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Development of Value-Added Beef Products

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Contents

DEVELOPMENT OF VALUE-ADDED BEEF PRODUCTS

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SUMMARY

Technologies were developed to improve the functionality of low-value beef and to incorporate it into value-added products, including restructured and emulsion-type beef products. Frankfurters formulated with shin beef treated with lactic acid had similar cook losses to topside and shin beef controls and were more tender, juicy and acceptable than shin beef control. The acid treatments had no detrimental effect on flavour of the frankfurters and in some cases the flavour was rated higher than the control. It was concluded that marination in lactic acid between 0.05M and 0.1M can increase the functionality of low-value beef for use in value-added products.

The enzymatic breakdown of collagen by collagenase may have potential in the treatment of low value shin beef. Texture profile analysis indicated that the hardness and chewiness of both low-value beef (LVB) and high-value beef (HVB) sausage-type products were reduced with the application of 0.04% w/w of the enzyme. Sensory panellists found the high content of connective tissue in LVB products unappealing and reported that these products were significantly chewier than those prepared using topside (*M. semimembranosus*). Collagen was effectively solubilised by collagenase (0.04% w/w). Microbial collagenases have not been evaluated for safety as food additives and thus taste panel assessment of products containing collagenase was not carried out. Although collagenase improved the textural properties of products, its effect on their palatability and flavour remains unknown.

A restructured steak was developed using brisket (*M. pectoralis*) with mechanical blade tenderisation and an enzyme preparation, transglutaminase (TGase), for cold binding. The restructured steaks were rated similar to the control striploin steaks in overall acceptability, tenderness, overall texture and firmness. The striploin steaks were rated better in flavour and juiciness but both rated good to very good. In further trials, mechanically tenderised restructured steaks were rated as even better than the natural striploin. Panellists rated a re-formed joint, using chuck muscles from beef forequarter, better in juiciness, tenderness, flavour and colour in comparison to a natural striploin.

INTRODUCTION

Consumers are demanding convenience foods but are increasingly concerned about issues of safety, quality and health. The meat sector must develop innovative beef products that are cost efficient, convenient, nutritious, visually attractive, wholesome to eat and above all safe. This will give consumers alternatives to traditional products. Fish and poultry muscles are low in connective tissue and high in functional protein. Beef muscle, particularly from low-value cuts, needs modification to degrade the intrinsic collagen structure. The strong inverse correlation between value and collagen content in different cuts of beef (Kuypers and Kurth, 1995) shows the decisive influence of collagen on tenderness. Progress in lowering the level of collagen or 'background' toughness in meat has been limited (Tarrant, 1998).

Enzymatic, mechanical and chemical treatments may be applied to breakdown collagen, thereby producing a product with the desired tenderness and texture. However, a disadvantage of enzymatic tenderisation is the preferential hydrolysis of functional myofibrillar and sarcoplasmic proteins over connective tissue proteins. The use of organic acids in marinading has long been recognised as a traditional culinary technique used to enhance the flavour and tenderness of meat prior to cooking. Marination affects the collagen structure by releasing acid-labile cross-linkages, thus loosening the structure, and also acts on the myofibrils causing them to swell. These techniques may enhance the use of beef in processed products similar to those currently produced from poultry and fish muscle.

Blamey (1995) reported that value-added poultry sales represented 20% of sales in the US in 1995 and anticipated that they would account for 75% of sales by the end of 2000. In contrast, figures from the CSO on the value of exports of beef from Ireland in 1999 show a low proportion of processed beef products, approximately 5%. This work investigated technologies to improve the functionality of beef, particularly low-value beef to increase its versatility for the development of value-added restructured and emulsion-type beef products. More specifically the project objectives were (1) to increase the functionality of beef; (2) to develop innovative beef products;

(3) to increase the use of low-value carcass cuts as a functional ingredient in beef products.

The research was carried out in three stages: solubilisation of connective tissue components of beef using organic acids, application of proteases to beef model systems to increase functionality, and physical disruption of connective tissue in beef by mechanical treatments such as needle and blade tenderising, tumbling and massaging.

THE USE OF ORGANIC ACIDS TO UPGRADE LOW-VALUE BEEF FOR USE IN EMULSION-TYPE MEAT PRODUCTS

Effect of acetic, lactic and citric acid on low-value beef for use in frankfurters

Shin beef was used to represent "low-value beef"(LVB) and topside (*M. Semimembranosus)* was used as a control "high-value beef"(HVB). A preliminary trial was carried out using acetic, lactic and citric acids at a 0.5M concentration. The acid was added to both LVB and HVB at a 10% v/w (10cm^3 acid per 100g of treated meat). Analysis showed that the LVB had a higher total collagen content than the HVB (4.6% *vs* 0.8%). The acid treatments, in particular citric acid, reduced water-holding capacity (WHC) in both LVB and HVB. The meat turned brown at a faster rate after citric acid than the other treatments.

For the product trial, shin beef obtained from a local abattoir was treated with citric, lactic and acetic acids at concentrations of 0.5M and 0.05M. The meat was minced through a 5mm plate and then mixed with the acid at 10% v/w and left in a chill at 1°C overnight. pH was measured before and after addition of the acid (1h and 24h). The treated beef was then preweighed, vacuum packed and frozen at -20°C until use. Frankfurters (25-30% fat) were manufactured with the treated beef and pork backfat according to the recipe of Desmond and Troy (2001). Topside (*M. semimembranosus*) and untreated shin beef were used as controls.

