Agriculture and Food Development Authority

FINAL REPORT

Project RMIS No. 4898

Adding value to Beef Forequarter Muscles

Ashtown Food Research Centre

RESEARCH & TRAINING FOR THE FOOD INDUSTRY

RESEARCH REPORT NO 98

ADDING VALUE TO BEEF FOREQUARTER MUSCLES

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NATIONAL DEVELOPMENT PLAN

Teagasc Oak Park Carlow Co. Carlow

CONTENTS

SUMMARY

The forequarter constitutes 50% of the weight of a beef carcase but only about 25% of its value. To fulfill the objectives of this project, the work was organised into 4 parts as follows:

1. *Characterisation of the available raw material*, in terms of properties of individual muscles seamed out from carcasses of representative types of animals produced in Ireland.
2. *Comparison of yields and operator time for seaming and conventional boning.*
3. *Utilisation of separated muscles in added-value products* using appropriate tenderising, bonding and forming technology.
4. *Transfer of the knowledge and technology to the industry.*

Part 1 – Testing of 15 x PAD-trimmed muscles from each of 9 forequarters from R3-grade steer carcases showed wide variation between muscles in composition and properties. Tenderness (Warner-Bratzler shear force) values ranged from the very tender *Infraspinatus*/featherblade (29 Newton) to the *Pectoralis profundus*/brisket (67 Newton). Ten of the 15 muscles had shear values less than 50N, corresponding to an acceptable level of tenderness as judged by taste panel. Coefficients of variation (CV) for the shear values were in the range 1-10% indicating that they were near to the true values for the population. There was a reasonably consistent relationship between collagen content, shear force value and sensory panel tenderness score. For example, the clod muscles had collagen content of 2.22%, shear force value of 61N and sensory score of 1.4, in contrast to figures of 0.54%, 33 N and 4.5 for the cube roll. Colour in terms of redness (a*) varied from 9.4 (*Teres major*) to the most red 17.3 (*Semispinatus capitis*). There were significant differences between muscles in the rate of colour deterioration. For example, *T. brachi*/LMC and *Longissimus dorsi*/cube roll were good, *Infraspinatus* intermediate and *External Abdominal oblique* poor in colour stability. If re-formed products are to be prepared from combinations of muscles, it would be important to take account of tenderness and colour in order to avoid inconsistency in the final product. Fat content was less than 2.0% in 12 of the

PAD-trimmed muscles making them potentially suitable as components of low-fat diets. It was only slightly higher, at 3.1-3.4%, in the featherblade, Jacob's ladder and ear of brisket. For protein extractability, the muscles could be categorised into three groups. Extractability was relatively high for *Pectoralis profundus* (brisket) and *Longissimus thoracis et lumborum* (cube roll), intermediate for *Supraspinatus* (chuck tender) *and Infraspinatus* (featherblade) and low for *Serratus ventralis* (Jacob's ladder).

KEY FINDINGS:
Ten of the 15 muscles were acceptably tender. Fat content was less than 2% in 12 muscles. Colour stability differed significantly between muscles.

Part 2 – The test boning data showed wide variation in the PAD yield of muscles. For example, the "Ear of Brisket" had a yield of only 36%, PAD on seamed muscle. It is therefore more profitable to keep it as part of the whole brisket to be sold for rolling and tieing. Muscles with a relatively high yield were the LMC, the cube roll and the chuck tender, at 80-85%. Average time taken by one butcher to seam out , trim and PAD-trim 14 muscles from a beef fore was 37 minutes, as against 25 minutes to break a fore by conventional boning into 6 primal cuts and 3 lots of manufacturing meat.

Part 3 – Comparison of 4 cold-set bonding agents in preparation of re-formed whole-muscle joints and steaks from each of two muscles, brisket and leg of mutton cut (LMC), showed that all four agents achieved acceptable bonding but gave differences in colour, texture and cook yield. Based on the combination of efficiency of cold-bonding and convenience in application, Activa TGase product was employed as bonding agent in all further re-forming trials in the project. The TGase acts by catalysing the cross-linking of proteins.

Method of mechanical tenderisation affected tenderness significantly in trials on preparation of re-formed steaks from each of 2 forequarter and 2 hindquarter muscles. For example, re-formed steaks made from *Pectoralis profundus* showed a reduction in shear value, i.e. in toughness, from 81N for non-tenderised steaks to 62N for blade tenderised, 46N for needle tenderised

and 40N for injected (with brine)+ vacuum-pulsed steaks . Other muscles responded similarly. In most cases these reductions were reflected in sensory panel ratings. Thus, the needle and injection + vacuum pulsing treatments as used here were more effective than blade tenderisation for beef for use in re-formed joints but account needs to be taken of higher bacterial numbers found to arise from the injection + vacuum-pulsing treatment.

Enhancement of meat tenderness and juiciness through addition of liquid by injection has been widely adopted by the industry in the U.S. and, to a lesser extent, in Europe for both beef and pork. In order to check if enhancement is compatible with re-forming, samples of each of 2 muscles were subjected to 4 treatments: (i) whole uninjected controls, CO; (ii) whole injected at 15% level to give 0.5% salt and 0.3% phosphate(STPP) in the meat, WI; (iii) injected and re-formed , IR; and (iv) injected with added flavouring(a natural beef extract stock) to give 2% beef stock + 0.3% salt + 0.5% phosphate in the meat. The latter was included because inter-muscle differences in beefy flavour had previously been noted. The three injection enhancement treatments reduced shear force values of cooked samples and in most cases these reductions were reflected in sensory panel tenderness and chewiness ratings. For example, shear values for *Supraspinatus*/chuck tender were 83N/g in control samples and 50 in whole injected samples while corresponding sensory panel tenderness ratings were 3.6 and 5.2. Enhanced samples did not differ from controls in ease of slicing or in colour and binding ratings, indicating that enhancement combined with re-forming can give an acceptable roast beef product. Addition of beef stock did not result in higher flavour ratings by sensory panels. Whole injected samples scored higher for flavour than both control ($p<0.01$) and injected + re-formed ($p<0.05$) samples. All samples for both muscles had satisfactory ease of slicing. Colour measurements on raw steaks showed very few differences between treatments for either muscle. Inclusion of the beef stock did not give a better flavour compared to control samples. The results indicate that injection enhancement is compatible with re-forming for the production of roast beef joints that would be acceptable to the consumer.

KEY FINDINGS:

A cross-bonding enzyme preparation was an efficient cold-set bonding agent in preparation of re-formed joints. Roller-blade tenderisation was the least effective of 3 methods of physical tenderisation. Injection enhancement combined with re-forming gave joints of acceptable eating quality.

