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Agriculture and Food Development Authority

FINAL REPORT

Project Armis No. 4390

Producing Food Ingredients by Extrusion Cooking

The National Food Centre

RESEARCH & TRAINING FOR THE FOOD INDUSTRY

RESEARCH REPORT NO 34

Contents

PRODUCING FOOD INGREDIENTS BY EXTRUSION COOKING.

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SUMMARY

The objective of the project was to improve the quality and acceptability of convenience foods produced by extrusion cooking.

A range of acceptable, quality ingredients and food products was produced by extrusion cooking. These products had acceptable textural properties and were received favourably in consumer pre-test studies. However, a trade and consumer market analysis suggests that it would be difficult to develop a market for extruded meat products.

Cold extrusion
A novel method for the manufacture of sausages and frankfurters by cold extrusion was devised. The process combines two unit operations into one. Product was also prepared by the traditional bowl chop method for comparison. Following process optimisation, cold-extruded frankfurters and sausages of comparable quality to bowl chopped products were manufactured.

Hot extrusion
A method was developed for the manufacture of puffed snack products using cereals and low value meat cuts. Two products were prepared, a semolina/dried beef textured snack and a maize/dried beef textured snack. Both products were received favourably in consumer pre-test studies, in particular the maize based product.

Forequarter beef or liver, at 20% or 40% addition, was combined with soya to produce possible meat extenders. These ingredients were successfully incorporated into beefburgers as a partial replacement for meat.

INTRODUCTION

A simple definition of extrusion is shaping by forcing softened or plasticised material through a die by pressure.

Extruders are based on the principle of the Archimedes screw. The screw is housed in a metal barrel, which can be of variable length and through which cooling water or steam can circulate. Extruders can be described as single screw or as twin screw. Twin-screw extruders may be co-rotating or counter rotating. The screws have pitch and kneading elements. The narrower pitch elements tend to be found on the end of the screw located nearest the die face. This compresses the feed material and results in a greater pressure at the die face. There are kneading elements which aid mixing and aid heat transfer to the feed, and reverse pitch screws which can be included to create back pressure and therefore more shear. The functions of the screw are conveying, shearing, mixing, kneading and heating the food product. The die face is the small opening where the food product exits the extruder. Different shaped dies give different shaped products. A set of rotating blades cuts the product to the desired length as it exits the die (Harper, 1981).

In summary:

- Ingredients are mixed and fed to the screw at a fixed rate using a feeder.
- The action of the screw propels material along the barrel and then through the die at the end.
- Barrel length, screw configuration, screw speed, feed rate and die shape can be varied to give desired properties.

Extruders can be used for 'high temperature, short time' (HTST) cooking. The extrusion process began with pasta and cereals but has found new products over the years such as croutons, snacks, dry pet foods and textured meatlike materials from defatted high-protein flours. Other extrusion-cooked foods include textured soy protein for use as a meat extender, breakfast cereals, biscuits and crackers. HTST processes are safe as contaminating micro-organisms are effectively destroyed.

Cold extrusion

Sausage is manufactured by comminution of minced meat and incorporation of non-meat ingredients. This is normally accomplished by a bowl chopper, which consists of a rotating bowl with perpendicular rotating blades. Casings are filled with sausage batter using a filling machine (Girard *et al.*, 1988). A cooled twin-screw extruder fitted with tubular die may serve both functions in a single stage. The barrel can be cooled to counteract the heating effect of friction between the screws and the barrel. Twin-screw extruders cooled with ice water have been used to produce restructured pork chops (Hanna and Gennadios, 1996), and surimi used in the manufacture of fish gel-type foods (Kitabatake *et al.*, 1988). A similar system was used in this work for the manufacture of sausages and frankfurters.

The aim was to evaluate the quality of products prepared in a single step using an extruder, with products prepared by the separate conventional steps of mixing, bowl-chopping and filling.