The compositional analysis (Table 1) showed that the frankfurters were produced with the desired fat level of 25-30%. The acid treated frankfurters had higher moisture contents, in particular 0.5M lactic acid, and as a consequence lower protein values in comparison to both the shin beef and topside controls. Very little effect on cook loss was observed with all treatments having similar cook losses to the shin beef control. However the higher concentration of lactic acid reduced ($p<0.05$) the cook loss by c. 1.5%. The batter lost all functionality in the high citric and acetic acid treatments probably due to the decrease in pH to 4.6. The frankfurters had a cook loss of ~15% and a large amount of shrinkage within the casings and were unsuitable for further tests.

Sensory analysis of the frankfurters (Table 2) showed that the addition of a high concentration of lactic acid increased tenderness but to the detriment of flavour and acceptability. The addition of 0.05M lactic and citric acid had no apparent tenderising affect in comparison to the control shin beef; however frankfurters with the lactic acid treated beef were more tender than frankfurters with citric acid. Frankfurters manufactured with acid treated beef had similar juiciness scores to the topside control and were found to be significantly ($p<0.05$) more juicy than the shin beef control. Panellists rated

Table 1: Effect of acid treatments of beef on the chemical composition and cook loss of frankfurters.

Beef treatment	Moisture (%)	Fat (%)	Protein (%)	Cook loss (%)
Topside control	56.2^{c}	27.4^{b}	13.5^{a}	5.7^{ab}
Shin beef control	55.3^{c}	28.2^{a}	13.3^{a}	6.1^{ab}
0.05M lactic	58.5^{a}	25.8^{c}	12.9^{a}	6.8^{a}
0.05M citric	57.3^{b}	27.6^{b}	12.1^{a}	6.1^{ab}
0.5M lactic	58.3^{a}	26.2^{c}	12.3^{a}	5.3^{b}

$^{a\text{-}c}$ Means in the same column with different letters are different ($p<0.05$).

Table 2: Effect of acid treatments of beef on the sensory characteristics of frankfurters.

Beef treatment	Sensory attributes[1]						
	T	J	OFI	Oth.F	OF	OT	OA
Topside control	6.6[a]	6.1[a]	4.3[a]	2.0[b]	4.5[a]	4.3[a]b	4.4[a]
Shin beef control	5.7b[c]	5.5[b]	3.6[cd]	2.0[b]	3.9[c]	3.9[bc]	4.0[b]
0.05M lactic	5.6[c]	5.9[a]	3.9b[c]	2.1[b]	4.0b[c]	3.8[c]	4.0[b]
0.05M citric	6.1[b]	6.1[a]	4.1[ab]	1.9[b]	4.3[ab]	4.3[a]	4.4[a]
0.5M lactic	6.9[a]	6.0[a]	3.6[d]	2.8[a]	2.9[d]	2.4[d]	2.3[c]

[1] Sensory attributes: T, tenderness; J, juiciness; OFI, overall flavour intensity; Oth.F., other flavours; OF, overall flavour; OT, overall texture; OA, overall acceptability.
Tenderness, juiciness and overall flavour intensity were evaluated by means of eight-point scales (8=extremely tender, juicy and intense; 1=extremely tough, dry and bland).
Other flavours, overall flavour and overall acceptability were evaluated by means of six-point structured scales (6=extremely intense, very good and extremely acceptable; 1=none, very poor and not acceptable).
[a-d] Means in the same column with different letters are different ($p<0.05$).

frankfurters made with 0.5M lactic acid treated beef to have a slightly intense 'other flavour' while the other treatments were rated to have a 'just detectable' other flavour. Overall, 0.05M lactic acid gave better texture, flavour and acceptability than 0.05M citric acid or topside control. In terms of overall acceptability, frankfurters made from 0.05M lactic acid treated shin beef were similar to those made from topside beef.

Texture profile analysis (TPA) showed that frankfurters made with shin beef had the highest hardness value (Table 3) but were not significantly harder than the topside control, lactic (0.05M) and citric (0.05M). The higher concentration of lactic acid significantly ($p<0.05$) reduced the hardness value confirming the sensory panel results that this treatment was more tender.

Table 3: Effect of acid treatments of beef on the texture (TPA) of frankfurters.

Beef treatment	Hd	Sp	Co	Gm	Ch
Topside control	42.5^{a}	7.2^{a}	0.60^{c}	25.4^{b}	183.9^{b}
Shin beef control	46.6^{a}	7.4^{a}	0.63^{b}	29.1^{a}	213.9^{a}
0.05M lactic	46.0^{a}	7.5^{a}	0.64^{a}	29.5^{a}	221.8^{a}
0.05M citric	41.9^{a}	7.5^{a}	0.64^{a}	26.9^{ab}	200.0^{ab}
0.5M lactic	28.3^{b}	7.4^{a}	0.56^{d}	17.2^{c}	116.8^{c}

Hd-hardness; Sp-springiness; Co-cohesiveness; Gm-gumminess; Ch-chewiness.
$^{a-d}$ Means in the same column with different letters are different ($p<0.05$).