Part 4. For transfer of findings to industry, results were presented and demonstrated to industry personnel in two workshops held at Ashtown Food Research Centre and are described in the publications listed at the end of this Report.

In a one-on-one meeting with a major beef processing company, the application of re-forming, based on experience in the current project, in development of a range of added-value beef products was presented and discussed.

In-factory trials on re-forming of beef joints were conducted in collaboration with two SMEs which proceeded to marketing re-formed steaks and joints in raw and cooked forms. The marketing was successful until a fall in price of beef hind-quarter muscles imported from third countries made the re-formed products uncompetitive.

A manual, based on results in Parts 1 - 3, was produced. It includes photographic guidance to location and separation of forequarter muscles. Printed copies of the manual (ISBN 1 84170 516 0) were distributed to beef processing companies and other interested parties. Copies are available on request from Teagasc, Ashtown Food Research Centre.

CSO data on value of exports of beef from Ireland in 2007 in €M, excluding export refunds, show the following:

Chilled	Frozen	Processed raw	Cooked	Total Processed	Grand Total
1,206	120	68	69	137	1,600

These figures illustrate both the economic importance of the sector and the less than 10% proportion of processed beef (although it should be noted that this has increased from less than 5% since 1999). The latter feature compares unfavourably with that in the pork, poultry and fish sectors; in the case of poultry and fish the volume proportion processed is greater than 50%. The commercial challenges facing Irish beef processors include world trade liberalisation and, particularly, consumers leaning towards convenient meal solutions and away from traditional meat joints. Continuing reduction of EU export refunds has resulted in over 90% of beef exports from Ireland now going to intra-EU markets. Demand is strong for the noble cuts, fillet, loin and rib, and for manufacturing beef for the burger trade but it is difficult for the middle price cuts such as those from the chuck and shoulder in the forequarter.

The project was therefore designed to address (a) more profitable utilisation of the forequarter and (b) development of convenience beef products from lower-value muscles from both fore- and hindquarter. It was organised into 4 parts as follows:

1. **Characterisation of the available raw material** in terms of properties of individual muscles seamed out from carcasses of representative types of animals produced in Ireland. The properties measured were weight, colour, protein quality, proximate chemical composition, collagen content and drip loss on raw muscles, and shear value (tenderness) and sensory quality on cooked muscles.

2. **Comparison of yields and operator time** for seaming and conventional boning of forequarter.

3. **Utilisation of some of the separated muscles in added-value products** using appropriate tenderising, bonding and forming technology.

4. **Transfer of knowledge and technology to the industry.**

The overall aim was to provide the industry with some of the building blocks with which to design new added-value products from beef. The project was carried out jointly by staff of Teagasc AFRC and UCC Dept. of Food and Nutritional Sciences.

PART 1. SEAMING OF THE FOREQUARTER AND TESTING OF THE MUSCLES

INTRODUCTION

Seaming out and PAD preparation (the removal of all external fat and of external, epimysial connective tissue membrane) of beef muscles for export has increased significantly in Irish plants during the past decade but is not practiced universally. For this project, it was important to achieve precise identification and separation of target muscles of the forequarter from representative types of animals produced in Ireland. Several relevant reports on composition and properties of bovine muscles have been published, the most recent of which are from the NCBA–funded study in the U.S. i.e. Jones *et al.* (2004) and Von Seggern *et al.* (2005).

The manual produced in Part 4 of the project contains a description and photographs of one procedure that may be of use in commercial practice. For photographic guidance to location and separation of forequarter muscles, readers are referred to the manual itself. Printed copies of the manual (ISBN-10 1-84170-516-0) were distributed to beef processing companies and other

interested parties in July 2008. Copies are available on request from Teagasc, Ashtown Food Research Centre.

PROCEDURE

Methods of testing of the separated muscles

Twenty-eight individual muscles were identified and excised from a 10-rib forequarter. Based on weighing and analysis, 15 were chosen for further examination. The 15 muscles were excised from each of several R3-grade carcasses from Continental-type x Friesian steers at 2 days post-mortem, PAD-trimmed with the aid of a membrane-skinning machine, vacuum-packed without heat shrink and stored for a further 12 days at 0-2° giving a total of 14 days ageing. They were then frozen to - 30°C and held for thawing and testing as convenient, except for the drip loss test which was carried out on unfrozen samples. For chemical analysis, it was found in the case of some small muscles to be difficult to get a representative result from a sub-sample despite reports in the literature indicating no problem. Therefore, the whole muscles from each of 8 carcasses were homogenised and used for the chemical analysis. For the other tests described below, 8 carcasses were also used, except for protein quality for which 10 of the muscles were collected from each of 19 separate carcasses.

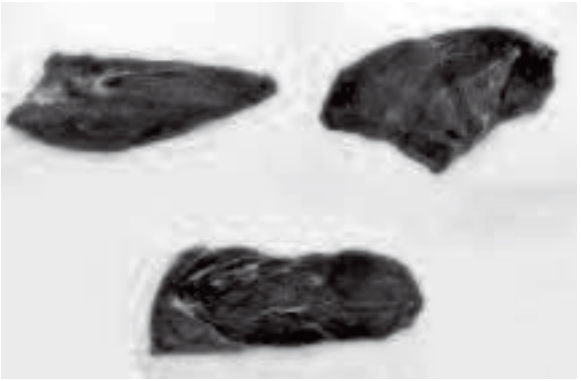

Figure 1: *Clockwise from top left, PAD'd chuck tender, LMC and featherblade*

Tests on raw muscle:

Compositional Analysis – Fat, moisture, protein and collagen were determined by chemical analysis. Only fat and collagen figures are shown below.

Drip Loss – This was calculated from the weight lost as drip from a suspended sub-sample over a 2-day period.

Colour - Meat colour was measured in CIE L* a* b* units using a HunterLab spectrometer (Ultrascan XE). Only the "a" values, measuring redness, are shown below.

Protein quality - This was determined in terms of *extractability* of myofibrillar protein in salt and phosphate solutions and *strength* of gels formed by heating of the extracted proteins.

Colour stability - Ten of the muscles were excised at 24 hours *post-mortem* and stored in vacuum packs at 0°C for 14 days followed by 6 days at 4°C under retail fluorescent lighting. The rate of colour deterioration was measured as Hunter 'a' value.