Hot extrusion

Extrusion of combined meat and cereals has been little researched. Some work has been done on the development of blends of meat and non-meat ingredients, to produce expanded and non-expanded snack products (Rhee *et al*, 1997). Expansion of cereal/meat products is a result of high temperature and pressure inside the extruder barrel. Under high pressure, water remains liquid at temperatures in excess of 100°C. However, as the extrudate leaves the barrel via the die opening, the sudden decrease in pressure causes the water to convert to steam which rapidly evaporates and causes the extrudate to expand. On drying, the product has a puffed, snack type structure. Extrudates containing more meat tend to puff less. This may be due to the formation of new protein structures, which do not effectively capture water (Kim, 1993).

Cheaper meat cuts can be restructured and incorporated into value added meat products. Extrusion uses pressure and mechanical forces, both of which can tenderise meat. The aim of this project was to investigate the possibility of combining low economic value meat cuts with cereals to produce novel food products and ingredients.

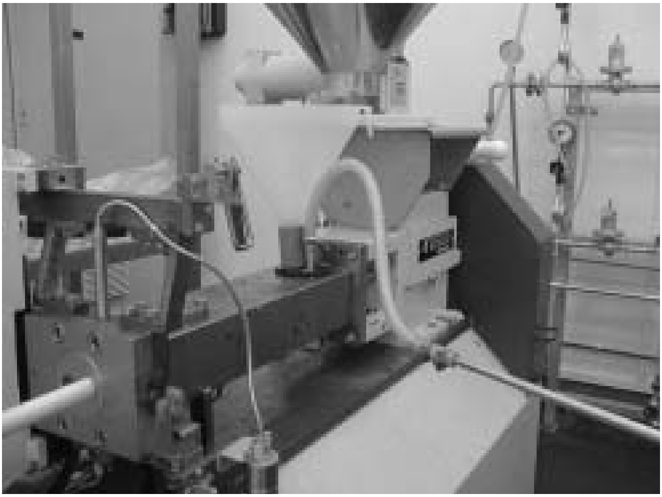
The following sections detail the methods used in cold and hot extrusion.

The formulation for breakfast sausage consisted of pork (70%), water/ice (17.5%) and preseasoned rusk (12.5%).

Fresh pork bellies (50% visual lean) were cut into strips and minced through a 3.5-mm plate (Mincer Model No. RK 82, A.B. Schaub & Co., Stockholm, Sweden). The minced pork was then mixed for 2 min in a paddle mixer (Mainca, RM 90, 2058, 1995. Equipmientos Carnicos, Spain), and stored overnight at 0-4°C.

Bowl chop

Pork mince (8.4kg) was chopped in a bowl chopper (Model M22, Equipamientos Carnicos S.L., Spain) with 1.4L of water for 2 min at bowl speed 2 and knife speed 1. Pre seasoned rusk (1.5kg) (Blakes, Dublin) was then added and the batter chopped for a further 1 min. The remaining water (0.7L) was added and the batter mixed for a further 2 min. Batter was filled into casing (Devro collagen casing - 28cm, Food Processing Technology, Dublin) using a vacuum filler (Type 60, Schrofner-Stemedseder, Feekirchen, Austria). Sausages were hand linked, frozen overnight at -20°C and then vac-packed.



The twin screw Bühler extruder.

Extrusion
An initial experiment to examine the effects of screw configuration and barrel length, with fixed screw speed (300 rpm) and feed rate, was conducted. Sausages were produced by a combination of three extruder barrel lengths/diameter ratios (20, 16 and 12 L/D) and three screw configurations at each barrel length (described as ‘kneading’, ‘shearing’ and combined ‘kneading/shearing’) giving a total of 9 extrusion treatments (Table 1). Harper (1981) gives further information on the components of an extruder.

A twin screw laboratory extruder (DNDL-44 Bühler, Uzwil, Switzerland) was used to prepare breakfast sausages using the formulation given above. Meat was fed to the extruder at a rate of 6.7g per sec using a vacuum filler (Type

Table 1: Variation in screw configuration and barrel length/diameter ratio for different extrusion processes used to prepare sausages.

Manufacturing process	Screw configuration	Barrel length to diameter ratio (L/D)
1	Kneading	12
2	Kneading/shearing	12
3	Shearing	12
4	Kneading	16
5	Kneading/shearing	16
6	Shearing	16
7	Kneading	20
8	Kneading/shearing	20
9	Shearing	20
0	Bowl chopped	Bowl chopped

Preparation of sausages by cold extrusion.

