



## The Effect of Tumbling Time on the Quality and Binding Ability of Restructured Beef *M. Pectoralis profundus* with Alginate Binder

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**ABSTRACT :** Meats with alginate binders including sodium alginate, glucono-delta-lactone and calcium carbonate were tested in restructured steaks made from *M. pectoralis profundus* of beef steers in terms of meat quality and binding ability by tumbling time. The treatment with 25 min tumbling time was significantly lower ( $p < 0.05$ ) for crude protein than 5 and 15 min, while higher ( $p < 0.05$ ) for moisture content. This corresponded with sensory panel juiciness ratings, which showed the treatment for longer tumbling times to be significantly juicier ( $p < 0.05$ ) than that for a shorter time. Cooking loss decreased ( $p < 0.05$ ) linearly with an increased tumbling time, and Kramer shear force also significant decreased ( $p < 0.05$ ) with tumbling time. This corresponded with sensory panel tenderness ratings, which showed that the treatment for longer tumbling times was more tender ( $p < 0.05$ ). The texture results indicated that longer tumbling time had lower ( $p < 0.05$ ) hardness and chewiness values. Sensory panels ranked binding ability in the order 5 min, 15 min and 25 min from best to worst, and the overall acceptability for slices from roasts of treatments for 5 and 15 min were rated by the sensory panelists as moderate to very acceptable, but those for 25 min were rated as fair to moderate. (**Key Words :** Alginate, Tumbling, Restructured Meat, Sensory Attributes, Binding Ability)

### INTRODUCTION

There is a low salvage ability of value from the forequarter of a beef carcass than the rest of the carcass and so an increased utilization of muscles of poor quality is essential for maximizing the yield of marketable products. *M. pectoralis profundus* is the second largest muscle in the forequarter. This has stimulated research into various methods of restructuring low-value cuts to produce a uniform, palatable steak that resembles intact muscle in textural properties. A problem, however, with these restructured meat products, is that salt and phosphate are added in order to improve binding ability of the meat pieces, and the products are usually distributed as frozen meats. This causes problems, not only because of discoloration, but also due to consumer's lower appreciation of frozen meat products. Therefore restructured meat products often receive lower prices compared to fresh, unfrozen products (Kuraishi et al., 2001; Kumar et al., 2004). Furthermore, these frozen, restructured products cannot be sold in a

refrigerated counter like the unfrozen products of intact muscles, which complicates the marketing.

Alginate, a polysaccharide extracted from brown seaweed, can be used for binding comminuted or diced meat pieces (Means et al., 1987). Sodium alginate is the form most often used in meat applications. Common ingredients in alginate binding systems are an alginate salt, a calcium source, an acidulant and a sequestrant (Chen et al., 2006). When calcium ions are introduced into an alginate solution, a thermo-irreversible gel is formed (Boles and Shand, 1998). Acidulants and sequestrants can be used to modify the reaction rate, thus controlling the hydration rate and the gel setting time, which are affected by tumbling time. Although researches (Boles and Shand, 1998, 1999) have been carried out on the quality and binding effects of alginate on restructured ground meat, there was no research to investigate the effect of tumbling time on the quality and binding ability of meat pieces restructured with alginate from diced meat, which maintains naturally muscle fibers similar to fresh meat. The objective of this study, therefore, was to investigate the effect of tumbling time on meat quality and binding ability of meat pieces restructured with alginate from diced beef *pectoralis profundus*.

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Received March 27, 2006; Accepted June 9, 2006

**Table 1.** The formulation for restructured meat

Ingredients	%
Beef	96.2
NaCl	0.5
Sodium tripolyphosphate	0.3
Alginate compound	
Sodium alginate	1.6
Glucono-delta-lactone	0.8
Calcium carbonate	0.6

## MATERIALS AND METHODS

### Preparation of sample steaks

Five *M. pectoralis profundus* were excised from carcasses of five Irish R-3 grade steers (live weight = 640±30 kg) sired by one Belgian Blue bull from Holstein-Friesian cows, and denuded completely of all surface fat and visible connective tissue using a membrane-skipping machine. The muscles were vacuum packed and aged for 14 days at 0±1°C. After 14 days, unpacked muscles were injected with a brine solution using a 20-needle brine injector (Dorit PSM-21 Inject-O-Mat brine injector, Germany) at 11% (w/w) to give a concentration of 0.5% salt (NaCl) and 0.3% sodium tripolyphosphate (STPP) in the meat as shown in Table 1. Muscles were weighed before and after injection to determine brine pick up through the injector. After determining brine pick up, the muscles that had not reached their target were injected with a hand injector to the assigned injection level, and excess brine was allowed to drain off.