Tests on cooked muscle:

Shear Force/Tenderness – Tenderness was measured on cooked samples as force required to shear through a sample. Shear force was expressed in Newtons (N) and values below 50N indicate acceptable tenderness. As the shape or size of some of the muscles did not allow cutting of cores in the direction of the grain(fibre), which is necessary for reliable measurement of shear value, all muscles were cut into slices and re-formed into rectangular shaped joints with the aid of Activa transglutaminase cross-bonding enzyme preparation. From the re-formed joints, steaks of 25mm thickness were cut and used for coring for the shear force test.

Sensory quality - This was assessed by taste panels comprising trained experienced panellists who were asked to rate cooked muscle samples for tenderness, chewiness, residual connective tissue (RCT), juiciness, overall flavour and overall acceptability. Scores on a scale from 1 (worst) to 6 (best) were assigned to the ratings; means of the panellists' scores for tenderness are shown in the results on following pages.

Oxidative stability – This was measured over 8 days as TBARS value on cooked patties prepared from 10 of the muscles which had been aged for 14 days.

RESULTS and DISCUSSION

Composition, drip, colour, shear force, sensory score

The results (Table 1) show the significant variation between muscles in some characteristics. For the larger muscles, tenderness and shear force values are the most important characteristics but for smaller muscles, which are more likely to be further processed, other features, such as colour and collagen content, are also important.

Collagen levels varied widely between muscles. This is important when evaluating usefulness for processing, as it is an indicator of the internal connective tissue of the muscle which cannot be removed by trimming or PAD-trimming. High collagen levels are associated with tough meat and the figures in Table 1 show a reasonably consistent relationship between collagen content, shear force value and sensory panel tenderness score. For example, the clod muscles had collagen content of 2.22%, shear force value of 61N and sensory score of 1.4 in contrast to figures of 0.54%, 33 N and 4.5 for the cube roll.

Tenderness (WB shear force) values for the 15 muscles showed a wide variation, ranging from the very tender *Infraspinatus* (29N) to the *Pectoralis profundus* (67N). Ten of the 15 muscles had shear values less than 50N, corresponding to an acceptable level of tenderness as judged by taste panel. Brisket and clod muscles (*Pectoralis profundus*, *Pectoralis superficialis*, *Omotransversarius* and *Brachiocephalicus*) were significantly less tender than most of the others. Coefficients of variation (CV) for the shear values were in the range 1-10%, indicating that they were near to the true values for the population.

Colour measurements showed that redness (a*) varied from 9.4 (*Teres major*) to the most red 17.3 (*Semispinatus capitis*). If re-formed products are to be prepared from combinations of muscles, it would be important to take

account of tenderness and colour in order to avoid inconsistency in the final product.

Fat content was less than 2.0% in 12 of the PAD-trimmed muscles making them potentially suitable as components of low-fat foods. It was only slightly higher, at 3.1-3.4%, in the featherblade, Jacob's ladder and ear of brisket.
Drip loss, which is an indicator of the water-holding capacity of the meat, was 1.0% or less for all except LMC long head and cube roll, for which it was c. 2%.

Moisture content was 76-77% in all muscles except the cube roll in which a value of 75.6% was obtained. Protein content was 21-22% in all except featherblade and Jacob's ladder, in which it was in the range 19.5-20.5%, corresponding to the slightly higher fat content in those muscles.

Table 1: Mean values for some properties of 15 forequarter muscles in PAD form (n = 8)

		RAW			COOKED	
Muscle *(Commercial Name)*	Weight (kg)	Collagen (g/100g)	Redness (a* value)	Fat (g/100g)	Shear force value(N)	Taste panel tenderness score
Brachiocephalicus (Clod)	1.01	2.22	14.0	1.10	60.5	1.4
Omotransversarius (Clod)	0.51		13.2	1.15	67.1	
Latissimus dorsi (Flank/rib cap)	1.68	1.09	13.2	1.20	47.3	3.3
Infraspinatus (Featherblade)	2.28	0.98	13.6	3.20	29.5	5.1
Supraspinatus (Chuck tender)	1.38	1.02	14.3	1.57	40.5	3.3
Longissimus dorsi (Cube roll)	1.86	0.54	15.5	1.66	34.7	4.5
Triceps brachii longum (LMC long head)	3.05	0.80	14.8	1.54	39.2	4.8
T.br.laterale (LMC lateral head)	0.45	1.31	11.3	1.28	41.2	3.0
Semispinatus capitis (neck)	1.62		17.3	2.26	47.9	
Pectoralis superficialis (Ear of brisket)	1.18	1.78	17.0	3.08	60.9	2.2
Teres major (Shoulder tender)	0.39	0.58	9.4	1.78	30.6	4.0
Subscapularis (Sous d'epaule)	0.52	0.69	11.7	1.14	34.1	4.3
Pectoralis profundus (Brisket)	3.39	1.06	16.6	1.29	66.9	2.7
Rhombideus (Cigar Muscle)	1.20	1.19	14.8	1.41	55.8	2.7
Serratus Ventralis (Jacob's Ladder)	4.00	0.87	15.2	3.39	39.4	4.5
Least sig. diff., LSD,($p<0.05$)			2.2	0.52	7.8	

Protein quality

Tests were carried out in University College Cork on 10 forequarter muscles from each of 19 R3-grade Continental-cross steer carcasses using salt (NaCl) and phosphate (STPP – sodium tripolyphosphate) extractant solutions.

The results for extractability of protein, listed in Table 2 for some of the muscles tested, show an expected increase in amount of functional protein extracted from the muscles as concentration of salt was increased and an even greater increase in extraction when phosphate was included with salt. The muscles could be categorised into three groups with high, medium and low protein extractability. Extractability was relatively high for *Pectoralis profundus* (brisket) and *Longissimus thoracis et lumborum* (cube roll), intermediate for *Supraspinatus* (chuck tender) *and Infraspinatus* (featherblade) and low for *Serratus ventralis* (Jacob's ladder).

Table 2: Extractability (mg/ml extractant) of salt-soluble protein from forequarter muscles

Muscle	1% NaCl	2.5% NaCl	2.5% NaCl + 0.3% STPP	Protein Extractability
M. long. thoracis et lumborum	14.45+/-1.39ab	16.61+/-1.72ab	28.22+/-2.48a	High
M. pectoralis profundus	14.87+/-1.4a	17.13+/-1.86a	28.35+/-2.6a	High
M. supraspinatus	13.68+/-0.69b	15.1+/-1.26bc	25.23+/-1.67b	Intermediate
M. infraspinatus	13.41+/-1.19b	16.24+/-1.01ab	26.14+/-1.47ab	Intermediate
M. serratus ventralis	12.63+/-1.01bc	15.2+/-1.24bc	24.09+/-1.83bc	Low

Values are means and std. deviations of four trials; values in a column followed by a common letter are not significantly different at $p<0.05$

For determination of bind strength, the extracted protein pastes were heated to form gels the hardness of which was measured by means of texture profile analysis. Harder gel corresponds to greater bind strength. The results, listed in Table 3 for some of the muscles tested, showed that differences in gel hardness were not significant between muscles when NaCl alone was used as extractant but were so ($p<0.05$) when NaCl +STPP was used. The muscles could be roughly categorised as yielding protein with good, intermediate or poor gel forming ability and corresponding bind strength.

