temperature, cooking method and type of meat. Huffman et al. (1981) reported increase in cook yield with increase in salt level and phosphate level for restructured pork chops. Lower cook yield and correspondingly lower moisture of the cooked samples were obtained at 100 °C than at 70 °C (Arganosa et al. 1991). Highly acceptable restructured chicken block was developed with incorporation of gizzard and fat and with shelf life of 10 days under refrigerated storage condition (Sudheer et al. 2011).

The aim of present study was to evaluate effect of meat chunk size, massaging time and cooking time on quality of restructured pork blocks.

Materials and methods

Materials

Hams were obtained from crossbred pigs (Landrace × desi) weighing between 60 and 70 kg slaughtered in Divisional Experimental Abattoir. The deboning of hams was done after chilling (4±1 °C) them overnight. After the removal of all external fat, fascia and separable connective tissue, pork was packed in low density polyethylene bags and stored in the freezer for subsequent use in experiments after proper thawing. Condiments mix was prepared with onions and garlics by cutting into small pieces and then homogenized in a domestic mixer in 3:1 ratio to obtain a fine paste.

The technique for preparation of restructured pork blocks

The massaging technique was used for the preparation of restructured pork blocks. The curing solution consisted sodium chloride 120.0 g, cane sugar 60.0 g, sodium tripolyphosphate 25.0 g, monosodium glutamate (MSG) 0.5 g, sodium nitrite 0.75 g and 1,000 ml water. The ingredients were dissolved in 1 l distilled water and filtered through sieve (2 mm^2 pore size).

Experiment 1: Standardization of meat chunk size for processing of restructured pork blocks

The pork was first cut into pieces of two different sizes viz 2–3 cm, 4–5 cm. The curing solution was prepared as per the composition mentioned above. For 1 kg of pork pieces, 200 ml of curing solution and 5% condiments were added in the peddle mixer. Now the massaging was done to a fixed time (12 min) for both the batches (2–3 cm, 4–5 ms). The pork mix (batter) thus obtained was filled into aluminium moulds ($16^{1/2}$X8X6 cm^3) and was steam cooked for 50 min.

The boxes were removed from cooker and were allowed to cool. The pork blocks were removed and kept for chilling in refrigerator (4±1 °C). The weight of the individual blocks was recorded for the calculation of product yield. The pork blocks were made into slices of 5 mm thickness using slicer (OMAS, Type H 300, Italy).

Experiment 2: Standardization of massaging time for processing of restructured pork blocks

Pork chunks of 2–3 cm were made. Three batches each of which containing 500 g of pork chunks were put in the peddle mixer with curing solution and condiments and massaged for three different timings viz 6 min, 8 min and 10 min at a constant speed. The batter thus obtained was filled into aluminium moulds and was cooked for 50 min. The pork blocks were then removed, chilled and cut into slices for sensory evaluation.

Experiment 3: Standardization of the cooking time for processing of restructured pork blocks

For the standardization of the cooking time, 1,500 g of pork chunks (2–3 cm) with curing solution and condiments were massaged for 10 min. The pork mix was filled into three different aluminium moulds and subjected to three different cooking time viz 40 min, 45 min and 50 min. The pork blocks were then removed, chilled and cut into slices of 5 mm thickness for sensory evaluation.

Analytical procedure

pH

pH of the restructured pork slices was determined by using the method described by Strange et al. (1977). Ten grams of sample was homogenised with 50 ml distilled water for 1 min in Ultra Turrax (T-25 Germany) tissue homogenizer. The pH of the suspension was recorded by dipping the combined glass electrode of digital pH meter (Elico, India, Model LI 127).

Product yield

The weight of restructured pork blocks before and after cooking was recorded. The product yield was calculated as below:

$$\text{Product yield}\,(\%) = \frac{\text{Weight of cooked blocks}}{\text{Weight of raw blocks}} \times 100$$

Batter stability (ES)

The batter stability was determined by the procedure described by Kondaiah et al. (1985). About 25 g of batter in triplicate were taken in polyethylene bags and heated in a thermostatically controlled water bath at 80 °C for 20 min. After draining out the exudate, the cooked mass was cooled and weighed. The percentage of cooked batter was expressed as batter stability. Cooking loss of the product was inversely proportional to its emulsion/batter stability.