Injected samples were next diced flat strips of approximately 70 mm wide and 20 mm thick in parallel to the muscle grain. The diced sub-samples were assigned randomly to three groups by tumbling times of 5 min, 15 min and 25 min. The weight of each batch was approximately 16 kg. The assigned samples were then added to vacuum tumbler (80-100 kPa, 8.0 rpm, 2°C) with sodium alginate 1.60% of meat weight, glucono-delta-lactone (GDL) 0.80% of meat weight, calcium carbonate 0.60% of meat weight. The tumbled meats were packed in twelve plastic moulds (50×20 cm) of each 1.5-2.0 kg, with the meat fibres running in parallel with the long sides, vacuum packed and stored at 0±1°C for 24 h to allow completion of the protein cross-linking reaction of meat pieces. Joint was defined by samples bound with meat pieces each other in a plastic mould, and each joint was cut into one-half. Cut twelve samples (four joints/samples per each tumbling time) were vacuum-packed in Cryovac CN 530 cooking bags and cooked in a steam/air cooker at 82°C to a core temperature of 70°C to analyse cooking loss, Kramer shear force, instrumental texture and sensory analysis. The other twelve samples (joints) were frozen at -20°C until experimentation for chemical composition, pH, drip loss, color and differential scanning calorimetry (DSC).

### Chemical composition

Frozen samples were thawed in their bags in circulating water and the samples were homogenized using a blender (R301 Ultra, Robot Coupe Ltd.). The blended samples were stored in airtight plastic containers and covered with onion-skin paper. Moisture and fat contents were determined by CEM analyzer using the method of Bostian et al. (1985). Protein content was measured by LECO analyzer using the method of Sweeney and Rexroad (1987). Ash was determined by furnace using the ISO 936 method (ISO, 1978).

### pH and drip loss for raw meat joints

pH was measured using a portable pH meter (Orion Research Inc., Boston, MA 02129 USA) at 5 min, 15 min and 25 min tumbling times and an Amagross pH electrode (pH/mV Sensors Ltd., Murrisk-Westport, Co. Mayo, Ireland), which was corrected for muscle temperature. Sub-samples, 2.5cm thick, of similar dimensions and weighing 100 g were removed from each joint and suspended in an expanded bag, so that the meat did not come in contact with the bag. The samples were stored at 2°C for 96 h, lightly blotted with tissue and re-weighed. Drip loss was expressed as a percentage of the original weight (Honikel and Hamm, 1994).

### Color

Sub-samples were placed in laminated retail polystyrene trays, over-wrapped with PVC film and stored at 2°C. Color was measured using a Hunter Lab spectrophotometer with CIE ( $L^*$   $a^*$   $b^*$ ) color scale, D65 illuminant and 10° observer (Ultrascan XE, Hunter Associates Laboratory Inc., Virginia, USA) on the cut surface of PVC film-covered steaks. Measurements were taken on 10 locations per slice and averaged.

### Cooking of joints, cooking loss and Kramer shear force

Joints in Cryovac cooking bags were weighed and cooked in a steam/ air cooker at 82°C to a core temperature of 70°C. For cooking loss, cooked joints were allowed to cool and excess solidified juices were removed. The joints were re-weighed and cooking loss was calculated as a percentage of the raw weight. After measurement of cooking loss, roasts were chilled to 2°C and sliced at a thickness of 1 mm on an electric slicing machine. Slices for testing were vacuum-packed in 10-slice lots and chilled at 2°C, except for slices for Kramer shear value, which were frozen at -20°C pending testing.

Kramer shear force was measured on thawed slices by placing 30 g of the 1 mm-thick slices in the bottom of a 10-blade Kramer Shear cell attached to an Instron model 4301 texture meter and using Instron Corporation Series IX

**Table 2.** The effect of tumbling time on proximate composition (%) in uncooked restructured beef joints

	Tumbling time (min)			SEM <sup>1</sup>
	5	15	25	
Crude fat (%)	3.55	3.48	3.51	0.31
Crude protein (%)	20.98 <sup>a</sup>	19.84 <sup>a</sup>	16.52 <sup>b</sup>	1.1
Moisture (%)	73.80 <sup>b</sup>	74.9 <sup>b</sup>	77.8 <sup>a</sup>	1.2
Ash (%)	1.50	1.52	1.49	0.3

<sup>a,b</sup> Mean values within the same row with different superscripts are significantly different ( $p < 0.05$ ).

<sup>1</sup> Standard error of mean.

Automated Materials Testing System software for Windows (Instron Ltd.). Measurements were expressed as Newtons force per g of cooked meat sample. Three measurements for each joint were taken and averaged.