Differences between treatments in the internal colour of the cooked frankfurters (Table 4) were small, although significant, and are probably not detrimental to the product. Arganosa and Marriott (1989) reported that cooked restructured steaks treated with acid were whiter than controls. Acid

Table 4: Effect of acid treatments of beef on the HunterLab colour values of frankfurters.

Beef treatment	L-value	a-value	b-value
Topside control	52.1^{b}	8.2^{b}	9.3^{b}
Shin beef control	54.9^{a}	7.7^{c}	9.3^{b}
0.05M lactic	53.8^{a}	7.7^{c}	9.6^{a}
0.05M citric	53.9^{a}	8.1^{bc}	9.4^{ab}
0.5M lactic	45.4^{c}	9.9^{a}	8.7^{c}

$^{a-c}$ Means in the same column with different letters are different ($p<0.05$).

treatment appeared to enhance the conversion of myoglobin to metmyoglobin, which has a lower colour intensity.

This trial demonstrated that citric and lactic acid altered the functionality of the meat. The addition of acid had very little affect on cook loss and at low concentrations had no apparent tenderising affect. However, at a higher concentration a significant effect on tenderness was observed, but to the detriment of flavour and acceptability. The juiciness of the frankfurters was increased by the addition of the acids while lactic acid at the lower concentration improved overall texture and acceptability. Objective texture measurements indicate that lactic acid has a tenderising effect particularly at higher concentrations. This study indicates that lactic acid has the potential to improve the functionality of shin beef.

Optimisation of lactic acid addition to low-value beef for use in frankfurters

The previous trial showed that lactic acid increased the functionality of low-value beef giving a better quality frankfurter. To optimise the concentration of acid to be added to shin beef it was necessary to examine different concentrations (0.05M, 0.075M, 0.1M and 0.25M). Treatment of shin beef with lactic acid and manufacture of frankfurters from treated and control beef was carried out as described above in the first trial.

The addition of the lactic acid had no effect on pH (Table 5). The shin beef control treatment had the lowest cook loss ($p<0.05$), approximately 2% compared to the topside control (3.5%). The acid treatments significantly increased the cook losses of the frankfurters; although significant, it was a marginal increase. Consequently, the acid treatments reduced the water-holding capacity (WHC) in comparison to the shin beef control but had similar values to the topside control. Sensory analysis (Table 5) showed that in all cases the acid treatments improved tenderness scores in comparison to the shin beef control. The 0.075M and 0.25M treatments gave the highest score. The acid treatments had no detrimental effect on the flavour of the frankfurter and panellists detected no off-flavours.

Table 5: Quality characteristics of frankfurters manufactured from shin beef treated with different concentrations of lactic acid.

Parameter	Topside control	Shin beef control	0.05M	0.075M	0.1M	0.25M
pH (1h)	5.5^{b}	5.9^{a}	5.9^{a}	5.8^{a}	5.6^{a}	5.5^{a}
pH (24h)	5.5^{b}	5.9^{a}	5.8^{a}	5.8^{a}	5.6^{b}	5.5^{b}
Chemical composition						
Moisture (%)	56.4^{ab}	55.3^{b}	56.7^{a}	56.7^{a}	57.7^{a}	56.8^{a}
Fat (%)	25.8^{c}	28.0^{a}	27.2^{ab}	27.4^{ab}	26.9^{b}	27.1^{ab}
Protein (%)	14.0^{a}	12.9^{b}	11.8^{c}	11.7^{c}	11.5^{c}	11.7^{c}
Cooking properties						
Cook loss (%)	3.4^{ab}	2.3^{c}	3.9^{a}	3.1^{b}	3.5^{ab}	2.8^{bc}
WHC (%)	77.8^{ab}	79.3^{a}	74.7^{bc}	74.8^{bc}	74.2^{bc}	72.8^{c}
Sensory analysis[1]						
Tenderness	6.0^{d}	5.9^{d}	6.8^{bc}	7.2^{a}	6.5^{c}	7.1^{ab}
Juiciness	6.0^{b}	5.8^{b}	5.9^{b}	6.1^{ab}	5.9^{b}	6.5^{a}
Overall flavour intensity	4.1^{a}	3.7^{b}	3.7^{b}	3.8^{ab}	4.1^{a}	4.0^{ab}
Other flavours	2.3^{a}	2.1^{a}	2.2^{a}	2.2^{a}	2.1^{a}	2.2^{a}
Overall flavour	4.0^{a}	3.6^{a}	3.7^{a}	3.7^{a}	3.9^{a}	3.9
Overall texture	4.3^{a}	3.8^{b}	3.9^{b}	3.8^{b}	3.9^{b}	3.9^{b}
Overall acceptability	4.2^{a}	3.7^{b}	3.9^{ab}	3.9^{ab}	4.1^{a}	4.0^{ab}
Instrumental texture analysis						
Hardness (N)	45.8^{bc}	53.4^{a}	43.5^{c}	46.9^{bc}	47.2^{bc}	49.8^{ab}
Springiness (mm)	7.0^{b}	7.2^{a}	7.1^{ab}	7.2^{a}	7.1^{a}	7.1^{a}
Cohesiveness	0.5^{b}	0.6^{a}	0.6^{a}	0.6^{a}	0.6^{a}	0.6
Gumminess	26.3^{cd}	31.9^{a}	26.0^{c}	28.5^{bcd}	29.0^{bc}	30.2^{ab}
Chewiness	181^{d}	234^{a}	185^{cd}	206^{bc}	210^{b}	216^{ab}
Instrumental colour analysis						
L-value	48.7^{c}	52.2^{b}	52.1^{b}	53.2^{a}	52.2^{b}	52.5^{ab}
a-value	9.4^{a}	8.8^{b}	8.2^{c}	7.5^{d}	7.9^{c}	7.9^{c}
b-value	9.8^{b}	10.0^{a}	10.0^{a}	10.0^{a}	10.1^{a}	10.0^{a}

