FINAL REPORT

Project Armis No. 4199

Up-grading of Low-value Meats and By-products for use in Consumer Foods

The National Food Centre

RESEARCH & TRAINING FOR THE FOOD INDUSTRY

RESEARCH REPORT NO 12

Contents

UP-GRADING OF LOW-VALUE MEATS AND BY-PRODUCTS FOR USE IN CONSUMER FOODS

Authors

Tony Kenny M.Sc. Ph.D.
Eoin Desmond B.Sc. Ph.D
Patrick Ward

**The National Food Centre,
Teagasc, Dunsinea, Castleknock, Dublin 15**

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Teagasc 19 Sandymount Avenue, Ballsbridge, Dublin 4

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SUMMARY

The investigation was concerned with the up-grading of:

(i) connective tissue material in the form of beef membrane, pig rind and turkey skin;
(ii) muscle material from low-value cuts and from offals such as beef heart;
(iii) heart muscle, by extrusion processing;

(i) An emulsified material from beef membrane and beef replaced up to 5% of lean meat in corn beef and up to 10% in beefburgers without impairing cooked yield and eating quality.

A collagen emulsion paste (CEP) from pig rind replaced up to 5% of lean meat in ham prepared from diced meat, and between 2 and 5% in ham prepared from whole muscles without reduction in cooked yield, texture, appearance and eating quality.

Turkey skin was minced, chopped and incorporated at 10, 15 and 20% levels in a mix with turkey leg meat, which was used to make battered and breaded re-formed steaklets. Steaks containing up to 20% of emulsified skin were similar to control samples in flavour, juiciness and overall acceptability. An antioxidant may be required to prevent rancidity during frozen storage.

(ii) Yields of surimi-like material, prepared by water-extraction, sieving and centrifuging, were 16% from lean of topside of beef (used as control for comparison), 39% from beef heart, 17% from pork mechanically recovered meat, 11% from beef weasand and less than 5% from beef cheek meat. The beef heart surimi was studied for its gelation properties and for its performance as an ingredient replacing lean meat in frankfurters and in beefburgers at levels between 3 and 15%.

In frankfurters the addition of the surimi reduced cook loss and increased tenderness. For overall eating quality the frankfurters with 7 or 10% of surimi were preferable, and those with 15% equal, to those with none.

In beefburgers cook loss was decreased from 32 to 25% by the addition of 15% surimi. Other results were similar to those for frankfurters, showing that the surimi could be added at 10 to 15% level without impairing texture or flavour.

(iii) Cold extrusion processing of beef heart muscle with the aim of increasing its functionality showed that gelation properties of the material were not improved by extrusion compared to bowl chopping; moreover, the extruded product had a strong odour and dark colour.

INTRODUCTION

Animal offals can be divided into (1) edible offals and by-products including fats, blood, and low-grade trimmings such as poultry skin and pork hock meat; (2) extracts from edible offals for use as ingredients in food products; (3) inedible offals; (4) hides and skins; (5) raw materials for extraction of pharmaceuticals or chemicals; (6) raw materials for sundry by-products.

This project is concerned with (1) and (2). Edibility of by-products is determined by consumer acceptability, regulations, hygiene, tradition and religion. Traditionally edible offals ("variety meats" in the USA) included liver, brain, tongue, kidney, heart, sweetbreads, oxtails, cheek meat, head meat, thick skirt, thin skirt, snouts, lip meat, tripe, mountain chain tripe, pigs' tails, pigs' feet and fats. Whole blood used directly also fits in this category, as do intestines for sausage casings. The emergence of the BSE risk has eliminated bovine and ovine brain from edible use and restricted the usage of beef MRM (mechanically recovered meat from beef bones).

Ireland has the greatest degree of surplus production of edible offals within EU countries and exports both chilled and frozen items. Economic loss occurs through poor harvesting of offals at the abattoir and down-grading in the face of market gluts, e.g. having to consign edible material to waste or to pet food manufacture.

At the same time many functional ingredients of plant origin, such as soya, are used in processed meat products to perform functions such as binding of fat, retention of water and formation of gels. Consumers are increasingly demanding foods that contain fewer additives. Plant-derived ingredients are perceived as additives and many are chemically modified.

Thus, there is apparent opportunity for development of extracts or preparations from edible by-products for use as ingredients. This includes the recovery of proteins from blood, bones, skin, offals, membranes and trimmings and their preparation into forms suitable for incorporation as ingredients, thus reducing waste and increasing value. Such recovery and preparation from offals and trimmings requires refining treatments to overcome problems of inconsistency or flavour or colour.

Current or recent industrial operations in processing of edible by-products include:

Blood - separated into plasma and red cell fractions, the former usable as a meat extender and binder of fat and water in comminuted meat products.

Bones - used in several processes including: rendering, giving food-grade fats; mechanical recovery of meat (MRM); pressure cooking and then evaporation, yielding marrow, stock and broth; acid treatment, giving protein fractions and edible bone phosphate.

Skin and connective tissue - processed into emulsion pastes for use as meat extenders and binders of water.