Table 3: Gel hardness (N) of pastes from forequarter muscles

Muscle Name	2.5% NaCl	2.5% NaCl & 0.3% STPP	Gel forming ability
M. infraspinatus	25.59±6.99a	53.47±6.81a	Good
M. triceps brachii (caput longum)	27.72±6.06a	51.75±11.04a	Good
M. supraspinatus	27.84±10.57a	48.11±9.56ab	Intermediate
M. pectoralis profundus	23.00±3.53a	43.33±11.52ab	Intermediate
M. longissimus thoracis et lumborum	27.11±4.14a	38.30±7.35b	Poor

Values are means and std. deviations of four trials; values in a column followed by a common letter are not significantly different at p <0.05

Colour and oxidative stability

There were significant differences in the rate of colour deterioration between muscles. For example, *T. brachii* and *Longissimus dorsi* were good, *Infraspinatus* intermediate and *External Abdominal oblique* poor in colour stability. Muscles also differed significantly ($p< 0.05$) in oxidative stability in the cooked form, with M.*Infraspinatus* (featherblade) showing the greatest lipid oxidation (TBAR value) and M. *longissimus dorsi* (striploin) the least.

PART 2. COMPARISON OF YIELDS AND OPERATOR TIME FOR SEAMING AND CONVENTIONAL BONING OF FOREQUARTER

Introduction

Companies are unwilling to divulge data on yields and throughput achieved in their own beef boning, whether conventional or seaming. In order to provide some guideline on yields in the manual for industry produced in Part 4 of the project, a test boning exercise was carried out at AFRC, after consultation with industry, comparing cutting of the forequarter in a conventional way with seaming out of fourteen muscles (i.e. partial seam boning).

Procedure

The trial was carried out on 6 steer forequarters of R3L and R4L-grade (Figure 2) which were selected at a commercial plant and transported to AFRC. The forequarters were weighed before seaming/boning. Four of the forequarters were chosen at random and seamed out, removing the 14 muscles characterised in Part 2.

Figure 2: *A R3L 10-rib steer forequarter used in the yield trial in Part 2*

The corresponding (other side) forequarters of two of the seamed out forequarters were boned in a conventional manner, generating the following cuts and 3 lots of manufacturing meat of varying visual lean (VL) content: Cube Roll, Chuck Roll, Chuck Tender, Whole Brisket for tieing (95VL), LMC, Featherblade Manufacturing meat - 98VL, 95L and 75L.

The seamed-out muscles were weighed after removal from the carcass, after trimming to remove accessible fat from the muscle and after PAD to remove the membrane tissue from the trimmed muscle (Figure 3). In the case of the conventionally-boned forequarters, the cuts and VL meat were weighed. The time taken to seam out/bone out the forequarters was also recorded. Some of the data generated is shown in Tables 4 to 9 below.

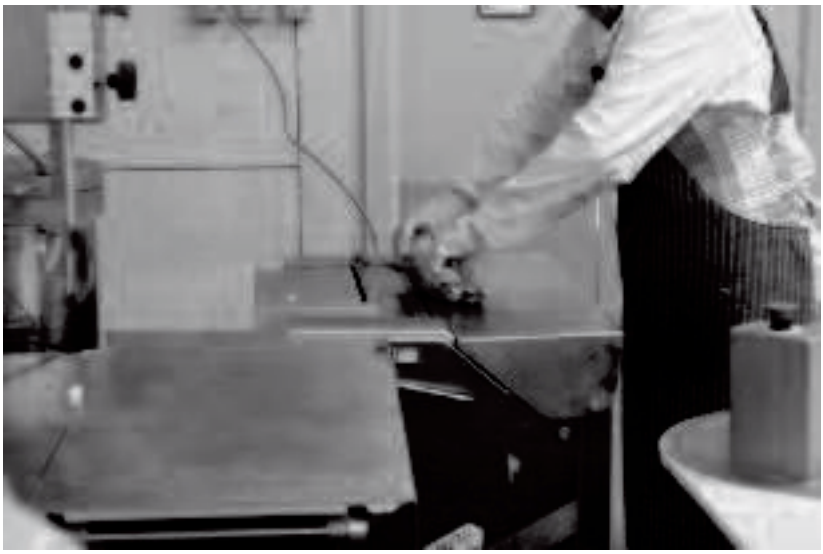

Figure 3: *PAD-trimming of a muscle using a (Graselli) membrane skinner*

Results

Seaming

Table 4: Seaming of Forequarters – yields of tissues

Forequarter No.	Weight of Fore (kg)	% Bone	% Fat	14 Muscles %	% Residual Muscles	% Trim
1 (R4L)	82.4	21.48	16.2	41.06	7.66	13.60
2 (R3L)	56.9	22.50	9.0	44.66	12.91	10.93
3 (R3L)	70.3	21.76	12.3	40.58	11.31	14.05
4 (R3L)	64.3	23.03	13.1	42.22	9.70	11.95
Average		**22.13**	**13.0**	**42.13**	**10.39**	**12.63**

Table 5: Seaming of Forequarters – time taken (minutes)

Forequarter No.	Seaming Time	Time for PAD step	Total Time
1	77	12	89
2	18	15	33
3	25	17	42
4	20	15	35
Mean*	**21**	**16**	**37**