[1] Sensory attributes: tenderness, juiciness and overall flavour intensity were evaluated by means of eight-point scales (8=extremely tender/juicy/intense respectively; 1=extremely tough/dry/bland respectively).

Other flavours, overall flavour and overall acceptability were evaluated by means of six-point structured scales (6=extremely intense/very good/extremely acceptable respectively; 1=none/very poor/not acceptable respectively).

[a-d]Means in the same row with different letters are different ($p<0.05$).

The topside control was rated the highest ($p<0.05$) for overall texture while no difference was found between the shin beef control and the acid treatments. The 0.1M treatment scored similarly to the topside control for overall acceptability. Texture profile analysis (TPA) showed similar results (Table 5) to those obtained for sensory analysis. The 0.05M and 0.1M treatments gave the lowest hardness values and were similar ($p>0.05$) to the topside control. Very little difference was found for between the treatments for springiness. The task of optimising the addition of lactic acid showed that lactic acid marination between 0.05M and 0.1M increased the functionality of low value beef.

USE OF AN ENZYME TO UPGRADE LOW-VALUE BEEF

The enzyme collagenase was used to enhance the textural properties of sausage-type beef products prepared from low value beef. The specific objective was to examine the effect of collagenase on the texture, water holding capacity, composition and collagen content of sausage-type products prepared from shin beef.

As before, shin beef represented low value beef (LVB) and topside (*M. semimembranosus)* represented high value beef (HVB). Both were trimmed of excess fat, minced through a 10-mm plate and treated with a microbial collagenase from *Clostridium histolyticum* (Sigma Blend Type F; Sigma-Aldrich Ireland). The collagenase (1.8 – 2.2 FALGPA hydrolysis units/mg) was suspended in distilled water and added to the minced LVB and HVB at levels of 0.01 or 0.04% w/w (g enzyme per 100g of treated meat). The same weight of distilled water was added to the control samples. The meat containing the collagenase suspension was mixed thoroughly to aid dispersion of the enzyme. The control and treated samples were stored overnight at 40°C. The beef was re-minced through a 10-mm plate prior to stuffing into 22mm diameter cellulose casings (Viscofon, Food Process Technology) using a bench-top hand filler.

The products in casing were cooked in a water-bath to an internal temperature of 50°C and held at this temperature for 10 min to facilitate collagenase activity (Foegeding & Larick, 1986). The temperature of the water bath was

increased to 80°C and the products were cooked to a final internal temperature of 72°C. The cooked products were showered in cold water until cool, kept overnight at 4°C, vacuum packed, and frozen at -20°C until required for analysis.

Effect of collagenase treatment on product texture

Mean panellist scores indicated that the untreated LVB products were chewier ($p<0.001$) than the HVB products (4.4 vs 2.9). The chewier texture observed may be attributed to the higher level of collagen in these products. Many panellists commented on the presence of connective tissue and residual chewiness in the LVB products.

Texture profile analysis (Table 6) showed that the application of 0.04% w/w collagenase to the low and high value products resulted in reduced hardness and chewiness values (Table 6) and this may be attributed to the ability of collagenase to hydrolyse and solubilise collagen (Bailey, 1988). The textural properties of the products were unaffected by the addition of 0.01% w/w collagenase. This suggests that either the 0.01% level of collagenase did not have an effect, or alternatively, that the Instron was not sensitive enough to record the textural changes that may have occurred with the application of the lower level of enzyme.

Table 6: Hardness and chewiness values of sausage-type products prepared from low value beef (LVB) and high value beef (HVB) with or without collagenase.

	Hardness (N)		Chewiness (J)	
	HVB	LVB	HVB	LVB
Control	23 ± 2[a]	24 ± 3[a]	78 ± 11[a]	78 ± 9[a]
Collagenase 0.01%	25 ± 3[a]	24 ± 1[a]	71 ± 13[a]	71 ± 4[a]
Collagenase 0.04%	15 ± 4[b]	19 ± 3[c]	30 ± 13[b]	47 ± 9[c]

[a,b,c] Means (± standard deviation) in the same column or row, within a main effect, with unlike superscripts are different ($p<0.05$).

The 2x3 factorial design used to analyse the results of this work permits the examination of potential interactions. Analysis of variance (Table 7) showed that the application of collagenase to emulsion type beef products affected the hardness and chewiness of the low and high value beef products. An interaction was observed between beef type and enzyme level on hardness and chewiness as assessed by TPA. This interaction may be explained in terms of the collagenase to collagen ratio. Collagenase may be more effective in the HVB products than in the LVB products because the ratio of enzyme to collagen is higher in the HVB products.