Solid offals and boning hall trimmings - such as (1) fat trim subjected to specialised low temperature rendering procedure to produce “partially de-fatted chopped beef “ (or pork) with good retention of protein functionality; (2) liver, ground, extracted with slightly acidified hot water and the stock concentrated to a paste under vacuum or low temperature, yielding liver extract as a raw material for pharmaceutical nutritional supplements.

In line with the objectives of the current project it was decided to investigate the up-grading of:

(i) skin and connective tissue, by preparation of emulsified products from beef membranes, pig rind and turkey skin and examination of performance of these as ingredients in processed meat products.

(ii) muscle, by developing surimi-like extraction, as used for fish, for a number of low-value muscle raw materials and evaluating the extracts for functional properties and for performance in both emulsion-type and comminuted meat products.

(iii) heart muscle, by cold extrusion through a twin-screw extruder.

PROCEDURE AND RESULTS

Up-grading of skin and connective tissue

The main protein in skin and membrane tissue is collagen or, more correctly, collagens, since every tissue seems to have its own modification of collagen. Collagen in its native un-denatured state is composed of straight stiff fibres which have a triple helix 'rope' structure composed of three primary 'strands' of polypeptide chain.

Properties of collagen which are relevant to its use as an ingredient include the following:

(i) When heated in water collagen fibres shrink and shorten at 60 - 65^{0}C to about a third of their original length. At the same time the helical structure begins to unwind and dissociate to three peptide chains or some intermediate stage, transforming the collagen to gelatin, which is soluble. However, the proportion of collagen converted to gelatin is small until temperatures exceed 80^{0}C, though this can vary depending on the amount of intra- and inter-molecular cross-linking in the collagen.

(ii) Collagen fibres can have significant water-binding and fat-binding ability, of potential benefit in processed meat products. Concentrated dried collagen fibre is being marketed on this basis, e.g. the Fibron product by Stork-Protecon Ltd. Collagen contained in comminuted connective tissue preparations such as rind "emulsions" is also traded. A small number of reports have been published on its performance at levels in the range 2 - 15% in meat products, mainly sausage emulsions. Fineness of final grinding of the connective tissue is more important than, for example, pre-cooking to solubilise some of the protein, in determining the effect of added rind emulsion on cook loss from products.

(iii) Nutritional value of collagen protein is deemed to be poor because it is lacking in the essential amino acids tryptophan and methionine. However, this is not a problem in a mixed diet and it has been estimated that collagen could constitute a third of total protein intake without adverse effects.

Guidelines exist in the UK and in Germany on limits on the proportion of collagen in meat products and these should be taken into account in drafting recipes containing collagen emulsions. Likewise, EU Regulations specify upper limits for collagen-to-total protein ratio for processed meat products for export to third countries, though this is for export subsidy categorisation rather than nutritional or technological reasons.

Beef membranes

A commercial beef emulsion (BE) which had been prepared by chopping beef cheek meat with emulsified beef membrane (mainly epimysium which is the outer large layer of connective tissue surrounding entire muscles), water and proprietary binding additive was evaluated at 5% and 10% levels as a replacement for lean beef in two test products, burgers and corn beef. The effects were measured in terms of cooking yield (as an indicator of binding of fat and water), eating quality, texture and chemical composition.

Test samples of corn beef and burgers were made according to the formulations in Tables 1 and 2.

Table 1: Formulations for batches of corn beef containing beef emulsion (BE)

Ingredient %	Control (0% BE)	5% BE	10% BE
Beef trim, 70% visual lean (VL)	54.0	54.0	54.0
Beef shoulder, 95% VL	11.0	6.0	1.0
Beef emulsion (BE)	0.0	5.0	10.0
Potato starch	11.0	11.0	11.0
Salt	2.5	2.5	2.5
Sodium ascorbate	0.1	0.1	0.1
Sodium nitrite	0.05	0.05	0.05
Water	21.4	21.4	21.4

Table 2: Formulations for test batches of burgers containing beef emulsion (BE)

Ingredient %	Control (0% BE)	5% BE	10% BE
Beef trim, 70% visual lean (VL)	59	59	59
Beef shoulder, 95% VL	11	6	1
Beef emulsion (BE)	0	5	10
Burger seasoning	3	3	3
Starch	2	2	2
Rusk	5	5	5
Water	20	20	20

Preparation of Corn Beef

In preparation of the corn beef, the meat and beef emulsion (BE) were minced coarsely and chopped to an emulsion in a bowl chopper with the water and other ingredients. The emulsion was stuffed into casings, held overnight to allow curing, pressed into moulds, cooked to a core temperature of 80^{0}C, cooled, unpacked and trimmed to remove fat cap.

For burgers, the meat and BE were minced through a 5 mm plate, mixed with the other dry ingredients and with the water, re-minced through a 3 mm plate and formed into patties weighing 100 g.

Samples of the corn beef and of the burgers were chemically analysed, subjected to taste testing by a panel of 8 testers and tested for texture on a Kramer texture meter.