**The mean did not include forequarter 1, which was used in a practice run.*

Table 6: Summary of the weights and yields of individual muscles

Latin Name	Commercial Name	Mean weight of seamed muscle, before trim, kg	Mean weight of muscle after trim, kg	Mean weight after PAD, kg	Yield, PAD % of seamed muscle
M .latissimus dorsi	Short Rib/Flank	2.79	2.0	1.40	50.1
M. infraspinatus	Featherblade	2.40	2.21	1.83	76.2
M. supraspinatus	Chuck Tender	1.57	1.46	1.33	84.8
M. longissimus thoracis et lomburum	Cube Roll	1.71	1.56	1.38	80.4
M. triceps brachii caput longum	LMC Long Head	3.18	3.01	2.66	83.7
M .triceps brachii caput laterale	LMC Lateral Head	0.66	0.58	0.49	74.0
M. semispinatus capitis	Neck Muscle	1.62	1.44	1.22	74.9
M. pectoralis superficialis	Ear of Brisket	2.15	1.10	0.77	35.8
M. teres major	Shoulder tender/ Fish muscle	0.44	0.42	0.32	71.1
M. subscapularis	Sous d'epaule	1.16	0.96	0.82	70.0
M. pectoralis profundus	Brisket	4.06	3.55	3.0	73.9
M. rhomboideus	Cigar Muscle	1.15	1.01	0.75	65.1
M. serratus ventralis	Jacob's Ladder	5.16	4.36	3.60	69.8
M. scalenus ventralis		0.67	0.61	0.43	63.9
TOTAL		**28.72**	**24.26**	**19.98**	**69.5**

Conventional Cutting Method

Table 7: Conventional Boning - yields of tissues

Forequarter No.	Weight of Fore, kg	% Bone	% Fat	% Cuts	% Trim
A	62.95	23.82	6.03	69.08	1.04
B	69.7	20.16	9.04	68.39	2.41
Mean	66.32	21.99	7.53	68.73	1.72

Table 8: Conventional Boning of Forequarters – time taken (minutes)

Forequarter	Boning Time	Time for PAD step	Total Time
A	23	0	23
B	28	0	28
Mean	25	0	25

Table 9: Conventional Boning of Forequarters – weights of individual cuts, kg.

CUT	A	B	Mean
Cube Roll	2.84	2.57	2.70
Chuck Roll	7.17	6.75	6.96
Chuck Tender	1.30	1.49	1.39
Whole Brisket for tying (95VL)	4.60	4.94	4.77
LMC	2.79	3.03	2.91
Featherblade	2.21	2.29	2.25
98VL	9.99	10.99	10.49
95VL	4.96	5.44	5.20
75VL	6.65	10.20	8.42

Conclusions

The results above are based on one skilled butcher doing the initial seaming or boning and the trimming manually, and also doing the PAD-trimming by machine. Use of mechanical muscle-pulling devices would increase the speed at which the muscles are seamed but not the yields. Accordingly, the data in the above tables provide a realistic guide for meat plants considering switching over to whole or partial seam butchery of forequarters.

The wide variation in the PAD yield of muscles is apparent from the tables above. For example, the "Ear of Brisket" had a yield of only 36% PAD on seamed muscle. It is therefore more profitable to keep it as part of the whole brisket to be sold for rolling and tieing. Muscles with a relatively high yield were the LMC, the cube roll and the chuck tender, at 80-85%.

PART 3. UTILISATION OF SOME OF THE SEPARATED MUSCLES IN ADDED-VALUE RE-FORMED PRODUCTS USING BONDING, TENDERISING AND MEAT ENHANCING TECHNIQUES

INTRODUCTION

Re-formed beef joints are assembled from pieces of whole muscle to form a product which has intact fibres and, therefore, characteristics of a natural whole-muscle joint. They are distinguishable from re-structured products such as burgers which are prepared from comminuted meat. Re-forming offers a possible means of up-grading low-value or small or awkward-sized muscles, provided that the quality and processing cost of the re-formed joints or steaks are acceptable.

Bonding of meat pieces is achieved through forming a gel on the surface of the pieces by

- heat–induced gelation, in cooking, of meat protein extracted during massaging with salt and, usually, phosphates;

or

- chemically-induced gelation in the cold by means of an appropriate gelling system – the bonding needs to survive through chilled distribution, cooking and hot and cold slicing;

or

- a combination of protein extraction and cold-set bonding.

Because of the high connective tissue and low fat content of many of the PAD forequarter muscles, it was considered useful to investigate the application of tenderisation and enhancement treatments to them before or with addition of bonding agent and forming treatment.

PROCEDURE and RESULTS

General method used for preparation of re-formed raw joints and steaks
Efficiency of bonding of muscle pieces in re-forming is affected by

- extracted or added protein on the surface of the lean, providing additional substrate for the action of bonding agents such as enzymes;
- pliability of the muscles for pressing into the desired shape - increasing extraction of myofibrillar protein from meat improves pliability for re-forming but increases the risk of the product becoming less fibrous and more rubbery in texture;
- removal of trapped air which can cause cavities or holes in the product.

Muscles were PAD-trimmed and cut into strips or chunks of c. 200g. The cold-set bonding agent was mixed with water according to supplier's guidelines and applied to the meat pieces by manual mixing or by slow rotation in a vacuum tumbler. For forming, the coated pieces were placed in layers in a lined rectangular mould with, as far as possible, the grain of the muscle parallel to the long side so that steaks could be cut across the grain. This was inserted into a lay-flat vacuum bag and the mould was withdrawn, leaving the formed muscle in the bag which was then evacuated and clip-sealed. The final shape of the re-formed joint was determined by the degree of slack fill within the bag. Products with a tight fill formed a round shape while those with a slack

fill resembled a striploin joint. Joints were held at 2°C overnight to allow bonding to proceed.

For chilled steaks, the re-formed joints were surface-tempered at -20°C and cut into 25mm-thick steaks which were then vacuum packed or MA-packed and stored chilled until tested.

For frozen steaks, the joints were frozen at -20°C, cut with a band saw into 25mm-thick steaks and stored frozen until use.

Comparison of cold-set bonding agents

Four cold-set binders were compared: Activa EB, a preparation of transglutaminase cross-linking enzyme(TGase), supplied by Ajinomoto Gmbh; alginate, a polysaccharide, supplied by ISP Corporation; Textor, a modified starch, supplied by Scobie & Junor Ltd., and Fibrimex, a blood derivative utilising the clotting reaction, supplied by Harimex b.v.

In re-formed beef steaks prepared from each of two muscles, brisket and leg of mutton cut (LMC), all four binding agents gave acceptable bonding but produced differences in colour, texture and cook yield (Table 10).