Table 7: Analysis of variance using a 2x3 factorial design on the application of collagenase to sausage-type beef products.

	Beef	Enzyme	Beef*Enzyme
Hardness	ns	***	*
Chewiness	ns	***	*
% Moisture	*	**	ns
% Fat	***	ns	ns
% Protein	ns	ns	ns
Water holding capacity	ns	ns	ns
Total collagen content	***	ns	ns

Significance level: ***p<0.001, **p<0.01, *p<0.05

Effect of collagenase treatment on product composition

Moisture losses occurred in HVB and LVB products during cooking (Table 8). Products prepared using shin beef had a higher fat content than topside products. The fat content was expressed as a percentage of the whole weight tissue, which was greater in HVB products due to their higher moisture content.

Table 8: Composition of raw and cooked high value beef (HVB) and low value beef (LVB) products.

	%Moisture		%Fat		%Protein	
	HVB	LVB	HVB	LVB	HVB	LVB
Uncooked						
Control	73.4[a]	74.3[a]	2.6a[a]	3.3[a]	22.8[a]	21.2[a]
Cooked						
Control	66.7[b]	66.2[b]	3.2[a]	5.6[b]	27.6[b]	26.9[b]
Collagenase 0.01%	67.5[b]	66.3[b]	2.9[a]	6.1[b]	26.9[b]	26.9[b]
Collagenase 0.04%	69.1[c]	67.3[b]	2.5[a]	5.5[b]	26.5[b]	26.4[b]

[a,b,c] Means (± standard deviation) in the same column or row, within a main effect, with unlike superscripts are different ($p<0.05$).

The moisture content of HVB products increased on addition of 0.04% w/w collagenase. There was also a trend towards an increase in the moisture content of low value products following collagenase treatment. These changes may be attributed to the solubilisation of collagen by collagenase. The enzyme degrades native collagen producing a complex mixture of low molecular weight fragments that are capable of binding water. The more notable moisture increase in products manufactured using high value beef may be due, in part, to the higher collagenase/collagen ratio, allowing the enzyme to act more effectively on the lower level of collagen present in the HVB products.

Collagen analysis confirmed taste panellists' observations, with LVB products containing significantly more collagen than products prepared using high value beef. Expressing collagen concentration as a percentage of total protein, or fat free dry matter, or weight of tissue showed differences between HVB and LVB muscles. The LVB products in this study were found to contain on average 10% collagen when collagen was expressed as a percentage of the protein content.

The mean soluble collagen content of the LVB products, when expressed as a percentage of the total collagen content on a cooked weight basis, was

Table 9: Collagen contents of cooked sausage-type products prepared from low value beef (LVB) and high value beef (HVB), with or without collagenase.

	TOTAL COLLAGEN				*SOLUBLE COLLAGEN*	
	g/100g cooked product		% total protein	% of FFDM*	g/100g cooked product	% total collagen
	HVB	LVB	LVB	LVB	LVB	LVB
Control	0.85[a]	2.74[b]	10.14[a]	9.72[a]	0.43[a]	15.81[a]
Collagenase 0.04%	0.83[a]	2.79[b]	10.63[a]	10.19[a]	1.37[b]	51.46[b]

[a,b] Means in the same column or row, within a main effect, with unlike superscripts are different ($p<0.001$). *FFDM: Fat free dry matter

15.81%, while some of the values were found to be as high as 19%. These results are similar to those of Dransfield (1977) who reported that 20.5% of the *M. extensor carpi radialis* collagen was heat soluble. The application of 0.04% w/w collagenase to the LVB products increased the soluble collagen fraction to above 50% of the total collagen.

The results suggest that collagenase may have some potential to increase the usefulness of low value shin beef in value-added beef products. Its effect on the textural properties of the sausage-type beef products was very encouraging. Texture profile analysis indicated that the hardness and chewiness of both LVB and HVB products were reduced with the application of 0.04% w/w level of the enzyme. The inclusion of 0.01% w/w collagenase, however, resulted in little or no change in the texture of the products. The graded addition of collagenase to emulsion type products should be investigated in the future to ascertain the most effective level of collagenase. This may also help to explain why the lower level of enzyme did not produce a significant effect. Regardless of what mechanical devices are employed to predict textural properties of a product, the ultimate judge of acceptability is the consumer. Therefore, it is important that sensory evaluation be conducted to support these mechanical findings when a food-grade collagenase is available.

PHYSICAL DISRUPTION OF CONNECTIVE TISSUE IN BEEF BY MECHANICAL TREATMENTS

Development of restructured steaks from brisket muscle

A restructured steak was developed using brisket (M. *pectoralis*) from the forequarter, mechanical blade tenderisation and a transglutaminase (TGase) enzyme preparation for cold binding.

After preliminary screening trials the following procedure was employed:

Cow briskets were trimmed free of fat, membrane and connective tissue. The meat was given about 5 passes through a 36 blade manually operated tenderiser (Fig 1) with the grain (fibres) of the meat parallel to the blades, followed by about 5 passes with the grain at right angles to the blades. The mechanically treated muscle was then cut, parallel with the grain, into strips about 10mm thick and 50 to 70 mm long. The strips were chilled to 2°C and

Figure 1: Tenderisation of meat sample by 36 blade manually operated tenderiser.

coated, by manual mixing, with a solution/suspension containing TGase preparation, water and a proprietary meat seasoning mixture. For restructuring, the coated tenderised strips were layered in a vacuum packed bag in a mould, pressed into the mould shape, stored at 2°C for 12 hours to allow TGase-catalysed bonding to proceed, frozen to –20°C and band-sawed into steaks of 20mm thickness.