For texture analysis (Bourne, 1978), two slices of 2 cm thickness were also taken. Five cores (diam. 2.5 cm × ht. 2 cm) per slice representing the whole slice were compressed to 50% of their original height using a 2.5 cm circular flat disk attached to a 500 N load cell with a crosshead speed of 5 cm min<sup>-1</sup>. The following texture parameters were measured from the force-deformation curves: hardness, springiness, cohesiveness and chewiness. Hardness was defined by peak force during first compression cycle and expressed in g. Cohesiveness was calculated as the ratio of the area under the second curve to the area under the first curve. Springiness was defined as a ratio of time recorded between the start of the second area and the second probe reversal to the time recorded between the start of the first area and the first probe reversal. Chewiness was obtained by multiplying hardness, cohesiveness and springiness.

#### Differential scanning calorimetry (DSC)

The endothermic transition of intramuscular connective tissue was determined using DSC2010 (TA Instruments) with refrigerating cooling system (RCS) which was calibrated with mercury (mp -38.8°C, ΔHm 11.4 Jg<sup>-1</sup>), distilled water (mp -0.0°C, ΔHm 334.5 Jg<sup>-1</sup>) and indium (mp 156.6°C, ΔHm 28.45 Jg<sup>-1</sup>), according to the procedure of Aktaş and Kaya (2001) and King (1987). Ten gram pieces of meat were homogenized with Ultra Turrax (T25, Janke and Kunkel, GmbH and Co KG, Germany) in 100ml phosphate buffer solution. (0.1 M KCl 0.02 M KH<sub>2</sub>PO<sub>4</sub> and 0.1 M KCl 0.02 M K<sub>2</sub>HPO<sub>4</sub>). The intramuscular connective tissue homogenized was then washed in 100 ml distilled water. Approximately 10 mg of sample were weighed into an aluminium pan, sealed and heated from 10°C until 95°C at a rate of 5°C/min. An empty pan was used as a reference and was run 3 times per sample. In comparing endothermic transition of intramuscular connective tissue between 5 and 25 min tumbling times, three measurements for each joint were taken and averaged.

**Table 3.** The effect of tumbling time on pH, drip loss (%), cooking loss (%), Kramer shear force (N/g) and CIE ( $L^*$   $a^*$   $b^*$ ) in restructured beef

	Tumbling time (min)			SEM <sup>1</sup>
	5	15	25	
pH	5.54	5.57	5.55	0.24
Drip loss (%)	1.49 <sup>b</sup>	1.58 <sup>b</sup>	1.88 <sup>a</sup>	0.32
Cooking loss (%)	44.25 <sup>a</sup>	39.30 <sup>b</sup>	35.45 <sup>c</sup>	3.52
Kramer shear force (N/g)	112.8 <sup>a</sup>	109.7 <sup>ab</sup>	75.4 <sup>b</sup>	16.8
$L^*$	42.01	42.26	43.33	1.88
$a^*$	17.16	17.05	16.84	0.67
$b^*$	13.42	13.37	13.48	0.44

<sup>a,c</sup> Mean values within the same row with different superscripts are significantly different ( $p < 0.05$ ).

<sup>1</sup> Standard error of mean.

#### Sensory characteristics

An eight-member panel was employed to evaluate the sensory characteristics of the cooked beefsteaks using the methodology of the American Meat Science Association (AMSA, 1995). Prior to formal sensory sessions, panelists were familiarized with the characteristics to be evaluated in two preliminary sessions. Three samples, i.e. one of each of the treatments in the trial, were presented in each session. Steaks presented were grilled for 8 min on each side or until the internal temperature of each steak reached 70°C. The panelists assessed taste and appearance of slices of the roast beef for binding/cohesion, texture, tenderness, juiciness, color and overall acceptability on a scale of 1 (worst) to 6 (best). Samples from each replicate were presented twice, and scores averaged.

#### Statistical analysis

All data was analyzed using one-way analysis of variance to compare treatments (SAS, 1996). A different animal effect was not estimated because it was in the same breed and grade. Turkey's multiple comparison was used to identify differences between tumbling times, when significant  $F$ -values were obtained ( $p < 0.05$ ). Four replicates (joints) for each tumbling time were carried out in this study.