Results for corn beef

Chemical analysis of the raw meats (Table 3) showed fat contents ranging from 1.8% for the 95 VL beef to 30.8% for the 70 VL beef with corresponding variations in moisture and protein.

Table 3: Composition of beef emulsion (BE) and beef raw materials

%	BE	Beef 70% VL[1]	Beef 95% VL
Moisture	74.4	53.9	76.7
Fat	9.0	30.8	1.8
Protein	14.3	13.9	20.4

[1] visual lean

Analysis of the test samples of corn beef indicated (Table 4) that allowing for variability of raw meat, the BE-containing samples were comparable to the control in fat, salt and apparent fat-free meat and total meat content. (Fat-free meat is calculated using the protein and carbohydrate figures rather than being determined directly by analysis. Because of assumptions made in the calculation, the calculated figure is usually referred to as “apparent” meat content which is not necessarily the true meat content but is the only estimate available. Total meat is calculated as equal to fat-free meat + fat content). However, all test products were considerably higher in fat and salt and lower in meat content than a commercial corn beef product which had been bought in a supermarket. Binding of fat and water was not reduced by substitution of BE for lean meat as the figures for yield in Table 4 show.

Table 4: Composition and cooked yield of corn beef

Product:	Control 0 % beef emulsion (BE)	5% BE	10% BE	Commercial product
%				
Moisture	62.3	62.3	61.1	65.5
Fat	13.8	14.1	15.6	10.1
Protein	11.3	10.6	10.7	12.9
Ash	2.7	3.0	3.1	2.5
Carbohydrate	9.9	10.0	9.5	9.0
Salt	2.1	2.5	2.5	1.8
Apparent fat-free meat	45.4	42.1	42.9	53.1
Apparent total meat	59.2	56.2	58.5	63.2
Cooked trimmed yield	96.0	96.0	97.6	-

Sensory analysis (Table 5) indicated that juiciness was not reduced by adding either 5% or 10% of BE, but flavour and overall acceptability were impaired at the 10% level. All three test products were rated inferior in eating quality to the commercial corn beef; comments by tasters indicated that this was due to the lower meat content and higher salt and fat.

The texture readings showed that firmness and cohesiveness, as indicated by the puncture force, were not affected by the inclusion of BE and that elasticity/compressibility was increased by BE (Table 5).

Table 5: Taste panel average scores[1] and texture meter values for corn beef containing beef emulsion (BE) and for commercial product

Product:	Control (0% BE)	5% BE	10% BE	Commercial
Panel scores:				
Juiciness	2.4	3.1	2.8	3.6
Corn beef flavour	3.0	3.1	2.8	4.4
Overall flavour	2.4	2.4	2.0	4.0
Texture binding	2.5	3.0	2.6	2.9
Overall acceptability	2.9	2.8	2.5	4.1
Texture readings [2]				
- Compressibility	153	185	198	Not tested
- Puncture strength	36	36	36	Not tested

[1] On a scale of 1 = worst to 5 = best

[2] Newtons/100g

Results for burgers

Sensory scores (Table 6) indicated that meatiness of flavour was lower at 10% BE level but overall acceptability of eating quality was not reduced by BE at either 5% or 10% level of substitution.

Texture was not affected by inclusion of BE as indicated by the panel score and also by the firmness measurement on the texture meter (Table 6). Composition of the three test batches was similar as shown by moisture, fat, protein and apparent meat figures in Table 6.Binding of fat and water was not affected by adding BE up to 10% level as shown by the cook yield figures (Table 6)

Table 6: Taste panel average scores, firmness, composition and cook yield for burgers containing beef emulsion (BE)

	Control	5% BE	10% BE
Panel score [1]			
- juiciness	2.7	3.4	3.6
- meaty flavour	3.1	3.2	2.7
- texture score	2.9	3.1	3.1
- overall acceptability	3.9	4.0	4.0
Firmness by texture meter [2]	11	11	12
% Moisture	59.4	59.5	58.4
Fat	18.3	19.0	20.0
Protein	12.7	12.6	12.2
Apparent total meat	71.4	72.1	71.0
Cooked yield, %	83	81	83

[1] On a scale of 1 = worst to 5 = best

[2] Force in Newtons per gram to shear through product

Pork rind

Various procedures have been applied to convert rind to an ingredient, including cold comminution with water; boiling in water for 1 to 2 hours before comminution; soaking in citric acid solution, cold or at 70°C, before comminution. In this case the whole pork rind, with attached fat, was soaked for 18 to 24 hours in an acid solution containing citric and acetic acids. During acid treatment the collagen fibres swell and absorb water, and bacteria numbers decline. The rinds were then washed in cold running water to remove free acid, after which they were comminuted in a bowl chopper with the addition of ice/water, salt and proprietary alkaline 'stabilizer' solution. The chopped mixture was finally put through a colloid mill, giving a collagen emulsion paste (CEP) which was stored frozen at -20^{0}C in lined cartons until used.

A similar product being manufactured commercially in Ireland and elsewhere is known as Stabilized Protein Paste (SPP) to distinguish it from conventional rind emulsions made for sausage manufacture, from cooked rind and added fat.