Shear force value (SFV)

The restructured pork block was bored at different points with the help of a borer of 1 cm diameter. The bored pieces were sheared in the Warner-Bratzler Shear Press Apparatus (Model 81031307, G.R. Elect. Mfg. Co., USA). For each sample, 15 observations were recorded to obtain the average value of shear force and were expressed in kg/cm^3.

Texture profile analysis (TPA)

Texture profile analysis of restructured pork blocks was recorded as per the procedure described by Bourne (1978) using the texturometer TA-XT Texture Analyzer (Stable Microsystem Ltd, Surray, England). Refrigerated samples were allowed to thaw to room temperature (25 °C). Uniform sized pieces (1.5 cm × 1.5 cm) of each block were used as the test samples. The test sample was placed on the platform fixture and compressed to 80% of their original height at a cross head speed of 2 mm/s through two cycle sequence, using 50 kg load cell and 75 mm compression platen probe (P75). The test conditions were Version: W 11, Option: TPA, pretest speed: 10 mm per sec and trigger type: auto. Textural variables from force and area measurement were represented as TPA parameters (Bourne 1978). Three samples were analyzed under each treatment and the readings were averaged.

The TPA parameters computed were: Hardness (N): Peak force during the first compression cycle (maximum force/energy required to compress the sample), Cohesiveness: Ratio of the positive force area during second compression to that during the first compression (OR) and (The) ratio of the active work done under the second force displacement curve (A_2) to that done under the first compression curve (A_1) i.e. A2/A1 OR the extent to which sample could be deformed prior to rupture, Springiness (cm): Height to which the sample recovers during the time that elapses between end of the first bite and start of second bite OR the distance recovered by the sample after the first compression i.e. ability of sample to recover to its original height after the deforming force was removed, Gumminess (N/cm^2): Force required for complete disintegration of semisolid samples for swallowing i.e. hardness x cohesiveness, Chewiness (N/cm): Work required to masticate the sample for swallowing i.e. springiness x gumminess, Adhesiveness: negative force area for the first bite, representing the work necessary to pull the compressing plunger away from the sample.

Sensory evaluation of restructured pork slices

A sensory evaluation scale with an 8 point descriptive scale was developed with slight modification of 6 point descriptive scale by Ghavimi et al. 1987 was followed, where 8 = excellent; 1 = extremely poor. The panelists consisted of scientists and postgraduate students of the division. Samples were warmed in microwave oven for 1 min and served to the panelists. Water was provided to rinse the mouth between the samples. The panelists judged the samples for the attributes of general appearance, presence of spaces, presence of pin holes, flavour, juiciness, texture, binding and overall palatability.

Statistical analysis

Data generated from the three trials were evaluated statistically (Snedecor and Cochran 1994) by analysis of variance (ANOVA) at the institute's computer centre for estimation of means and comparison of means for statistical significance.

Results and discussion

Product yield

There was marked higher yield of restructured pork block prepared with smaller size (2–3 cm) meat chunks than the product made with larger size (4–5 cm) meat chunks (Table 1). Chesney et al. (1978) found that the use of small flakes produced lower cooking loss i.e. increased product yield than the medium and large flakes in flaked and formed pork chops. Sen and Karim (2003) reported that yield of restructured mutton steakettes increased significantly with smaller flake size. Cofrades et al. (2004) also reported similar findings.

As the massaging time increased from 6 min to 10 min, there was an improvement in the product yield (Table 2). This might be due to extraction of more proteins, which prevented cooking losses. Results are in agreement with Booren et al. (1981), Pietrasik and Shand (2004) and Lachowicz et al. (2003).