60, Schrofner-Stemedseder, Feekirchen, Austria) via a flexible PTFE tube to the extruder feed hopper (see extruder component description in Harper, 1981). Dry mix was fed at 1.2g per sec using a mechanical feeder (Ktron Soder, Niederlenz, Switzerland). Water was fed to the barrel at 1.7g per sec. The extruder barrel jacket was cooled by circulating ice water, which maintained product temperature at 5-10°C. A tubular die (200mm length, 10 mm diameter) was used. Extrudate was fed into the same casings as above. Sausages were hand linked, frozen and vac-packed as described previously.

Physical/chemical analysis

Proximate analysis: Fat and moisture were evaluated using a CEM Meat Analysis System (CEM Corporation, Matthews, NC, USA). Protein analysis was carried out using LECO Organic Nitrogen Determinator (Leco Corporation, St. Joseph, MI, USA). Analysis was carried out in triplicate on both the raw batter and the cooked sausage. For the cooked sausage, two sausages were blended in a Robot Coupe Blender.

Textural stability: The quality of the products was assessed by Texture Profile Analysis, Penetration and Warner Bratzler shear tests using the Instron

Universal Testing Machine. High apparent viscosity and consistency of sausage batters are necessary for stable meat emulsions (Gorbatov and Gorbatov, 1970). Due to the large particle size and lack of homogeneity within the batter, a modified Ottawa texture measurement system was used to measure batter viscosity.

Texture profile analysis (TPA): Each sample of conventional and cold-extruded breakfast sausage was cut into ten cylinders of 20mm length and 15mm diameter, which were allowed to equilibrate to room temperature. The TPA test was conducted on an Instron Universal Testing Machine Model No. 5544 (Instron Corp., MA). Results measured were hardness (Newtons), cohesiveness, springiness (millimetres), chewiness (Newtons x millimetres), and gumminess (Newtons) (Bourne, 1978).

Penetration: Ten cylinders were prepared per sausage as described above. Penetration was measured on the Instron by the method of Cavestany *et al.* (1994). Penetration force (N), work of penetration (Nmm), and elastic behaviour (mm) were measured.

Ottawa texture measuring system: Samples of uncooked sausage batter were placed to a height of 33mm in a modified Ottawa texture measurement apparatus. The piston was lowered to the sample surface. Sample was forced through a 10-mm orifice at a crosshead speed of 289 millimetres per minute. Force/distance data were recorded and the area under the curve-termed the work of extrusion-was calculated. Tests were conducted in triplicate.

Colour: Internal colour of the raw sausages was measured using a Hunterlab spectrophotometer (Ultrascan XE, Hunter Associate's laboratory Inc., Virginia, U.S.A.). Colour was measured using diffuse illumination (D65, 10°) with 8° viewing and a 1-inch port size with the specular component excluded. Three readings of L (lightness), a (+ve redness, -ve greenness) and b (+ve yellowness, -ve blueness) values were recorded for each sausage and the readings averaged.

Emulsion stability: A modified version of the Rongey (1965) method was used. The supernatant was further analysed for lipid content using a Tecator Soxtec system HT1043 extraction unit.

Water holding capacity: WHC was determined using the method of Lianji and Chen (1991). A 10g sample was placed in a glass jar and heated at 90°C for 10 minutes in a water bath. It was removed, cooled to room temperature and then centrifuged for 10 minutes at 10,000 rpm at 4°C. The sample was reweighed. The WHC was then calculated as follows:

$$\% \; WHC = \frac{1 - B - A}{M} \; x \; 100$$

where B = weight of sample before heating
A = weight of sample after heating and centrifuging
M = total water content in the meat sample.

Microbiology: Bacteriological examination of sausages was performed to check for the presence of food poisoning bacteria including *Salmonella* spp., *Listeria* spp. and *E. coli* O157:H7 using modifications of standard methods.