## RESULTS AND DISCUSSIONS

Chemical composition results indicated that crude fat and ash contents did not differ significantly between the treatments for tumbling time intervals (Table 2). 25 min tumbling time was significantly lower ( $p < 0.05$ ) for crude protein than 5 and 15 min, while higher ( $p < 0.05$ ) for moisture content, as expected. This corresponded with sensory panel juiciness ratings, which showed the treatment for a longer tumbling time to be significantly juicier ( $p < 0.05$ ) than that for a shorter time. The increase in the moisture content of the products as tumbling increased and the disruption effect of tumbling on the muscle sarcolemma

**Table 4.** The effect of tumbling time on instrumental texture in cooked restructured beef

	Tumbling time (min)			SEM <sup>1</sup>
	5	15	25	
Hardness (g)	322.3 <sup>a</sup>	304.4 <sup>ab</sup>	245.3 <sup>b</sup>	64.3
Springiness	4.64 <sup>a</sup>	4.28 <sup>b</sup>	4.13 <sup>b</sup>	0.17
Cohesiveness	0.54	0.53	0.52	0.05
Gumminess	149.7	134.0	106.0	21.4
Chewiness (g)	778.6 <sup>a</sup>	659.3 <sup>ab</sup>	439.9 <sup>b</sup>	67.5

<sup>a-b</sup> Mean values within the same row with different superscripts are significantly different ( $p < 0.05$ ).

<sup>1</sup> Standard error of mean.

probably account for the increased juiciness (Gillett et al., 1981; Lawlis et al., 1992; Boles and Shand, 1999).

Tumbling time intervals did not affect the pH of *M. pectoralis profundus* (Table 3). The result for drip loss showed 25 min tumbling time to be significantly higher ( $p < 0.05$ ) than 5 and 15 min, but no significant difference was shown between 5 and 15 min. The cooking loss result decreased ( $p < 0.05$ ) linearly with increased tumbling time. The result was in agreement with the finding of Dzudie and Okubanjo (1999), who reported that the products tumbled for a longer time had a lower cooking loss, when compared to those cooked for a short time due to increased amount of extractable soluble proteins. Whiting (1988) reported that the lower cooking loss associated with the longer tumbling time were consistent with the higher moisture levels and extractability of salt soluble proteins.

Kramer shear force showed a significant decrease ( $p < 0.05$ ) with tumbling time (Table 3), possibly due to

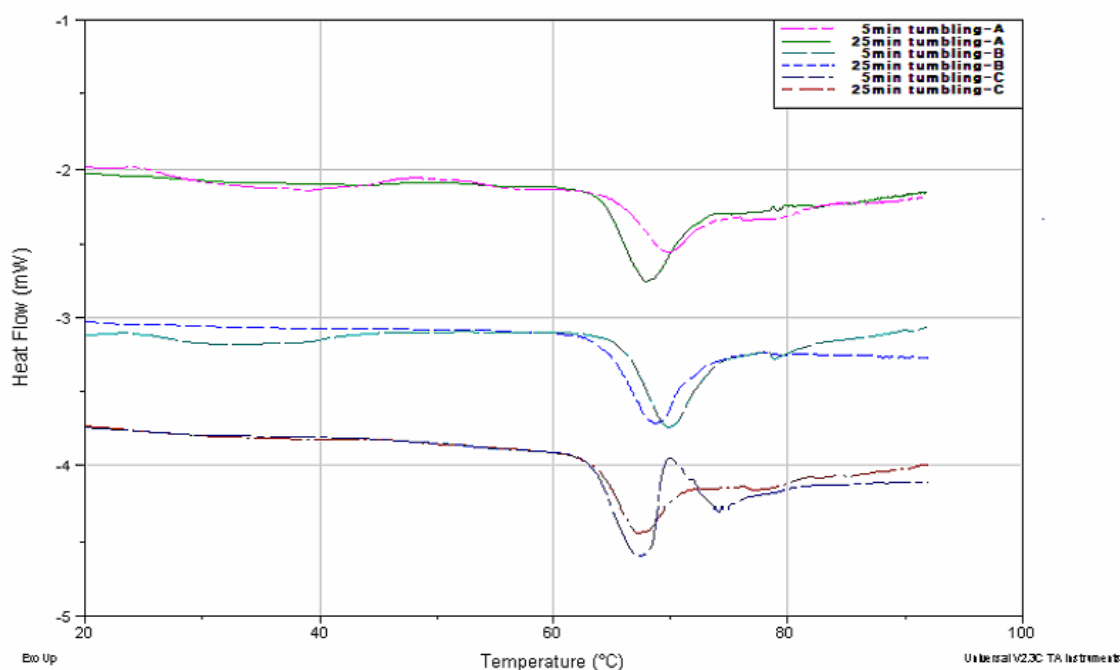
**Table 5.** The effect of tumbling time on sensory attributes in cooked restructured beef