Table 10: Comparison of binding agents with two beef forequarter muscles

Muscle	Binder	Tenderness (Newtons)	Cooking Yield (%)	Colour (a*)	Overall Acceptability
M.P. profundus (brisket)	Activa	49.7^{a}	66.7^{a}	18.9^{a}	3.0^{a}
	Textor	46.0^{b}	72.6^{a}	18.6^{a}	3.6^{b}
	Alginate	51.6^{a}	72.0^{b}	18.6^{a}	3.1^{a}
	Fibrimex	48.9ab	70.8^{b}	19.9^{b}	3.0^{a}
M. Triceps brachii	Activa	42.0^{a}	65.2^{a}	18.9^{a}	4.5^{a}
	Textor	34.8^{b}	74.8^{b}	16.6^{b}	4.0^{b}
	Fibrimex	36.6^{b}	73.2^{b}	15.5^{b}	3.9^{b}

Note: Values in a column with a common superscript letter are not significantly different at P<0.05

Based on the combination of cold-bonding efficiency and convenience in application, the Activa TGase product was employed as bonding agent in all further re-forming trials in the project. The TGase catalyses the polymerisation and cross-linking of proteins through the formation of covalent bonds between lysine and glycine amino acid residues in the proteins in, e.g. the surface of lean meat. Factors affecting bonding performance were examined in a supplementary trial in which 2 concentrations of Activa (0.5 and 1.0% by weight of meat) were tested in conjunction with vacuum pulsing, netting and vacuum packaging. The best binding was obtained with joints that were treated with 1.0% Activa, vac- packed without netting and either pulsed or not pulsed.

Mechanical tenderisation of beef muscles for re-forming

Many forequarter muscles contain high levels of connective tissue and therefore require tenderisation prior to re-forming.The increase in tenderness by blade or roller-knife tenderisation is attributed to partial destruction of connective tissue and severance of muscle fibres giving reduced resistance to shear force, mastication and swallowing.

A trial was conducted to compare the effects of 3 methods of tenderisation on the processing characteristics and tenderness of 2 muscles from the beef forequarter (*M. pectoralis profundus/brisket* and *M. supraspinatus/chuck tender*) and 2 from the round in the hindquarter (*M. semimembranosus/topside* and *M. vastus lateralis/knuckl)*.The tenderising methods were assessed in conjunction with preparation of re-formed beef joints using Activa cold-set binder. Muscles were assigned to one of four treatments- 1) non-tenderised, 2) blade tenderised, 3) needle tenderised and 4) injected + vacuum-pulsed. Five replicates of each treatment were tested. The blade tenderised (BT) muscles were passed once through a commercial roller-blade tenderiser in which blades from opposing rollers overlapped by 10mm. Needle tenderised (NT) muscles were passed through a commercial Tender Star Model TSE tenderiser with solid stainless steel chisel-shape needles. The muscles were cut into c.200g pieces following BT and NT treatment. Injected and vacuum-pulsed muscles (VP) were injected with brine at 16% rate to give a concentration of 0.5% salt and 0.3% sodium tripolyphosphate (STPP) in the meat, chopped to give pieces of c.200g weight

and vacuum-pulsed for 14 hours in a Rühle vacuum tumbler-mixer using a "Tender beef " programme at 0 – 2°C which alternated between 90% and 10% vacuum (100 and 900 hPa residual pressure).

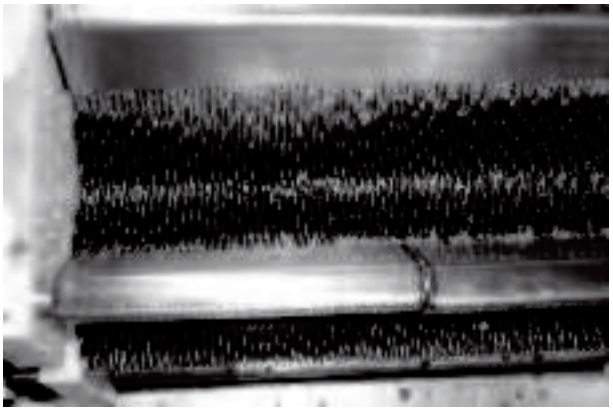

Figure 4: *Roller-blade tenderiser*

Shear value measurements and taste panel ratings showed that method of tenderisation affected steak tenderness significantly. Re-formed steaks made from *Pectoralis profundus* showed a reduction in shear value, i.e. in toughness, from 80.8N for non-tenderised steaks to 61.8N for blade tenderised, 46.1N for needle tenderised and 40.4N in injected + vacuum-pulsed steaks (Table 11). Other muscles responded similarly. In most cases these reductions were reflected in sensory panel ratings, with re-formed *Pectoralis* steaks rated 1.7 for tenderness in non-tenderised, 2.9 in blade tenderised, 3.1 in needle tenderised and 4.0 in injected + vacuum-pulsed steaks on a scale of 1 (very tough) to 6 (very tender). Overall, needle tenderisation and injection + vacuum-pulsing treatments gave about equal levels of tenderisation, while blade tenderisation had a lesser effect. Cook loss from steaks was not affected by treatments. Injected + vacuum-pulsed samples retained more juiciness than those from other treatments for all four muscles. For example, re-formed non-tenderised *Pectoralis* steaks were given a sensory score of 3.4 on a scale of 1 to 6 for juiciness, compared to 4.9 for injected + vacuum-pulsed samples. Injected + vacuum-pulsed steaks were rated better ($p<0.05$) for flavour than control steaks

in the case of two of the muscles. Colour of the re-formed steaks was not affected by method of tenderisation. Total bacterial counts were highest ($p<0.01$) on day 0 for injected + vacuum-pulsed steaks, at $5.1x\ 10^5$ cfu/g, and remained highest by day 7, at $1.7\ x\ 10^6$, although this would still be within acceptable limits for raw beef.

Table 11: Effect of tenderisation treatments on shear force values and taste panel ratings of re-formed steaks.

	Pectoralis profundus				*Supraspinatus*				*Semimembranosus*				*Vastus lateralis*			
	CO	BT	NT	VP	CO	BT	NT	VP	CO	BT	NT	VP	CO	BT	NT	VP
WBSF*	80.8^a	61.8^b	46.1^c	40.4^c	54.6^a	37.7^b	30.7^c	31.0^c	49.2^{ab}	44.3^b	38.4^{bc}	33.7^c	47.2^a	34.5^b	32.8^b	35.7^b
Tend.**	1.73^a	2.88^b	3.08^b	4.03^c	2.38^a	3.25^b	4.70^c	5.03^c	2.85^a	4.22^b	4.38^b	4.93^b	4.00	3.93	4.90	4.55
Chew.#	1.73^a	$2.55b^c$	2.93^{cd}	3.70^d	2.48^a	3.08^a	$3.88b^c$	3.93^c	2.78^a	3.70^b	3.85^b	4.10^b	3.43^a	4.05^{ab}	4.08^{ab}	4.52^b
RCT §	2.28^a	2.95^b	3.28^b	3.48^b	2.83^a	3.08^a	4.08^b	4.00^b	3.45	4.22	4.18	4.07	4.18	4.43	4.70	4.13
Juicin. ¤	3.43^a	3.38^a	3.60^a	4.90^b	3.85^a	3.58^a	4.05^a	5.25^b	3.78^a	3.95^a	3.80^a	4.90^b	4.00^a	2.05^b	3.90^a	5.16^c
O. acc. «	2.35^a	3.03^{ab}	3.35^b	3.45^b	2.93^a	2.90^a	4.15^b	4.25^b	3.25^a	3.73^{bc}	4.18^d	4.00^{cd}	3.95^{ab}	3.50^a	4.18^b	4.31^b

a-d:Treatment means with different superscripts, for each muscle, are significantly different ($p<0.05$)
* Warner Bratzler Shear Force (N)
**Taste panel tenderness;# chewiness ; § residual connective tissue; ¤ juiciness; « overall acceptability
CO – Control (non-tenderised); BT- blade tenderised; NT- needle tenderised; VP- injected & vacuum-pulsed.