Sensory analysis: For each experiment using fixed barrel length and three different screw configurations, a separate sensory test was performed. Within each experiment samples produced using the different screw configurations were compared to each other and to conventionally manufactured sausages. Samples were assessed in duplicate. Samples were labelled with three-digit random codes. Samples were presented to panellists in individual booths, under controlled lighting and temperature conditions. Sausages were grilled for approximately 25 minutes until an internal temperature of 72°C was reached and sliced into 5 cm lengths. Four samples per session were served to panellists in random presentation order. Panellists were supplied with water to cleanse their palates between samples.

Eight experienced panellists were used to assess the sausages on a six-point scale:

Juiciness -	where 1 = very dry,	6 = very juicy
Saltiness -	where 1 = not salty,	6 = extremely salty
Spiciness -	where 1 = not detectable,	6 = extremely spicy
Other flavours -	where 1 = not detectable,	6 = extremely intense
Overall flavour intensity -	where 1 = not detectable,	6 = extremely intense

Overall texture -	where 1 = very poor,	6 = extremely good
Overall acceptability -	where 1 = not acceptable,	6 = extremely acceptable

'Other flavours' were described to panellists as non-meat, non-fat, and non-spice.

Consumer pre-test study: Product acceptability was evaluated using staff of The National Food Centre in 35 households with 61 persons, ranging from 14yr to 65yr, with an equal number of males and females taking part. Each participant received one bowl chopped sausage and one extruded sausage and corresponding questionnaires Panellists were asked to taste the products in their homes and to follow clear cooking instructions. The participants were asked to comment on different attributes including overall acceptability and flavour. Each was requested to indicate a preference for the extruded or bowl chopped sausages. Half the participants were asked to taste the extruded sausage first, while the remaining half tasted the bowl chopped sausage first. All consumer pre-tests described in this report were used to carry out an initial preliminary screening of the products prepared. They give preliminary indications of the product acceptability and may not reflect the preferences of the general population. This would require further studies.

Results

Attributes showing significant differences between samples in laboratory and sensory measurements are included in Table 2. Processes included in Table 2 are those that produced sausages most closely resembling the bowl chopped product in characteristics measured. There was no significant difference from the control (process 0) in colour for sausages made by manufacturing processes 1, 7 and 8. Manufacturing processes 6, 8 and 9 were not significantly different to the control (process 0) for textural attributes measured on the Instron. There were significant differences between processes with respect to total expressible fluids and expressible moisture; however, process 8 was the only process that was significantly different to the control (process 0) for these attributes. Although significant differences were found between samples for a number of sensory attributes, extruded products were in general found to be comparable to the control bowl-chopped product (process 0).

Table 2: Laboratory and sensory measurements on breakfast sausages manufactured by cold extrusion (processes 1,6,7,8,9) and conventional bowlchopping (process 0).

	Manufacturing process						
	0	1	6	7	8	9	Sig.
Hunter L	54.1	54.9	54.1	57.6	55.4	54.7	*
Hunter a	6.5	6.1	5.7	5.8	6.0	5.7	***
Hunter b	13.1	13.2	12.7	12.4	12.9	13.1	*
Hardness (N)	119	95	106	87	107	101	***
Cohesiveness (%)	0.51	0.29	0.41	0.43	0.41	0.44	**
Gumminess (N)	60.2	27.1	43.9	36.7	44.2	41.7	***
Chewiness (Nmm)	529	228	380	306	376	358	***
Penetration force (N)	8.2	8.3	8.4	6.9	7.4	7.3	***
Total expressible fluids (%)	3.2	2.9	2.5	2.6	2.3	2.6	***
Expressible moisture (%)	2.6	2.3	2.1	2.1	1.9	2.1	**
Saltiness	3.4	3.8	2.5	3.0	3.5	3.4	**
Spiciness	4.0	3.1	2.6	3.6	4.1	4.3	**
Overall flavour intensity	4.3	3.3	3.4	3.8	4.3	4.6	**
Overall texture	3.8	2.7	3.8	4.0	4.0	4.2	***
Overall acceptability	3.8	2.8	3.7	3.9	3.9	4.0	**

Sig.: Significance level: * = $p<0.05$, ** = $p<0.01$, *** = $p<0.001$

In consumer pre-test studies, no significant differences in acceptability, appearance, texture or flavour was observed between bowl chopped and extruded sausages.