Bacteriological analysis of the CEP showed (Table 7) that it was of acceptable quality.

Table 7: Bacteriological analysis of collagen emulsion paste (CEP)

Total viable bacteria, cfu/g	1.8×10^4
Total coliforms	None detected (ND)
E.coli	ND
Salmonella	Not isolated

The chemical composition of the CEP product varied with the amount of fat in the raw rind. Typical composition was:

Moisture	70-74 %
Protein	10-12 %
Fat	10-14 %
Salt (NaCl)	1.0-1.5 %
pH	5.6-6.6 %

Use of CEP in cooked ham

CEP was used to replace meat at 2, 5, 7 and 10% levels in cooked hams made from diced or from whole muscle pork, from both shoulder and leg, with added brine levels of 20, 30, 40 and 50%. The composition of the brine was chosen to give the following concentrations of ingredients in the brined meat, % by weight: salt 2.1, sugar 0.7, sodium tripolyphosphate 0.4, sodium nitrite 0.017 and sodium ascorbate 0.042. Five trials were carried out:

Trial 1: Pork leg meat was diced through a kidney plate; 20% by weight of curing brine was added and 0, 2, 5, 7 and 10% of the meat was replaced by CEP in separate batches. The mixtures were vacuum tumbled for 60 mins at a setting of 5 min on and 5 min off, filled into pre-stuck fibrous casing and cooked at 80°C to core temperature of 70°C.

Trial 2: The procedure was the same as in Trial 1 but with 40% addition of brine.

Trial 3: In this trial the meat was in whole muscle form and had been frozen and thawed. Brine was added at 32% by weight and CEP was added at the same levels as in Trial 1.

Trial 4: Shoulder meat was diced, brine was added at 40% and CEP at 0 and 5% level, and the mixture was filled into lined pots for cooking.

Trial 5: Shoulder meat from both older pigs (gilts for breeding) and normal pork pigs was used in whole muscle form. Brine was added at 50% and CEP at 0 and 5% levels, with and without milk protein and carrageenan. The mixtures were vacuum packed in clipped barrier bags for cooking. The milk protein was a commercial product containing 45% of sodium caseinate and 28% of lactose.

Trials 1 to 4 were performed at The National Food Centre and Trial 5 on a commercial scale at a factory.

Diced meat was used in trials 1, 2 and 4 in order to get uniformity between different batches. In those trials the brine was incorporated into the meat by a combination of soaking and vacuum tumbling. For the whole muscle meat in Trials 3 and 5, brine was injected by a multi-needle machine, followed by tumbling. In order to incorporate the CEP (around rather than within muscles or muscle fibre bundles) it was found necessary to pre-chop it with a portion of the brine and to add this dispersion into the tumbler with the brined meat.

Cooked products were cooled, trimmed free of surface jelly, weighed and sampled for texture measurement, using an Instron meter fitted with a Kramer shear cell. Samples were also submitted to a sensory panel of 6 or 7 people who rated them for several characteristics including texture and overall acceptability.

Results for Trials 1 to 4 are shown in Table 8 and for Trial 5 in Table 9.

Table 8: The effect of collagen emulsion paste (CEP) on quality and yield of cooked ham

	CEP level				
	0%	2%	5%	7%	10%
Trial 1 (leg meat, diced; brine 20%):					
Cook loss %	9.2	8.0	7.2	7.6	7.5
Firmness by texture meter[c]	19.0	18.0	19.0	15.0	14.0
Sensory panel average score:					
- Texture[a]	3.8	3.5	3.2	3.3	2.9
- Overall acceptability[b]	4.4	4.3	3.7	3.5	3.3
Trial 2 (leg meat, diced; brine 40%):					
Cook loss %	6.1	7.2	6.4	6.8	6.6
Firmness by texture meter[c]	22	20	21	21	19
Sensory panel average score:					
- Texture[a]	3.2	3.3	3.0	3.5	3.5
- Overall acceptability[b]	3.9	4.1	4.3	3.5	3.3
Trial 3 (thawed leg whole muscle, diced; brine 32%):					
Cook loss %	10.0	11.2	12.1	14.4	18.1
Firmness by texture meter[c]	32	34	29	30	30
Sensory panel average score:					
- Texture[a]	2.9	3.4	3.0	3.1	3.3
- Overall acceptability[b]	3.5	3.3	3.2	3.2	2.6
Trial 4 (shoulder diced; brine 40%):					
Cook loss %	6.5		6.8		
Firmness by texture meter[c]					
Sensory panel average score:					
- Texture[a]	2.7		3.0		
- Overall acceptabilityb	3.3		3.3		

[a] Texture scale: 1 = very rubbery; 2 = rubbery; 3 = sl. rubbery; 4 = sl. fibrous; 5 = fibrous; 6 = very fibrous.

[b] Acceptability: 1 = very poor; 2 = poor; 3 = fair; 4 = good; 5 = very good; 6 = excellent.

[c] Force in Newtons per gram to shear through product.