The main conclusion was that needle and injection + vacuum-pulsing treatments as used here are more effective than blade tenderisation for beef for use in re-formed joints but account needs to be taken of the possible higher bacterial numbers arising from the injection + vacuum-pulsing treatment.

Enhancement of beef forequarter muscles and re-forming

Addition of liquid by injection has been widely adopted by the industry in the US and, to a lesser extent, in Europe, for both beef and pork, to enhance the

quality by increase of tenderness and juiciness. There are several reports in the literature indicating that injection with a salt/ phosphate solution increases water-binding capacity, tenderness and juiciness of beef joints, but no report was found of enhancement combined with re-forming. Therefore a trial was conducted on enhancement of forequarter muscles in conjunction with preparation of re-formed joints using the cold-set binder Activa.

Two muscles, *supraspinatus (*chuck tender*)* and *triceps brachii caput longum, (*LMC*)*, from each of 16 forequarters were seamed out and assigned randomly to 4 treatment groups: (1) whole uninjected controls, CO; (2) whole, injected at 15% level to give 0.5% salt and 0.3% phosphate (STPP) in the meat, WI; (3) injected and re-formed , IR; and (4) injected with added flavouring (a natural beef extract stock) to give 2% beef stock + 0.3% salt + 0.5% phosphate in the meat, and re-formed, IF. The latter was included because inter-muscle differences in beefy flavour had earlier been noted e.g. *supraspinatus* had a flavour score of 3.3 compared to the better score of 5.0 for *longissimus dorsi*, corresponding with reports in the literature. The products from the 4 treatments were compared for drip loss, colour, cook loss, ease of slicing, Kramer shear force, tensile strength, eating quality and appearance.

Drip loss did not differ between treatments (Table 12). Cook loss was significantly higher for IF than for CO ($p<0.001$), WI ($p<0.001$) and RI ($p<0.01$) in the case of the *triceps brachii* muscle but there were no differences between treatments for the *supraspinatus* muscle. Colour (redness, a*) of raw steaks from either muscle showed very few differences between treatments. Ease of slicing, measured as the number of slices out of 10 remaining intact following slicing to 1mm thickness, was 100% for all samples of both whole and re-formed joints. Kramer shear force results showed that CO samples had a higher shear force, indicating lower tenderness, than all other treatments in the case of the *supraspinatus* muscle and than two of the three other treatments in the case of *triceps brachii*. Tensile strength figures showed that peak force required to pull apart an 8mm thick slice of IF and RI samples was not different for the *triceps brachii* muscle but, in the case of the *supraspinatus* muscle, the bond in RI samples was stronger ($p<0.01$). Sensory panel tenderness scores for

the *supraspinatus* muscle showed all samples were more tender than controls but the difference between CO and RI samples was not significant. There were no differences in ratings for binding between whole and injected samples. Panel rating of flavour showed that WI samples had the best flavour, with significantly higher ratings than both CO ($p<0.01$) and IF ($p<0.05$) samples. Thus, inclusion of beef stock at recommended level in IF samples did not improve flavour, which agrees with a report by Lawrence *et al.* (*Meat Science*, **67**, 129-137, 2004).

Table 12: Processing characteristics and quality of whole and re-formed enhanced forequarter muscles.

Treatment	*Supraspinatus*				*Triceps brachii (caput longum)*			
	CO	WI	RI	IF	CO	WI	RI	IF
Drip loss (%)	1.8	3.0	2.0	1.3	1.5	2.3	2.4	1.5
Cook loss (%)	33.2	33.5	33.4	33.6	31.3^{a}	31.5a	31.6^{a}	35.0^{b}
Tensile strength (kN)	10.6^{a}	8.5^{a}	10.5^{a}	5.1^{b}	16.2a	12.4^{a}	4.7^{b}	4.9^{b}
Colour a* Day 1	20.4^{a}	20.7^{a}	19.0^{a}	18.8^{a}	17.4^{a}	19.7b	20.0^{b}	17.5^{a}
Colour a* 3	19.5^{a}	17.0^{a}	18.4^{a}	17.1^{a}	15.5^{a}	17.6b	16.6^{ab}	16.6^{ab}
Kramer shear (N/g)	83.1^{a}	49.8^{b}	59.9^{c}	59.5^{bc}	78.3^{a}	60.4^{bc}	70.7^{ac}	58.6^{b}
Tenderness	3.6^{a}	5.2^{b}	4.3^{ac}	4.5^{bc}				
Binding	4.4^{a}	4.6^{a}	4.1^{a}	4.3^{a}				
Overall flavour	3.6^{a}	4.5^{b}	4.1^{ab}	3.8^{a}				
Overall acceptability	3.7^{a}	4.6^{b}	4.3^{b}	4.1^{ab}				

Treatment means in the same row, within a muscle, with a common superscript letter are not significantly different($p<0.05$); CO = Control; WI= Whole injected RI= Re-formed injected IF= Injected with added flavour and re-formed

In general, the results showed that injection enhancement is compatible with re-forming for production of acceptable roast beef joints.

Figure 5: *Dorit PSM-21 multi-needle injector*

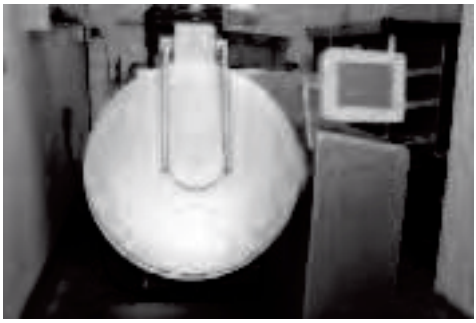

Figure 6: *Vacuum tumbler / mixer, model No MKR 150-000, Ruhle GmbH*

PART 4. TRANSFER OF INFORMATION AND TECHNOLOGY TO INDUSTRY

Workshops: Results were presented and products demonstrated to industry personnel in two workshops held at AFRC .