FRANKFURTERS

Pork bellies (50% visual lean) and lean pork ("slipper") were cut into strips and minced through a 3.5 mm plate. Pork bellies were mixed in a paddle mixer for 2 min at setting 2, to ensure an even distribution of fat. Both the mixed bellies and the lean pork were combined to give a pork mix with a final fat content of 16.5%. This was achieved by mixing pork belly (11.2 kg) with lean pork (18.8 kg) in the paddle mixer for 5.5 min at setting 2. Of this mix, 10.3 kg was set aside for the bowl chopped frankfurters, while the balance was used for the manufacture of the extruded frankfurters. The formulation for frankfurter manufacture was pork (86.3%), water/ice (11.3%), nitrite (1.5%), sodium tripolyphosphate (0.25%), sodium ascorbate (0.05%) and spices (0.5%).

Bowl chop

Pork mince (10.3 kg) was chopped in a bowl chopper for 1 min at bowl speed 1 and knife speed 1. Phosphate was added and the batter chopped for 30 sec. While still chopping, the liquid salt (dissolved in 350 ml of water), liquid smoke (dissolved in 100 ml of water) and spices were added. The batter was then chopped for a further 2 min., after which the bowl speed was increased to 2 and chopping was continued for a further 30 sec. At this stage the ascorbate was added and the batter chopped for 30 sec at a bowl and knife speed 1. At this stage one third of the ice was added and chopping proceeded for 1 min. The remaining ice was added and the mix chopped for 1.5 min. Batter was filled into casing (USA 24 calibre, Food Processing Technology, Dublin) using a vacuum filler. Frankfurters were hand linked and then cooked using a Kerres model C6 350 (Sulzbach-Murr, Switzerland). Frankfurters were cooked at 63°C for 25 min, then at 67°C for 20 min and then at 75°C for 30 min. This facilitated the development of the smoke flavour. Finally, frankfurters were frozen overnight at –20°C and then vac-packed.

Extrusion

Extrudate was fed into the same casings as above and frankfurters were hand linked, cooked, frozen and vac-packed as described previously. An experiment similar to that for the sausages was carried out to examine the effect of variation of screw configuration and barrel length/diameter ratio on product quality (Experiment 1). Process parameters were as described in Table 1. An experiment to examine the effects of screw speed and feed rate was also undertaken (Experiment 2).

Physical/chemical/sensory analyses

The frankfurters were analysed using the methods described previously for breakfast sausages.

Salt content: Salt was measured using a potentiometric method, suspending 3g of minced frankfurter in 100ml of 0.15% nitric acid and titrating this to an end point of 250mV using 0.1N silver nitrate (Fox, 1963).

Sensory analysis: The procedure described for sausages was used. For smoke flavour 1 = not smoky, 6 = extremely smoky. Frankfurters were heated by placing in boiling water for 5 minutes and then sliced into 5 cm lengths.

Consumer pre-test study: This was carried out as described for the sausages.

Results

First experiment: Manufacturing process 4 closely mimicked the control process for colour, in that it was not significantly different. Manufacturing processes 6, 7, 8 and 9 were not significantly different to the control process for textural attributes measured on the Instron Universal Testing machine. No significant sensory differences were found between extruded frankfurters and the control sample for any attribute. Manufacturing processes (4, 6-9) most closely resembling the control process (0) are included in Table 3.

Second experiment: Response surface methodology was used to optimise frankfurter properties with respect to screw speed and feed rate (Table 4). The data from this experiment is contained in Table 5.

None of the extrusion manufacturing processes differed significantly from the control, apart from process 7 which differed significantly from the control in extracted fat.

Table 3: Laboratory and sensory measurements on frankfurters manufactured by cold extrusion (process 4, 6-9) and conventional bowlchopping (process 0).