When cooking time increased, the core temperature of the product increased resulting into the lower product yield

Table 1 Effect of meat chunk size on quality of restructured pork blocks

Parameters	Meat chunk size	
	2–3 cm	4–5 cm
Product yield (%)	89.3±0.00	85.1±0.00
pH	6.8±0.01	6.7±0.01
Shear force (N)	2.1±0.00	2.7±0.00
Textural properties		
Hardness (N/cm_2)	39.0±0.41	43.0±0.52
Gumminess (N/cm_2)	22.7±0.49	25.7±0.84
Chewiness (N/cm)	20.1±0.51	22.2±0.73
Adhesivenss (Ns)	0.02±0.01	0.02±0.01
Springiness (cm)	0.89±0.01	0.87±0.02
Cohesiveness (Ratio)	0.58±0.01	0.60±0.03
Sensory attributes[a]		
Appearance	7.1±0.14[a]	6.6±0.14[b]
Presence of space	7.2±0.08	7.0±0.00
Presence of pinholes	7.0±0.00	7.0±0.00
Flavour	7.1±0.16	6.8±0.15
Juiciness	7.0±0.00	6.9±0.07
Texture	7.1±0.13	6.7±0.14
Binding	7.1±0.13	6.8±0.17
Overall palatability	7.2±0.12[a]	6.7±0.14[b]

[a] Based on 8 point scale, where 8 = extremely desirable and 1 = extremely undesirable. Means in the same row with different superscripts indicate significant difference ($p<0.05$), $n=9$

(Table 3). Arganosa et al. (1991) reported lower cook yield and correspondingly lesser moisture content of the cooked samples at 100 °C than at 70 °C. Vasanthi et al. (2007) and Combes et al. (2003) reported higher cooking loss with the increasing cooking time.

pH

The pH of the product was higher as the meat chunk size decreased. This is in agreement with the results of Sen and Karim (2003) in restructured mutton steaks. However, Berry et al. (1999) and Suman and Sharma (2003) and reported that grind size had no influence on pH.

Increase in pH of restructured pork blocks prepared with increasing massaging time i.e. from 6 min to 10 min was observed. Plimpton et al. (1991) reported that salt treated samples had higher pH after tumbling irrespective of pre or post-rigor non tumbled samples.

There was slight increase in pH as the cooking time increased (Table 3). This increase in pH might be attributed to the loss of free acidic groups (Lawrie 1979).Vasanthi et al. (2007) reported increase in pH with the increasing cooking time.

Shear force

The restructured pork block prepared with smaller meat chunks (2–3 cm) had significantly lesser shear force value and were more tender compared to restructured pork block prepared with larger meat chunks (4–5 cm). Chesney et al. (1978), McDermott et al. (1999) and Berry et al. (1999) reported higher tenderness in restructured pork chops, reformed pork shoulder product and cooked beef patties, respectively made with smaller flakes. Berry et al. (1987) also found the lower shear force in restructured pork steaks processed from smaller flakes. Suman and Sharma (2003) and Roth et al. (1999) reported significant decrease in shear force as the meat particle size decreased.

As the massaging time increased from 6 min to 10 min shear force value of the products decreased. Similar findings of decrease in shear force with the increasing massaging time were reported by Booren et al. (1981) and Pietrasik and Shand (2004).

With increased cooking time of the product, shear force value decreased. This might be due to higher core temperature of the product obtained during longer

Table 2 Effect of massaging time on quality of restructured pork blocks

Parameters	Massaging time (minutes)		
	6	8	10
Product yield (%)	83.2±0.00	85.8±0.00	87.9±0.00
pH	6.5±0.02	6.6±0.01	6.7±0.01
Shear force (N)	3.5±0.00	3.5±0.00	2.2±0.00
Textural properties			
Hardness (N/cm_2)	52.3±0.37[a]	51.8±0.93[a]	42.1±0.93[a]
Gumminess (N/cm_2)	27.2±0.30[a]	30.9±0.64[b]	24.1±0.94[a]
Chewiness (N/cm)	23.0±0.52[ab]	26.3±0.71[b]	21.4±0.78[a]
Adhesivenss (Ns)	−0.04±0.00	0.004±0.01	0.02±0.01
Springiness (cm)	0.84±0.01	0.85±0.01	0.89±0.01
Cohesiveness (Ratio)	0.54±0.01	0.60±0.02	0.57±0.03
Sensory attributes[a]			
Appearance	6.0±0.26[a]	6.3±0.17[a]	7.0±0.13[b]
Presence of space	5.3±0.21[a]	6.1±0.08[b]	6.9±0.08[c]
Presence of pinholes	5.5±0.22[a]	6.1±0.08[b]	6.7±0.17[c]
Flavour	6.8±0.11	6.8±0.11	6.8±0.11
Juiciness	6.4±0.20	6.5±0.22	6.8±0.11
Texture	6.2±0.17[a]	6.2±0.11[a]	6.7±0.17[b]
Binding	6.1±0.15[a]	6.3±0.11[a]	6.8±0.17[b]
Overall palatability	6.0±0.18[a]	6.3±0.11[a]	6.9±0.08[b]