Table 9: The effect of collagen emulsion paste (CEP) on cook loss and yield of cooked ham prepared from shoulder muscle in a meat plant (Trial 5)

	Treatment			
	No. 1 Control	No. 2 5% of CEP	No. 3 5% of CEP 1.5% milk protein 0.5% carrageenan	No. 4 as No.3 but using shoulders from older pigs
Batch weight of raw meat, kg	42.3	25.9	22.7	25.0
Cook loss, %	9.4	20.8	18.0	10.3
Yield (trimmed ham % of boned raw meat)	136	123	127	139

Conclusions from tests on pig rind emulsion

Results in Trial 1 (Table 8) indicated that at low brine input (20%) and using diced leg meat as a test material, cook yield was maintained or slightly increased as CEP replaced lean meat up to 10% level, but eating quality declined above the 5% level. At a higher brine input (40% in Trial 2) results were broadly similar.

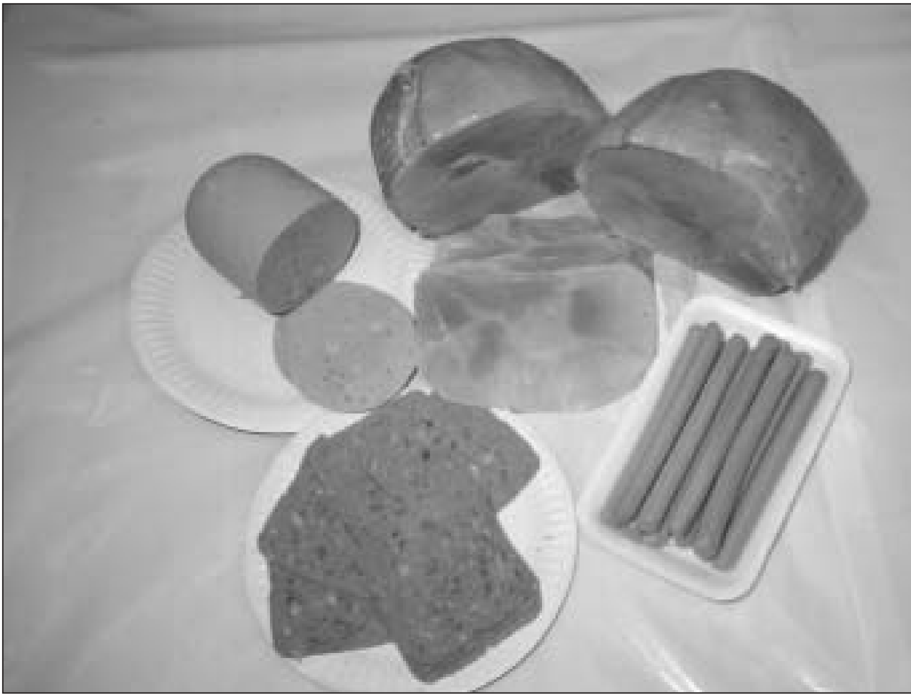
With whole muscle leg meat, pumped at 32% brine, the overall indication from Trial 3 was that meat could be replaced by between 2 and 5% of CEP to give a net gain in yield and no reduction in eating quality.

At higher levels of CEP there was a drop in yield, unlike the result with diced meat in Trials 1 and 2. A possible explanation is that the meat used in this trial had been frozen.

Shoulder meat (Trial 4) gave a similar result to that for diced leg meat (Trial 2) in that 5% of CEP did not alter yield or quality, though in this case the overall eating quality in both control and test batches was not good, as compared to whole muscle ham.

Whole shoulder muscles and 50% brine addition at a factory (Trial 5, Table 9) gave inconsistent results, showing a substantial increase in cook loss at 5% of CEP with or without the further inclusion of milk protein and carrageenan. The use of pork from older heavy pigs apparently counteracted this effect. The ham from the older pork shoulders was superior and this aspect may justify further investigation of up-grading of shoulder meat.

It was concluded that CEP is useful as a meat extender in cooked ham. Further investigation is needed with whole muscle shoulder meat.



Cooked meats prepared in the trials

Turkey skin

Turkey skin, which is discarded by many processors, was used to replace part of the lean meat in reformed turkey steaks. Fresh turkey skin from leg and breast was obtained from a poultry processor, trimmed of any blood spots or pin feathers and minced through a 3 mm plate.