	Manufacturing process						
	0	4	6	7	8	9	Sig.
Moisture content (%)	68	68	67	67	66	66	*
Salt content (%)	1.8	1.4	1.8	2.1	1.9	2.1	**
OTMS energy (J)	17.5	17.4	20.7	18.2	17.7	21.4	**
Colour L	94.8	90.8	89.7	88.6	88.4	87.4	**
Hardness (N)	33.7	21.7	27.0	28.0	26.7	28.8	**
Gumminess (N)	15.4	6.5	10.1	10.3	11.0	12.0	**
Chewiness (Nmm)	128	52	86	85	87	96	*
Shear force (N)	0.003	0.003	0.003	0.003	0.004	0.004	**
Penetration force (N)	5.0	3.9	4.8	4.3	5.1	5.8	**
Total expressible fluids (%)	1.1	1.8	1.3	2.1	1.8	1.9	*
Expressible fat (%)	0.9	1.5	1.2	1.7	1.6	1.7	*
Overall texture	3.6	3.1	3.6	3.5	3.9	3.5	**
Overall acceptability	3.3	2.9	3.5	3.1	3.7	3.3	*

Sig.: Level of significance: * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

Table 4: The cold extrusion process used in manufacture of frankfurters showing variation in screw speed and feed rate.

Manufacturing process	Screw speed (rpm)	Feed rate (g/min)	Manufacturing process	Screw speed (rpm)	Feed rate (g/min)
1	250	313	6	363	1460
2	250	887	7	475	313
3	250	1460	8	475	887
4	363	313	9	475	1460
5	363	887	Control	N/A	N/A

Table 5: Laboratory measurements on frankfurters manufactured by cold extrusion (1 to 9) and conventional bowlchopping (0) (Experiment 2).

	Manufacturing process										
	0	1	2	3	4	5	6	7	8	9	Sig.
Salt content (%)	1.58	0.68	1.08	2.36	1.92	1.26	2.55	0.62	0.87	2.40	**
Cook yield, waterbath (%)	98	83	86	99	90	83	99	84	88	97	*
Colour L	62.3	64.7	62.4	58.9	61.8	62.6	59.8	64.9	63.5	61.2	**
Colour b	6.3	6.9	6.3	6.0	6.8	6.1	6.5	7.0	6.7	6.7	**
Hardness (N)	49	29	26	44	36	32	50	22	32	44	*
Penetration force (N)	9.5	6.8	7.2	10.6	8.2	7.9	9.4	6.3	8.6	9.4	**
Fat extracted (%)	0.02	1.60	0.88	0.23	0.89	0.21	0.12	2.57	1.36	0.05	*

Sig.: Level of significance: * = p <0.05, ** = p<0.01, *** = p<0.001

No significant differences in preference, acceptability, appearance, texture or flavour were observed between samples in consumer tests.

SNACK PRODUCTS

Preparation of meat: Forequarter beef was minced through a 5mm plate (Mincer RK 82, A. B. Schaub & Co, Stockholm, Sweden) and dried for 96hr at a temperature of 55°C. Prior to mixing the dried meat was first ground to a fine texture (Urschel 3600, Serial No. 2080. Urschel Lab. Inc. Valparaiso, Ind. USA). Dried meat and cereal (maize/semolina) were combined by mixing for 2hr (Babcock Gardner, Type 50L, Serial No. 82307, Gloucester, England).

Snacks were manufactured based on optimised extruder conditions of screw configuration, barrel length, feed rate and screw speed (see Table 6), using a twin screw co rotating laboratory extruder. Dry mix (cereal/meat mix) was fed to the extruder using a mechanical feeder. In all cases the same screw configuration

Table 6: Extrusion conditions for manufacture of snack products.

Cereal type	Semolina low moist.	Semolina high moist.	Semolina control	Maize	Maize control
Beef content %	10	10	0	10	0
Die temp (°C)	175.3	176	182	176	194
Barrel temp (°C)	142	140	151	147	169
Feed rate (g/min)	910	910	840	960	960
Water flowrate (L/h)	2.4	3.8	2.8	4.7	2.0

(high shear), barrel length (20D), screw speed and die design (1mm x 5 mm) were used. Control samples were prepared without meat for comparison of product physical characteristics. Extruded snack products were dried for a period of two hours at 55°C. Moisture content was varied in semolina product to determine the influence of water content on physical properties.