[a] Based on 8 point scale, where 8 = extremely desirable and 1 = extremely undesirable. Means in the same row with different superscripts indicate significant difference ($p<0.05$), $n=6$

Table 3 Effect of cooking time on quality of restructured pork blocks

Parameters	Cooking time (minutes)		
	40	45	50s
Product yield (%)	90.3±0.00	89.1±0.00	87.5±0.00
pH	6.2±0.01	6.2±0.01	6.3±0.01
Shear force (N)	2.3±0.00	1.9±0.00	1.8±0.00
Textural properties			
Hardness (N/cm_2)	52.3±0.23[a]	48.9±0.95[b]	43.6±0.62[c]
Gumminess (N/cm_2)	28.5±0.78	28.2±0.91	25.0±0.85
Chewiness (N/cm)	24.0±0.88	23.7±0.85	21.6±0.95
Adhesivenss (Ns)	−0.040±0.03	−0.036±0.04	0.014±0.01
Springiness (cm)	0.84±0.01	0.84±0.01	0.86±0.01
Cohesiveness (Ratio)	0.54±0.01	0.58±0.04	0.58±0.05
Sensory attributes[a]			
Appearance	6.7±0.17	6.8±0.11	7.0±0.18
Presence of space	6.8±0.11	6.2±0.28	6.3±0.17
Presence of pinholes	6.7±0.11	6.3±0.31	6.5±0.22
Flavour	6.9±0.20	6.8±0.25	6.9±0.15
Juiciness	6.5±0.13	6.5±0.32	6.9±0.15
Texture	6.5±0.26	6.5±0.26	6.8±0.17
Binding	6.7±0.17	6.6±0.15	6.6±0.15
Overall palatability	6.4±0.15	6.5±0.23	6.8±0.21

[a] Based on 8 point scale, where 8 = extremely desirable and 1 = extremely undesirable. Means in the same row with different superscripts indicate significant difference ($p<0.05$), $n=6$

period of cooking. Draut (1972) attributed this decrease in shear force to the solubilisation of collagen, which increases with increasing temperature. Vasanthi et al. (2007) reported decrease in shear force value as the cooking time increased.

Texture profile analysis

Hardness value of the restructured pork block prepared with larger meat chunks (4–5 cm) was higher than the products made with smaller meat chunks (2–3 cm). There were also higher gumminess, chewiness and cohesiveness values for the restructured pork block prepared with large size meat chunks. There was no change in the adhesiveness of the products. However, springiness value was more in restructured pork block prepared with smaller size meat chunks than the products made with large size meat chunks. Suman and Sharma (2003) and Roth et al. (1999) reported lower hardness as the meat particle size reduced. Berry et al. (1999) also reported decreased hardness and chewiness values in cooked beef patties prepared with smaller grind size. Barbut (1990) observed lower hardness values in pork bologna with smaller lean particle size. Small et al. (1995) also reported an increase in hardness and more peak energy requirement for pork frankfurters with increase in particle size.

The hardness value decreased significantly with the increase in massaging time i.e. from 6 min to 10 min. This might be due to decreased shear force value with increase of massaging time. Zochowska et al. (2007), Pietrasik and Shand (2004) reported decrease in hardness with the increasing massaging time. Lachowicz et al. (2003) also found decrease in hardness, cohesiveness and chewiness with the increasing massaging time. Adhesiveness and springiness also decreased with increasing massaging time, but with no significant difference. Gumminess and chewiness values were significantly higher in restructured product massaged with 8 min than the product massaged for 10 min.