Inspection of restructured steaks after thawing showed that binding (cohesion) of the muscle pieces was excellent and that the they had a cut appearance like that of a natural steak. Samples of the restructured steaks, with and without overnight treatment with a marinade, were cooked by grilling and tasted by a 10 member sensory panel together with control beef striploin steaks which had been given similar preparation. The means of panel ratings, converted to numerical scores, are shown in Table 10. The

Table 10: Eating quality of restructured steaks prepared from beef brisket compared with natural striploin steaks. Data are mean scores from sensory panels.

	Marination		No Marination	
Sensory attributes*	Restructured	Control	Restructured	Control
Tenderness	5.6	5.6	5.3	5.4
Juiciness	5.1	5.8	4.9	6.7
Overall flavour	4.3	4.9	3.4	4.5
Overall firmness	5.6	5.6	5.4	5.5
Overall texture	4.9	4.8	4.2	3.6
Overall acceptability	4.6	4.5	4.1	3.9

*Tenderness, juiciness and overall firmness were evaluated by means of eight-point scales (8=extremely tender, juicy and firm respectively; 1=extremely tough, dry and mushy respectively). Overall flavour, texture and acceptability were evaluated by means of six-point scales (6=extremely good, very good and extremely acceptable respectively: 1=very poor, very poor and not acceptable respectively).

restructured steaks were rated as similar to the control striploin steaks in overall acceptability and in several important individual qualities, including tenderness, overall texture and firmness. The control steaks were rated better in flavour and juiciness but both were good to very good.

Marination seemed to affect the restructured steaks more than the control striploins. Marinated steaks were slightly more tender and juicy, had better flavour and as a result panellists found them to be slightly more acceptable.

Further work was conducted, both in pilot plant and with a meat processor, on mechanical blade tenderisation and use of transglutaminase (TGase) enzyme preparation in the development of a restructured beef steak from brisket muscle (*M. pectoralis*).

A pilot plant trial compared steaks from 3 treatments: (1) brisket mechanically tenderised and treated for binding with TGase enzyme; (2) brisket not tenderised but treated with TGase; (3) prime beef striploin aged but not mechanically tenderised and not treated with TGase. Twelve cow briskets were trimmed free of fat and membrane tissue, as done in PAD-style commercial preparation, and six were taken at random for each of treatments 1 and 2. For treatment 1, each of the six briskets was passed ten times through a 36-blade tenderiser (5 passes parallel to the muscle fibres and 5 perpendicular), cut parallel with the fibres into strips which were 100 mm wide and mixed with a 10% aqueous solution of "Activa EB" TGase-containing product at the rate of 10ml of solution per 100g of meat (giving a concentration of 1% of Activa EB, or 0.005% of TGase, in the meat).

The control strips were layered in a polythene-lined oval-shaped mould, pressed into the mould shape, and held at 4°C for 18 hours (to allow TGase-catalysed bonding to develop). The restructured log in the mould was tempered, by holding in a freezer for several hours, vacuum packed, stored in a freezer at -20°C for 4 weeks, and sawn into steaks of 20 mm thickness, which were vacuum packed individually and held frozen until required for taste panel testing.

Examination of the thawed steaks showed that cohesion of the muscle pieces was adequate, indicating the efficiency of the TGase treatment. Three

portions of steak (1 of each treatment, restructured tenderised, restructured non-tenderised, and striploin) were presented hot to a 6 member sensory panel and this exercise was replicated six times. The results, shown in Table 11 as means of panel ratings converted to numerical scores, indicate that the physical disruption of tissue in the raw meat by mechanical tenderisation had a marked beneficial effect in terms of tenderness, juiciness, overall texture and overall acceptability of the restructured tenderised steaks. The restructured tenderised steak was rated as even better than the natural striploin.

Table 11: Eating quality of restructured steaks prepared from beef brisket compared with prime striploin steak. Data are mean scores (n=36) from ratings by sensory panels.

Sensory attributes*	Restructured tenderised	Restructured non-tenderised	Striploin
Tenderness	5.0	3.7	3.8
Juiciness	4.9	4.2	4.1
Overall flavour	3.6	3.4	3.5
Overall texture	3.9	3.3	3.1
Overall acceptability	3.6	3.0	2.9

*Tenderness and juiciness from 1, extremely tough/dry, to 8, extremely tender/juicy; Overall flavour, texture and acceptability from 1, very poor/very poor/not acceptable, to 6, extremely good/very good/ extremely acceptable.

Development of reformed carvery joints from chuck muscle

A re-formed joint, from chuck muscles from beef forequarter, was then developed in pilot plant and at the premises of a fresh meat processor. The objective was to produce a re-formed joint resembling a natural striploin primal cut for supply in fresh chilled form to caterers.