Turkey leg meat was de-sinewed and minced through a 10 mm plate. Meat and skin were combined with other ingredients in the following formulations (Table 10):

Table 10: Formulation (%) of batches of turkey steaklets prepared with differing contents of skin

Turkey leg meat	96.5	86.5	87.5	76.5
Turkey skin	0.0	10.0	15.0	20.0
Seasoning	0.5	0.5	0.5	0.5
Salt	0.75	0.75	0.75	0.75
Sodium tripolyphosphate (STPP)	0.25	0.25	0.25	0.25
Water	2.0	2.0	2.0	2.0

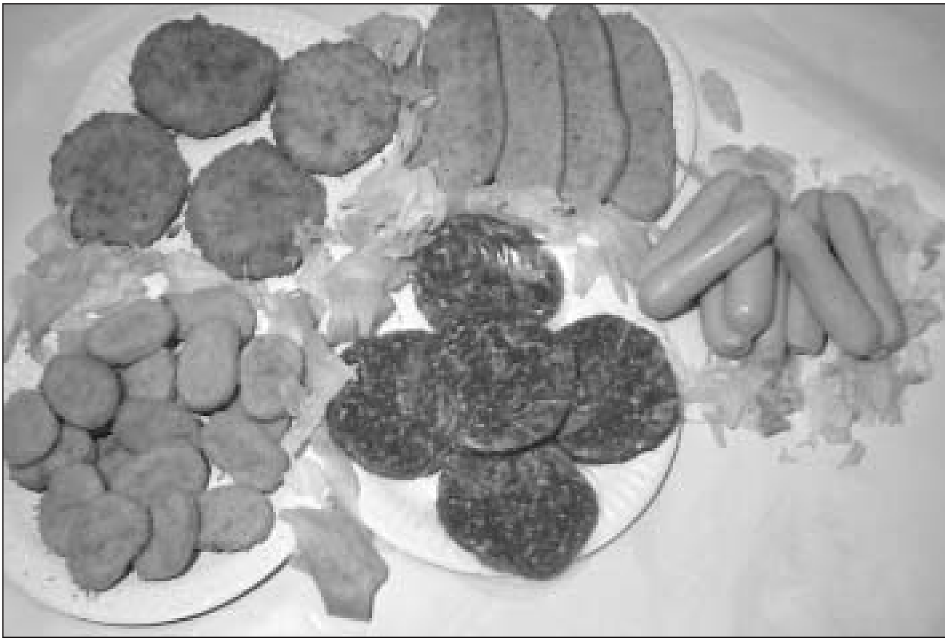
Using a food processor, batches were prepared by chopping one third of the leg meat with the seasoning, salt, STPP, water and turkey skin until an emulsion was formed. The remaining leg meat was added and chopping was continued for one minute. The blend was formed into turkey steaklets using a hand former. Each steaklet was wrapped in polythene film and frozen at -20°C for enrobing.

The frozen steaklets were dusted in plain wheat flour, coated in an adhesive batter and in crumb, and flashed fried in oil at 200°C for 15 seconds. After cooling for 1 minute they were held at -20°C for sensory and chemical analysis.

Sensory evaluation: Eight staff members with experience in assessment of meat products were asked to evaluate the steaklets on a scale of 1 to 8 for tenderness, chewiness, juiciness, meat flavour intensity; 1 to 5 for overall flavour; 1 to 6 for overall acceptability. The panellists were presented with hot samples of steaklet which had been baked to an internal temperature of 80^{0}C.

Tenderness increased from moderate to very tender with corresponding decrease in chewiness as level of skin increased above 15% (Table 11).

Steaks containing skin at 10, 15 and 20% levels were judged to be similar to the control in flavour, juiciness and overall acceptability. It was concluded that skin could be up-graded to replace 20% of leg meat in this type of product. Risk of development of rancidity during the frozen storage of such steaklets might warrant the inclusion of an antioxidant in the recipe.



▲ *Processed uncooked meats prepared in the trials*

Table 11: Taste panel score[1] for turkey steaklets containing skin emulsion

	Skin content of steaklet (%)			
	0	10	15	20
Tenderness	6.4	5.9	6.5	7.0
Chewiness	5.2	5.1	4.9	4.2
Juiciness	5.8	5.8	5.3	5.6
Meat flavour intensity	5.3	5.3	5.0	5.2
Overall flavour	4.1	4.2	4.3	3.8
Overall acceptability	4.6	4.8	4.7	4.5

[1] Averaged score; higher scores indicate better quality

Up-grading of low-value muscle

The aim was to develop and evaluate a surimi-like material made from by-products containing muscle. In a supplementary trial the extrusion of heart muscle was investigated.

Surimi is a Japanese term for a water-washed extract produced from fish, usually mechanically recovered fish slurry. The washing removes water-soluble sarcoplasmic proteins (including enzymes and pigments), blood, metal ions and some of the fat. The concentrated residue contains an increased proportion of the salt-soluble myofibrillar proteins that have useful functional properties in relation to texture of products.

Preparation of surimi-like extracts

Preparation of surimi from red meats is more difficult than from fish as the former usually contain more fat, pigment and connective tissue. Beef heart was chosen for initial trials based on cheapness and on indications in the literature that it could be a useful raw material. Fresh beef hearts were obtained from a commercial abattoir and trimmed to remove caps, vessels and external fat. The muscle was chopped in 5 volumes of iced water and the slurry was sieved to remove connective tissue and then filtered through cloth. The residue was re-washed, filtered and washed a third time, after which it was centrifuged to remove water. A mixture of salt (NaCl), sorbitol and phosphate (STPP) was mixed in as a cryoprotectant against de-naturation of protein during frozen storage. Finally, the surimi-like material was vacuum packed and stored at -20^{0} C for 2 to 3 weeks before testing.