Flavouring of snacks: Flavouring (Firmenich Beef Flavour 505082 THP0551) was supplied by J.E. O' Brien, Ballymoss Rd, Sandyford Industrial Estate, Foxrock, Dublin 18. Flavouring was added as a suspension in vegetable oil at a dose level of 0.2g per 100g of snack product.

Physical/chemical analysis

Bulk density of the unflavoured samples was measured by filling the samples into a weighed 2L graduated cylinder, up to the 2000ml mark. The cylinder was tapped on a surface to settle the product and remove some of the air pockets, and then refilled to the 2L mark. The cylinder including product was then weighed and the volume calculated.

Texture: The texture of the snack products was assessed by Warner Bratzler shear tests using the Instron Universal Testing Machine. Crispness was also measured using the method of Norton *et al.* (1998).

Microbiology: Samples were tested for the presence of pathogens and microbiological stability at 0 and 30 days after manufacture using a method modified from the International Commission on Microbiological Specifications for Foods (1978).

Sensory analysis: Two flavoured samples were selected for sensory profiling: maize/10% beef and semolina/10% beef (low moisture). Eight laboratory staff trained as sensory panellists participated in a familiarisation session prior to the profiling experiment. Samples were assessed in triplicate over three tasting sessions. In each session the panellists were presented with the two products and asked to assess them for different attributes. Samples were presented in random order, labelled with three digit random codes. The experiment was carried out in the sensory facility at NFC as previously described.

Panellists assessed the samples on scales of 1 – 5 as follows:

Hardness –	where 1 = very soft,	5 = hard.
Crispness –	where 1 = not crispy,	5 = extremely crispy.
Oily mouthfeel –	where 1 = not oily,	5 = very oily.
Tooth packing –	where 1 = low,	5 = very high.
Beef flavour –	where 1 = not detectable,	5 = extremely intense.
Saltiness –	where 1 = not salty,	5 = extremely salty.
Other flavour –	where 1 = not detectable,	5 = extremely intense.
Breakdown in mouth –	where 1 = slow,	5 = fast.

Consumer pre-test study: Staff of The National Food Centre were used as previously described. 48 panellists were asked to comment on snack product attributes in the dedicated sensory facility.

Results

The analyses on the snack products are contained in Table 7. There were significant differences between products on all physical attributes.

Colour A significant difference existed between the maize/10% beef snack (D) and the control (E) for all colour values.

Bulk density Higher beef and moisture content led to increased sample bulk density. Samples prepared from semolina (A, B, C) were significantly more dense than those prepared from maize (D, E).

Warner Bratzler Over time, shear force decreased and crispness increased except in the maize control product (E), in which the reverse occurred. At each time point, none of the semolina products (A, B, C) were significantly different from each other, with respect to either attribute. Initially, the maize/beef product (D) was significantly crisper and had a higher shear force than the control (E). After 4 weeks, the reverse of this was observed. Addition of beef resulted in harder, crisper textures in both cereals. An increased level of water also added to hardness in semolina. The maize/ beef snack (D) was harder than both semolina/ beef snacks (A, B). Changes in texture over time were greater in cereal-only snacks (C, E) than in meat-containing snacks (A, B, D). The Instron texture measurements conflicted with sensory results in some cases.

Microbiology Total viable counts on snack products revealed no change in microbial load between 0 days and 30 days.

Sensory/consumer pre-tests Sensory analysis revealed significant differences between samples, with respect to hardness, crispness, tooth packing and beef flavour (Table 7). The maize /beef snack (D) was significantly softer and crisper, with more beef flavour and higher tooth packing than the semolina/beef snack (A). Panel data indicated that the maize/beef snack (D) was significantly more acceptable than the semolina/beef snack (A). For appearance and flavour, the maize/beef snack (D) scored significantly higher than the semolina product (A).

Table 7: Physical, chemical and sensory analysis of snack products (A to E). Attributes showing significant differences between samples are shown.