Chuck meat from heifer forequarters was trimmed to remove visible fat and membranes, as in commercial PAD boning. Natural fat covering for the joints was prepared by cutting strips of meat, including cover fat, 10-15 cm wide, from the rib area. These were trimmed of excess fat to give uniform strips of 1.0 to 1.5 kg in weight, with flesh side as lean as possible to provide maximum bonding sites. Muscle and cover strips were mechanically tenderized using a 36-blade tenderiser, with muscle placed on top of lean surface of cover strips. Brine solution was mixed at 10ml per 100g of tenderised meat, giving concentrations in the meat of 1.0% of salt (sodium chloride), 0.2% of phosphate (STPP), 0.6% of dextrose, 0.3% of brown sugar, 0.025 of sodium ascorbate, 1% of Activa EB binder (0.005% of TGase active ingredient) and 7% of added water.

For the re-forming step, the muscle was placed in a polythene-lined mould with the grain of the muscle parallel to the long axis of the mould and the cover strips were placed on top. The meat and strips were pressed, using the spring-loaded lid, then removed, vacuum packed, replaced in the mould, re-pressed and held under pressure in the mould for 12 hours in a chill (0-4°C) to allow the TGase-catalysed bonding to develop. The re-formed striploin-shaped joints, measuring 90 mm high x 170 mm long, were vacuum packed and stored in a chill pending examination.

The raw re-formed joints described above showed satisfactory binding of the cover strip, good cohesion of muscles, acceptable red colour and a general appearance similar to, but more uniform than, that of natural striploins. Sections of re-formed joint and of a natural striploin were dry cooked in an oven at 180°C to a core temperature of 72-75°C. The reformed joint retained its shape during cooking as well as the natural striploin joint. A panel of six people tasted hot slices of both cooked joints and rated the reformed meat better in juiciness, tenderness, flavour and colour. Binding was rated equal in both samples.

The remaining portions of the joints were cooked, sliced and submitted as cold meat slices to a further panel of ten tasters. The results shown in Table 12 indicate that in cold slice form the re-formed product was equal to or better than the natural striploin in colour, tenderness, juiciness, flavour,

Table 12: Eating quality of cold slices of a reformed chuck joint and a natural prime striploin joint. Data are mean scores (n=10) from ratings by sensory panels.

Sensory attributes*	Reformed chuck	Natural striploin
Acceptability of colour	4.3	4.4
Tenderness	5.0	4.5
Juiciness	4.8	3.3
Overall flavor	4.8	4.4
Binding (cohesion)	4.7	4.5
Saltiness	2.4	1.4
Overall acceptability	4.7	3.7

*On scale of 1 to 6: 1 = not acceptable in colour / very tough / very dry / very poor in flavour / very poor in binding / not salty / not acceptable.
6 = extremely acceptable in colour / very tender / very juicy / extremely good in flavour / extremely good in binding / extremely salty / extremely acceptable.

binding and overall acceptability. Saltiness was, understandably, noticeably higher in the re-formed meat.

Extension of the results to industry is in progress, with the development of re-formed raw joints and steaks with a fresh meat SME, and of pre-cooked joints and slices with a cooked meats SME, both in the wholesale catering supply business.

Development of reformed roasting joints from brisket muscle

Brisket muscle (*M. pectoralis*) from heifer forequarter, tenderised and non-tenderised, was mixed with brine at 5% by weight of meat. The brine contained salt, phosphate, sugar and ascorbate in addition to Activa EB transglutaminase (TGase) ingredient as binding agent at a level to give 50 ppm of TGase in the meat. The re-forming procedure was similar to that described

previously. Strips of brined trimmed muscle and of cover fat were placed in layers and vacuum-packed in moulds. The meat and fat strips were pressed and held in the moulds for 12 hours in a chill to allow binding to develop.

Samples of the re-formed striploin-shaped joints and of natural aged striploin were cooked in heat-shrunk vacuumed bags to a core temperature of 73°C, cooled, weighed, dipped in (20%) caramel solution, flash-roasted for 12 minutes in a dry oven, re-cooled, sliced at 2 mm thickness and evaluated by an 8-member sensory panel. Cook losses (Table 13) were considerably higher for the natural striploin joint. The difference in net yield would be magnified when the added brine in the re-formed joints is taken into account. The re-formed products scored much higher than the natural joint in tenderness, juiciness and overall acceptability. There was little difference between tenderised and non-tenderised re-formed products in this case where the products contained salt and phosphate and were presented sliced, compared to the samples in an earlier trial, which had no added salt and were presented as steaks.

Table 13: Cook losses and sensory panel ratings* on cold slices of reformed joints from brisket muscle and for natural striploin joints.

	Reformed tenderised	Reformed non-tenderised	Striploin
Cook loss %	27.8	30.7	33.5
Roasting loss %	3.9	2.4	11.0
Tenderness	5.1	4.9	1.8
Juiciness	4.1	4.3	2.0
Overall acceptability	4.0	4.6	1.8

*Tenderness and juiciness from 1 (extremely tough /dry) to 8 (extremely tender /juicy); overall acceptability from 1 (not acceptable) to 6 (extremely acceptable).

Indicator values for boning out weights from the two forequarters of each of a cow, heifer and steer and for yields of reformed striploin-shaped joints, excluding neck, clod and shin meat, are shown in Table 14. Yields and projected values for reformed joints from chuck and brisket muscles only are shown in Table 15.