An increase in speed of chopping (to 750 rpm) gave an increase in yield, from 22.3% to 39.3% by weight (at about 80% moisture content). Pork mechanically recovered meat (MRM), beef weasand meat (the smooth muscular lining which surrounds the oesophagus from the larynx to the paunch) and beef square-cut cheek meat were also tested as raw materials for the surimi process. The results for yield, gelation strength and colour of the surimi products are summarized in Table 12.

Table 12: Effect of source on yield and properties of surimi-like material prepared from low-value beef and pork meats

	[1]Control surimi	Heart surimi	MRM surimi	Weasand surimi	Beef cheek meat surimi
[2]Total yield, %	16.3[b]	39.3[a]	17.1[b]	11.1[c]	< 5
[3]Gel hardness	24.4[a]	12.6[b]	5.3[c]	21.4[a]	-
[4]Kramer shear value	19.2[a]	8.5[b]	1.9[c]	-	-
Colour (Hunter L-value)	60.6[a]	44.4[d]	54.9[b]	50.8[c]	-

[a-d] Means within same row with different letters are significantly different (P<0.05)

[1] From lean of topside of beef

[2] Yield of wet material containing about 80% moisture

[3] Force in Newtons to compress gel to pre-set dimension

[4] Force in Newtons per gram to shear through material

Yields of surimi were highest for heart, relatively low for lean control and MRM and very low for weasand and cheek meat. Differences in yields are due in part to differences in connective tissue and fat contents of the raw materials. Gel hardness, measured by Texture Profile Analysis, for pork MRM surimi was significantly lower than that obtained for beef hearts. However, gel hardness for weasand meat surimi was higher than that obtained from heart surimi and similar to that obtained from the lean beef control. Kramer shear results showed a similar trend. This may be a reflection of myofibrillar structure being closer in smooth muscle than in cardiac muscle to that in skeletal muscle.

Due to the better yield it was decided to extend the testing of beef heart surimi only. The performance of the beef heart surimi was evaluated as an ingredient in an emulsion-type product, frankfurters, and a comminuted product, beefburgers.

Use of beef heart surimi in frankfurters

The surimi was added at 3, 7, 10 and 15% by weight, replacing lean meat in a commercial (30% fat) recipe. Chemical analysis of the products (Table 13) showed that the fat content was close to the target of 30%. Moisture or fat content were not affected by inclusion of surimi but protein content was slightly reduced.

Table 13: Chemical analysis of cooked frankfurters containing beef heart surimi

Content of surimi in raw frankfurters	% Moisture	% Fat	% Protein
0% (Control)	51.6[a]	29.1[a]	14.9[a]
3%	51.1[a]	30.2[a]	14.2[b]
7%	51.8[a]	29.8[a]	13.8[bc]
10%	51.7[a]	29.8[a]	14.0[b]
15%	51.4[a]	30.8[a]	13.4[c]

[a-c] Means in the same column with different letters are different (P<0.05).

Taste panel and instrumental measurements of quality are shown in Table 14.

Table 14: Effect of addition of surimi-like material from beef heart on quality of frankfurters

	Control	3% surimi	7% surimi	10% surimi	15% surimi
Cook loss	7.5[c]	6.8[a]	7.4b[c]	6.8[ab]	6.4[a]
WHC[2]	76.9[b]	77.0[b]	76.1[b]	75.8[b]	68.3[a]
Sensory properties[1]:					
Tenderness	5.7[a]	5.7[a]	6.6[b]	6.4[b]	6.7[b]
Overall acceptability	3.9[a]	3.9[a]	4.3b[c]	4.4[c]	4.0[ab]
Mechanical texture properties:					
Kramer shear force	20.4[c]	19.5[c]	15.4[a]	17.2[b]	13.9[a]
Hardness	62.8[d]	54.3[bc]	48.9[ab]	59.8[cd]	44.8[a]
Colour:					
L-value	63.8[c]	63.4[c]	62.5[c]	60.5[b]	57.8[a]

[a-d] Means within same row with different letters are significantly different ($P<0.05$).

[1] Mean panel scores on scale starting with 1= lowest quality

[2] Water-holding capacity (measured by a centrifugation method)

The addition of the surimi gave cook losses similar to or less than that for the control. Likewise, water-holding capacity (WHC) was similar to the control for all treatments except the 15% level which had a lower value (Table 14).

Measurement of texture of frankfurters

Panellists found no off-flavours and all the treatments scored similarly to the control in terms of overall flavour. For "overall acceptability" frankfurters with 7 and 10% of surimi were rated better than, and those with 15% equal to, the control. Mechanical texture analysis gave results which corresponded with the sensory analysis in that shear force and hardness were highest for the control and the 3% surimi treatment (Table 14).

In general, the addition of the surimi at levels above 3% improved the texture. This may be because addition of surimi at 15% reduced the protein content (Table 13) and the cook loss (Table 14) of the frankfurters.