Meeting: In a meeting with a major beef processing company, the application of re-forming, based on experience in the current project, in development of a range of added-value beef products was presented and discussed.

In-factory trials: Trials were conducted in collaboration with two SMEs which proceeded to marketing of re-formed steaks and joints in raw and cooked forms, assisted by a RTI grant from Enterprise Ireland.

The trials involved semi-automation of the production of re-formed beef joints, from muscles such as brisket from the forequarter and rump tails from hindquarter, for subsequent industrial cooking for supply in joint form to a retail multiple and in sliced form to caterers. Further test products were a re-formed ready-to-cook sandwich steak and a re-formed ready-to-cook joint for dry

roasting and slicing hot (if adequate slice cohesiveness could be achieved) for carvery or home use or cold for deli counter sale

The factory trials were accordingly centred on optimising the tenderising, tumbling, filling and moulding steps in moving from a manual to a semi-automated process. For example, selection of appropriate mechanical tenderisation gave better disruption of muscle fibres and connective tissue and, in turn, more pliable meat pieces which could be filled by vacuum-filler into casings without incurring folding and entrapment of air which causes cavities and holes in the product and also affects binding. Chunking of the muscles to allow for better filling but not to the extent of losing texture was developed. The tumbling step had to be varied to cope with variation in extractability of protein between muscles, giving variation in raw cold-bonding and, therefore, in texture of the cooked products. In addition, increasing the degree of vacuum in the tumbler was effective in prevention of air-holes in the cooked products. The filling trials progressed through hand-filling in vacuum-shrink bags and pressure moulding to stuffing into fibrous casing using a power-stuffing press to vacuum-filling into fibrous casings in vacuum shrink bags using either a rotary 6-vane or a chamber type of vacuum filler.

The factory trials were a response to technology transfer needs of industry and also served to identify priority parameters for more detailed laboratory-based investigation.

KEY FINDING:
The re-formed joint products proved acceptable in both retail and catering outlets. However, marketing was suspended when a fall in price of beef hind-quarter muscles imported from third countries made the re-formed products uncompetitive.

General publications: These include four Relay Research up-dating reports and other publications, listed below in Publications section.

Manual:
A manual (ISBN 1 84170 516 0) based largely on results in Parts 1 - 3 was distributed to the trade in printed form in 2008. It included photographic guidance to location and separation of forequarter muscles. Copies are available on request from Teagasc, Ashtown Food Research Centre.

GENERAL CONCLUSIONS FOR THE PROJECT

- While the butchery approach of disassembling carcasses into individual muscles or groups of muscles rather than into mixed-muscle cuts is not new, the selective re-assembly of some of the individual muscles into customised, re-formed joints by use of cold-setting bonding agents is a novel process.
- The application of this technique in conjunction with pre-tenderisation of muscles and with further enhancement by injection of brine before the re-forming step increases the novelty of the process. It provides a means of controlling and optimising consistency and quality from otherwise variable and low-value meat and thus the opportunity for new products.
- Injection enhancement combined with re-forming gave joints of acceptable eating quality.
- The matching of muscle characteristics with tenderisation method with enhancement solution with bonding agent with forming technique constitutes a new technology package.
- The technology transfer activity, including the direct interaction with industry on product development, combined with the knowledge gained on basic properties of the muscle protein extracts and lipid and pigment stability, serves to identify several aspects for further research of potential industrial value.
- The study provided industrially relevant information in 5 main areas:
  (i) characterisation of individual beef forequarter muscles in terms of size, chemical composition, texture, extractability of protein and oxidative stability, defining their suitability for processing into re-formed joints;

(ii) comparison of performance of cold-set bonding agents to be used in development of re-formed whole-muscle joints that could be marketed as chilled product;

(iii) measurement of effects of methods of tenderisation and of enhancement of muscles as preparatory treatments;

(iv) application of the foregoing in development of new, re-formed products in joint and steak forms, including heat-and-serve products, for sale raw or pre-cooked through food service and retailing sectors, for serving hot or cold;

(v) comparison of yields and boning time between seaming + PAD procedure and conventional boning of forequarters.

RECOMMENDATIONS TO INDUSTRY

- Precise information on the properties of the individual muscles of the forequarter is useful when considering product development.
- Processors will have to adopt seaming and PAD trimming increasingly as consumers demand low-fat products. Fat content was around 1.5% in most of the fifteen forequarter muscles tested in PAD form (and 10 of the 15 had shear values when cooked of less than 50 N, denoting an acceptable level of tenderness)
- However, yield of PAD on seamed-out muscle was above 80% for only 3 of the 15 muscles, which reduces the potential for adding value by PAD-trimming unless value can be added to the fat and connective tissue accumulated as trim.
- Cold-set re-forming techniques, enhancement treatments and mechanical or other tenderisation methods can be combined with the selection of compatible individual muscles to provide opportunities for design of many added-value beef products.
- Such treatments are applicable to beef or lamb muscles of low or medium tenderness provided the addition of value through separation, tenderisation, enhancement and re-forming would exceed the cost of ingredients and processing.

- The principles can be applied in the heat-and-serve whole muscle type of beef products already on the market but also in development of cured/marinated, finger and snack beef items.
- The latter could include such items as fajitas, shredded beef (flavoured and texturised), shaved beef, dry-cured beef sticks, beef cake and beef sheets. Such forms of beef products could also be availed of to market nutritionally - modified beef, e.g. CLA-enriched, and thus gain a share for beef in the rapidly-developing market for functional foods and nutraceuticals.
- The evaluation of the forequarter indicates that a similar examination of the properties of individual muscles in the hindquarter would be worthwhile. It would facilitate portion control and the development of products from high-value cuts which could include single or half-muscle servings instead of conventional sliced or steaked forms.

ACKNOWLEDGEMENTS

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PUBLICATIONS FROM THIS PROJECT

Kenny, T., Ward, P., Lennon, A., Sullivan, P., McDonald, K. and O'Neill, E. 2008. Adding Value to Beef Forequarter Muscles – A Manual for Industry. Teagasc ISBN 1 84170 516 0.

Kenny, T., O'Neill, E., Lennon, A. and Ward, P. 2003-2004. Presentations at RELAY Workshops on "Hot Topics for the Meat Industry" (AFRC, 20 Feb 2003) and "Developing beef products from low-value cuts" (AFRC, 30 November 2004).

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