The figures in Tables 14 and 15, while not comprehensive, illustrate the potential for deriving added value from re-forming of selected beef forequarter cuts into joints for sale in raw chilled form e.g. to caterers.

Table 14: Yield of re-formed striploin-shaped joints from whole forequarters of beef.

	Cow	Heifer	Steer
Weight of two forequarters of beef (kg)	145	130	156
Cost per kg (€)	1.17	1.90	1.90
Total cost (€)	169.65	247.00	296.40
Lean muscle + capping fat (%)	34.6	36.1	37.2
Lean trim (%)	30.1	31.0	27.3
Fat trim (%)	11.9	7.7	8.6
Bone (%)	23.2	25.4	25.1
Re-formed joints			
Number	10	9	12
Weight (kg)	53.0	47.7	62.2
Yield (%)	36.6	36.7	39.8
Value at c. €6 per kg (€)	318.0	286.2	373.2

Table 15: Yield of re-formed striploin-shaped joints from heifer chuck and brisket cuts.

	Chuck	Brisket
Bone-in wt. (kg)	11.60	15.36
Cost per kg (€)	2.16	2.03
Total cost (€)	25.06	31.18
Lean muscle + capping fat (%)	47.7	37.2
Lean trim (%)	18.8	17.6
Fat trim (%)	14.1	20.8
Bone (%)	20.3	24.4
Re-formed joints		
Number	1	1
Weight (kg)	6.2	6.9
Yield (kg)	53.0	45.2
Value at c. €6 per kg (€)	37.20	41.40
+ Value of lean trim, at €2.54/kg (€)	5.54	6.87
Total value (€)	42.74	48.27
Cost of ingredients (€)	2.92	2.92

OVERALL CONCLUSIONS

- The incorporation of citric and lactic acid into low-value beef for the manufacture of value-added beef products alters the functionality of the meat.
- The addition of lactic acid, at a concentration between 0.05M and 0.1M, to low-value beef significantly improved the organoleptic quality of frankfurters.
- Microbial collagenase reduced the hardness and chewiness of sausage-type products manufactured from low and high value beef. Its effect on the palatability and flavour of a food product remains unknown.
- Restructured steaks produced from mechanically tenderised beef brisket muscle using transglutaminase, showed excellent binding of the muscle pieces and the steaks had a cut appearance like that of natural steak.
- The restructured steaks were rated as similar to the control striploin steaks in overall acceptability and in several important individual parameters, such as tenderness, overall texture and firmness.
- Reformed joints made from chuck muscle were equal to or better than the natural striploin in colour, tenderness, juiciness, flavour, binding and overall acceptability.
- Reformed roasting joints made from brisket muscle had a lower cook loss than natural striploin joint. The reformed roasted joints were more tender, juicy and more acceptable than the natural joint.

RECOMMENDATIONS TO INDUSTRY

The beef-processing sector is under increasing commercial pressure due to competition from other meats and damage to consumer confidence. As the value of beef falls and this natural commodity is produced in excess, meat scientists and processors are challenged to develop new approaches to increase the market-share of beef. It is clear that the future of the beef sector will be greatly affected by its 'ability to add value beyond the boning-hall stage'.

The industry in the US is reacting by developing convenience beef products, particularly the "heat and serve" type of re-formed, guaranteed tender, microwaveable (in 7 to 10 minutes) product. Such products include a versatile 'Boneless Beef Fillet' which is a thin, lean tender beef chuck cut and claims to be an alternative to the chicken breast; fully cooked 'Ground Beef Crumbles' which is lightly seasoned ground beef with homemade taste, texture and appearance and ready to use in any recipe calling for ground beef; the marinated 'Today's Roast' which is a sirloin tip roast, pre-marinated and vacuum-packaged and the Rotiss-A-Roast™ which is a premium quality beef roast that is prepared in the same type of rotisserie oven as chicken.

A number of cold-set binding ingredients, utilising chemically rather than thermally induced (heat-set) gelation are now available. These have made it more feasible to overcome the limitations of salt/phosphate systems and to pursue the development of higher quality whole-muscle chilled re-formed beef products. Cross-linking enzymes provide one of the latest methods for cold-set gelation bonding of meat pieces. Transglutaminases (TGases) are a widely-distributed class of enzymes that can catalyse formation of cross-links within and between meat proteins. The microbial TGase marketed as "Activa" preparation is active over a wide range of pH (5-8) and temperature (2-60°C). It is approved in the US for use in processed meat products up to a level of 65 ppm. In Europe it is regarded as a "processing aid" and therefore not required to be declared in labelling. Factors that affect the performance of TGase in re-forming include meat leanness, air removal, available protein, reaction temperature and reaction time.

This project identified areas with potential to address the technological problems associated with value added products using low-value cuts from the

forequarter. The incorporation of organic acids in meat product formulations, in particular lactic acid (which occurs naturally in meat) can offer a tenderising effect. The use of TGase in combination with blade tenderisation can produce restructured steaks and roasts of similar eating quality to the natural products. The availability of this cold-set binding system is a significant advance in enabling beef processors to modify cheaper forequarter cuts to meet consumer requirements for convenience but with quality comparable to that of dearer whole-muscle cuts.

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