Measurement of colour indicated that as the content of surimi was increased from 3% to 15%, lightness (L-value) decreased (Table 14), which would be expected in view of the light brown colour of the surimi. However, these differences are very small visually and probably not detrimental to the appearance of the frankfurters.

Use of heart surimi in beefburgers

Heart surimi was added at levels of 5, 10 and 15% by weight replacing lean meat in a burger formulation containing about 20% of fat. The quality of the products is summarised in Table 15.

Table 15: Effect of addition of surimi-like material from beef heart on the quality of beefburgers

	Control	5% surimi	10% surimi	15% surimi
Cooking loss	31.9[b]	28.6[ab]	28.9[ab]	24.6[a]
Sensory properties[1]:				
Tenderness	7.0[a]	6.6[ab]	6.6[ab]	6.4[b]
Overall acceptability	4.2[ab]	4.0[b]	4.5[b]	4.2[ab]
Mechanical texture properties:				
Shear force	28.2[b]	27.8[b]	32.7[a]	28.3[b]
Hardness	91.3[a]	86.0[a]	90.5[a]	86.3[a]
Springiness	6.1[c]	6.6[b]	7.0[a]	6.8[ab]
Chewiness	173.8[b]	213.4[ab]	246.9[b]	230.9[b]
Colour properties:				
L-value	43.6[a]	42.1[b]	43.3[ab]	43.3[ab]
a-value	9.6[a]	9.1[ab]	8.3[c]	8.5[bc]
b-value	12.0[a]	11.5[b]	11.9[a]	11.9[a]

[a-c] Means within same row with different letters are significantly different ($P<0.05$).

[1] Mean panel scores on scale starting with 1= lowest quality

Cook loss was decreased from 31.9 to 24.6% by addition of surimi at the 15% level, due presumably to the water-binding properties of the surimi protein.

Sensory analysis showed very little differences among the treatments. As the surimi level was increased to 15% the tenderness score decreased, but burgers in all treatments had high tenderness values (Table 15). Panellists found no off-flavours; they found all treatments to be similar in flavour and rated the burgers from moderately to very acceptable.

Colour and mechanical texture measurements showed very little difference between controls and burgers containing surimi.

Extrusion processing of heart muscle

The aim was to increase the functionality of the heart muscle by a physical kneading action to release actin and myosin proteins from the fibres. This was based on the known mixing and kneading characteristics of the self-wiping type of twin extruder and a report in the scientific literature suggesting that the twin extruder could therefore be applied in surimi-type processing (Kitabatake et al., 1988. *Journal of Food Science*, **53**: 344-348).

Minced heart muscle was cold extruded (5-10^{0}C) at two feed rates (200 and 1320 g/min), two screw speeds (100 and 400 rpm) and with addition of salt either as solid at a rate of 200 g/min or saline solution (26% w/v) at 200 ml/min. The extruded product was collected directly into collagen casings. Gels were produced by heating and evaluated for hardness using Texture Profile Analysis. The gel hardness was between 17.6 and 35.2 N depending on the extruder setting. These values are higher than that obtained for surimi-type material from heart but similar to those for gels made from heart muscle which was chopped at high speed using a Stephan chopper. The extruded product had a deep red/purple colour and strong odour and may be unsuitable for direct incorporation into meat products.

CONCLUSIONS

- An emulsion prepared from beef connective tissue and cheek meat was satisfactory when used at a 5% level in corn beef and burgers;
- An emulsion prepared from pig rind successfully replaced 5% of lean meat in cooked hams;
- Turkey skin was upgraded to replace 20% of leg meat in re-formed turkey steaklets without impairing juiciness, flavour or overall acceptability;
- A surimi-like material was prepared from beef heart and used at levels of up to 15% to replace lean meat in frankfurters and burgers without impairing flavour and texture and with a gain in cook yield.

PUBLICATIONS from this Project

Scientific (refereed):

Desmond, E.M. and Kenny, T.A. 1997. Characteristics of surimi-like material from beef and beef by-products (Abstract). Irish Journal of Agricultural and Food Research, **36**, 282.

Desmond, E.M. and Kenny, T.A. 1998. Preparation of surimi-like extract from beef hearts and its utilisation in frankfurters. Meat Science, **50** (1): 81-89.

Proceedings of workshops for industry:

Desmond, E.M. and Kenny, T.A. Characteristics of surimi-like material from beef and beef products. Presentation at Workshop on results from Non-Commissioned Food Research Programme, Teagasc, The National Food Centre, 10 April 1997.

Kenny, T.A. and Ward, P. Use of meat by-product emulsions in reformed meat products. Presentation at Workshop at The National Food Centre, 10 April 1997.

Ward, P. and Kenny, T.A. Use of skin in reformed turkey steaklets. Presentation at Workshop on poultry processing, at The National Food Centre, May 1998.

The National Food Centre

RESEARCH & TRAINING FOR THE FOOD INDUSTRY

Dunsinea, Castleknock, Dublin 15, Ireland.

Telephone: (+353 1) 805 9500

Fax: (+353 1) 805 9550

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