The hardness of the product decreased significantly with increasing cooking time from 40 min to 50 min, which might be due to decrease in the shear force of the product with increasing cooking time. Negative value of adhesiveness indicates gooieness of the products. Vasanthi et al. (2007) reported increase in tenderness with increasing cooking time. Gumminess, chewiness and adhesiveness also decreased with increased cooking time, but no significant difference was observed. There was slight increase in springiness and cohesiveness of the product cooked to 50 min than the product cooked for 40 min.

Sensory evaluation

The appearance and overall palatability were significantly better for the restructured pork blocks made with the smaller meat chunks (2–3 cm). All other attributes like presence of spaces and pinholes in the slices declined while flavour, juiciness, texture and binding of the products improved as the meat chunk size decreased, but there was no significant difference between them. Small et al. (1995) reported higher sensory scores at lower particle size of 1.4 cm than 2.0 cm in pork frankfurters. Berry et al. (1999) reported increase in tenderness of hot processed ground beef with decrease in particle size from 0.95, 0.48 to 0.32 cm. Suman and Sharma (2003) reported significant increase of overall palatability in patties prepared with smaller grind size and attributed this to the increased binding due to smaller particle size. However, Sen and Karim (2003) reported that meat particle size reduction had no significant effect on acceptability of restructured mutton steaks. Similarly, Marriot et al. (1986) reported that particle size had no effect on flavour and juiciness of restructured pork, but tenderness decreased as particle size increased from 3 to 9.9 mm. Meat chunk size of 2–3 cm was selected for further studies due to higher product yield and significantly better appearance and overall acceptability of the products.

As the massaging time increased, the appearance, texture, binding and overall palatability also improved significantly. Even there was significant decrease in spaces and pinholes in the slices. There was no significant difference in flavour and juiciness. But juiciness increased with increasing massaging time. Gillet et al. (1981) reported that as the massaging time increased, the bind also enhanced in ham slices. Booren et al. (1981) reported that flavour and juiciness improved with increased mixing time. A massaging time of 10 min was chosen for further studies in view of higher product yield, significantly better appearance, texture and overall acceptability.

There was no significant difference in sensory attributes of products cooked for different periods. However, there was an improvement in appearance, juiciness, texture and overall palatability of the product cooked for 50 min than those cooked for 45 and 40 min. Vasanthi et al. (2007) reported similar higher sensory scores as the cooking time increased. Cooking time of 50 min was selected for making restructured pork blocks in view of better sensory attributes of the product.

Conclusions

Meat chunk size of 2–3 cm was found better due to higher product yield and significantly better appearance and overall acceptability of the products. All the sensory attributes improved with the increasing massaging time except the flavour, which remained constant. Massaging time of 10 min was found to be optimum as it gave higher product yield, significantly better appearance, texture and overall acceptability. Cooking time of 50 min was found suitable for making restructured pork blocks in the view of better sensory attributes of the product.

Acknowledgement The first author gratefully acknowledges the financial assistance in the form of Institute Research Fellowship provided by Director, IVRI, Izatnagar.

References

Arganosa GC, Godber JS, Tanchotikul U, McMilan KW, Shao KP (1991) Processing ingredients affecting oxidative and textural stability of restructured beef roasts. J Food Sci 56:1480–1483, 1496

Barbut S (1990) Effects of three chopping methods on bologna characteristics. Can Inst Food Sci Technol J 23:149–153

Berry BW, Smith JJ, Secrist JL (1987) Effects of flake size on textural and cooking properties of restructured beef and pork steaks. J Food Sci 52:558–563

Berry BW, George MEB, Eastridge JS (1999) Hot processing and grind size affect properties of cooked beef patties. Meat Sci 53:37–43

Booren AM, Mandigo DG, Olson DG, Jones KW (1981) Effect of muscle type and mixing time on sectioned and formed beef steaks. J Food Sci 46:1665–1668, 1672

Bourne MC (1978) Texture profile analysis. J Food Sci 32:62–66, 67

Chesney MS, Mandigo RW, Campbell JF (1978) Properties of restructured pork products as influenced by meat particle size, temperature and comminution methods. J Food Sci 43:1535–1537

Cofrades S, Serrano A, Ayo J, Solas MT, Carballo J, Colmenero FJ (2004) Restructured beef with different proportions of walnut as affected by meat particle size. Eur Food Res Technol 218:230–236