	Tumbling time (min)			SEM <sup>1</sup>
	5	15	25	
Binding (cohesion)	4.44 <sup>a</sup>	3.72 <sup>b</sup>	3.60 <sup>b</sup>	0.34
Texture	4.82 <sup>a</sup>	3.93 <sup>b</sup>	3.25 <sup>c</sup>	0.22
Tenderness	3.03 <sup>b</sup>	3.48 <sup>ab</sup>	3.85 <sup>a</sup>	0.28
Juiciness	4.38 <sup>b</sup>	4.75 <sup>ab</sup>	4.88 <sup>a</sup>	0.20
Color acceptability	4.38	4.13	4.63	0.31
Overall acceptability	4.12 <sup>a</sup>	4.02 <sup>a</sup>	3.13 <sup>b</sup>	0.22

<sup>a-b</sup> Mean values within the same row with different superscripts are significantly different ( $p < 0.05$ ).

<sup>1</sup> Standard error of mean.

disruption of myofibrillar proteins by the longer tumbling process. The result was in agreement with the findings of Dzudie and Okubanjo (1999), who reported that shear force values of hams decreased with the increased tumbling time. Chow et al. (1986) showed that the Instron measurements on pork hams massaged for a short time were significantly higher than for longer times. This corresponded with sensory panel tenderness ratings showing that the product with longer tumbling times was more tender ( $p < 0.05$ ; Table 5). Longer tumbling times led to lower ( $p < 0.05$ ) hardness and chewiness values (Table 4), while springiness was significantly higher ( $p < 0.05$ ) for 5 min than 15 and 25 min, although there was no significant difference between 15 and 25 min. No significant differences in cohesiveness and gumminess were found in tumbling times.

**Figure 1.** Thermal transition of intramuscular connective tissue obtained from restructured beef joints vacuum tumbled for 5 min and 25 min.

Sensory panelists rated binding in the order 5 min, 15 min and 25 min from best to worst, but little difference was found between 15 and 25 min (Table 5). Slices from roasts of treatments for 5 and 15 min were rated by the sensory panelists as good to very good for binding. Panelists showed that texture worsened with increasing tumbling time. Generally, it appeared that the longer tumbling time was required to incorporate brine into the muscle cells and to provide more favorable conditions for protein solubilization and extraction, and thus led to increased yield and tenderness (Pietrasik and Shand, 2004). This may be especially important for beef products due to stronger collagen connections and differences in the muscle structure (Figure 1). It seems, however, to make the treatment for 25 min tumbling time rubbery for sensory texture.

The texture results were reflected in the changes of thermal transition of intramuscular connective tissue from DSC. The endothermic transition of intramuscular connective tissue showed 25 min tumbling time to have a lower onset and melting temperature than the 5 min tumbling time. The thermal stability of intramuscular connective tissue is known to be dependent on the amount of water within its structure (Luescher et al., 1974). Finch and Ledward (1972) reported that the increase in thermal stability was due to both a change in bound water structure and to the greater freedom of movement of the polypeptide chains. These researchers also indicated that increased thermal stability was associated with decreased endothermic heat change. In this study, DSC results indicated that a longer tumbling time could disrupt the intramuscular connective tissue protein.

Taste panel juiciness significantly increased ( $p < 0.05$ ) with longer tumbling times. The result may be due to a higher moisture content and lower cooking losses for treatments with a longer tumbling time as compared to 5 min. The pattern of better binding and texture was reflected in overall acceptability ratings, with the treatment for 5 min being more acceptable than that for 25 min. Slices from roasts of treatments for 5 and 15 min were rated by the sensory panelists as moderate to very acceptable for overall acceptability, but those for 25 min were rated as fair to moderate. No significant differences between tumbling times were found in color acceptability, which panelists rated as moderate to very acceptable.

## CONCLUSION

Tumbling times in a vacuum tumbler affected alginate-bound meats, in terms of chemical composition, drip and cooking losses, texture, DSC parameters and sensory attributes. Longer tumbling times (25 min) gave alginate-bound product a higher moisture content, lower protein content and lower cooking losses, but there was a negative

effect on texture and sensory attributes (binding, sensory texture and overall acceptability) for the longer tumbling time despite the superior tenderness and juiciness. The results of this pilot trial suggest that 5 min tumbling time would be more acceptable than 25 min in terms of texture, overall acceptability and binding ability of restructured beef forequarter *pectoralis profundus* muscle.

## ACKNOWLEDGMENTS

This work was supported by The National Food Centre in Ireland, and authors thank D. Troy, Director of The National Food Centre for providing the materials and facilities. Thanks are also given to Paul Sullivan for his assistance in English writing of this article. This work was supported by the Post-doctoral Fellowship Program of Korea Science & Engineering Foundation (KOSEF).

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