Combes S, Lepetit J, Darche B, Lebas F (2003) Effect of cooking temperature and cooking time on Warner-Bratzler tenderness measurement and collagen content in rabbit meat. Meat Sci 66:91–96

Draut HN (1972) Changes in meat during cooking. In: Presented at the 25th annual reciprocal meat conference of the American Meat Science Association, pp 243–259

Ghavimi B, Althen TG, Rogers RW (1987) Effect of tumbling at various speeds on some characteristics of restructured cured beef. J Food Sci 52(3):543–544, 553

Gillet TA, Cassidy RD, Simon S (1981) Effect of continuous massaging on bind, yield and colour of hams. J Food Sci 46:1681–1684

Huffman DL, Ly AM, Cordray JC (1981) Effect of salt concentration on quality of restructured pork chops. J Food Sci 46:1563

Kondaiah N, Anjaneyulu ASR, Rao VK, Sharma N, Joshi HB (1985) Effect of salt and phosphate on the quality of buffalo and goat meat. Meat Sci 15:183–192

Lachowicz K, Sobczak M, Gajowiecki L, Zych H (2003) Effects of massaging time on texture, rheological properties, and structure of three pork ham muscles. Meat Sci 63:225–233

Lawrie RA (1979) The storage and preservation of meat II moisture control. In: Lawrie RA (ed) Meat science 3rd edn. Pergamon, Oxford, pp 243

Marriot NG, Phelps SK, Costello CA, Graham PP (1986) Restructured pork with texture variation. J Food Quality 10:425–435

McDermott M, Mitchell PC, Welch RW (1999) Effects of meat piece size and phosphate on maximum slicing rate, cooking loss and sensory quality of a re-formed pigmeat shoulder product. Int J Food Sci Technol 34:101–106

Pietrasik Z, Shand PJ (2004) Effect of blade tenderization and tumbling time on the processing characteristics and tenderness of injected cooked roast beef. Meat Sci 66:871–879

Plimpton RF, Perkins CJ, Sefton TL, Cahill VR, Ockerman HW (1991) Rigor condition, tumbling and salt level influence on physical, chemical and quality characteristics of cured, boneless hams. J Food Sci 56:6

Raharjo S, Dexter DR, Worfel RC, Sofos JN, Solomon MB, Shultz GW, Schmidt GR (1994) Restructuring veal steaks with salt/phosphate and sodium alginate/calcium lactate. J Food Sci 59 (3):471–473

Roth DM, Mckeith FK, Brewer MS (1999) Processing parameters effects on sensory and instrumental texture characteristics of reduced fat ground beef patties. J Muscle Foods 10:163–176

Sen AR, Karim SA (2003) Effect of meat particle size on quality attributes of restructured mutton steaks. J Food Sci Technol 40:423–425

Small AD, Claus JR, Wang H, Marriott NG (1995) Particle size and mixing time effects on sensory and physical properties of low-fat, high-moisture pork frankfurters. J Food Sci 60:40–41, 54

Snedecor GW, Cochran WG (1994) Statistical methods, 8th edn. IOWA State University Press, Ames, pp 136–157

Strange ED, Benedict RC, Smith JL, Swift CE (1977) Evaluation of rapid test for monitoring alteration in meat quality during storage I. Intact meat. J Food Prot 40:843–847

Sudheer K, Mandal PK, Das C, Pal UK, Santoshkumar HT, Rao VK (2011) Development of restructured chicken block utilizing

gizzard and its refrigerated storage stability. J Food Sci Technol 48:96–101

Suman SP, Sharma BD (2003) Effect of grind size and fat levels on the physico-chemical and sensory characteristics of low-fat ground buffalo meat patties. Meat Sci 65:973–976

Vasanthi C, Venkataramanujam V, Dushyanthan K (2007) Effect of cooking temperature and time on the physico-chemical, histological and sensory properties of female carabeef (buffalo). Meat Sci 76:274–280

Zochowska J, Lachowicz K, Sobczak M, Gajowiecki L, Kotowicz M, Zych A, Medrala D (2007) Effects of massaging on hardness, rheological properties, and structure of four wild boar muscles of different fibre type content and age. Meat Sci 75:595–602