		A	B	C	D	E	Sig.
Colour	Colour L	64.3	62.4	63.2	97.8	73.0	***
	Colour a	2.5	2.4	1.0	0.3	-1.2	***
	Colour b	15.7	15.8	15.1	0.03	19.9	***
Bulk density (g/cm^3)		71.4	88.2	31.9	25.4	17.2	***
Warner Bratzler	Shear force (time 0)	33.4	45.8	32.3	100.8	11.7	***
	Shear force (time 4wks)	18.4	23.3	7.7	11.2	95.6	***
	Crispness (time 0)	0.03	0.03	0.02	0.03	0.09	***
	Crispness (time 4wks)	0.06	0.07	0.06	0.11	0.04	***
Sensory	Hardness	4.4			3.6		***
	Crispness	3.3			4.2		***
	Tooth packing	2.9			3.6		*
	Beef flavour	2.0			2.6		**

A: Semolina/10% beef (low moist.) B: Semolina/10% beef (high moist.) C: Semolina control
D: Maize/10% beef E: Maize control
Sig.: Level of significance: * = p <0.05, ** = p<0.01, *** = p<0.001

MEAT EXTENDERS

Sulphur (0.1%) was combined with soya, by mixing for three hours (Babcock Gardner, Type 50L, Serial No. 82307, Gloucester, England). Forequarter beef or bovine liver was minced through a 5mm plate. Meat and soya were combined for 30 sec using a Stephan mixer (A. Stephan GmbH, 3250 Hamein Germany, Serial No. 714.060.01). The products containing 20% beef or liver and 40% liver received four separate mixes of 30 sec duration. Those containing 40% beef received six separate mixes, also of 30 sec.

Extrusion: Meat extenders were manufactured based on optimised extruder conditions of screw configuration (high shear), barrel length (20D), feed rate and screw speed, using a twin screw co rotating laboratory extruder (Table 8). Dry

Table 8: The optimum extruder settings used for the manufacture of meat extender ingredients.

Extender type/ settings	Soya/ beef	Soya/ beef	Soya/ liver	Soya/ liver	Soya control
Meat content %	20	40	20	40	0
Die temp (°C)	159	157	162	154	175
Barrel temp (°C)	140	140	147	140	152
Feed rate (g/min)	600	690	600	555	640
Water flowrate (L/h)	9.3	6.7	9.3	6.6	9.6

mix (cereal/meat mix) was fed to the extruder using a mechanical feeder. For all mixes the same screw configuration and die design (1mm x 5 mm) were used. Control soya samples were prepared without meat for comparison of product physical characteristics. Meat extenders were dried as described for snacks.

Beefburger manufacture

Burger composition was 80% beef (or 60% beef and 20% extender), water (18%) and seasoning (2%). Forequarter beef was minced through a 5 mm plate. Meat was combined with water and burger seasoning (W. Blake Ltd., Dublin) thoroughly mixed by hand, and minced again through the 5 mm plate before being formed into patties using a piston hand press. Patties were placed between cellulose burger papers and then frozen. Prior to inclusion, the soya based meat extenders were rehydrated in cold water for 20 min. After removal of excess water, each extender was minced then added on a wet weight basis.

Physical/chemical analysis

Water uptake (extenders): Products were weighed dry and rehydrated in excess cold water for 20 min. Excess water was removed and samples reweighed. Determinations were made in triplicate on each sample. The amount of water absorbed was calculated from the difference in weight and the absorption index was calculated as follows:

$$\textit{Water absorption index} = \frac{\textit{weight gain upon hydration (g)}}{\textit{dry weight (g)}} \times 100$$

Bulk densities: These measurements were carried out as described previously.

Cook loss: The burger was weighed and then cooked from frozen in vegetable oil at 190°C for 5 min. Four replicate measurements were made. Excess oil was removed and the burger was allowed to cool for 1 hour and reweighed. The percentage loss in weight was calculated as the follows:

$$\textit{Cook loss} = \frac{\textit{weight loss upon cooking (g)}}{\textit{raw weight (g)}} \times 100$$

Texture: Burgers cooked as above were chilled overnight and 20mm cores taken for texture measurements. Texture Profile Analysis was conducted on the Instron Universal Testing Machine. Attributes measured were hardness, springiness ratio, cohesiveness, gumminess and chewiness.

Microbiology: Testing was carried out as described for snacks, prior to sensory analysis.

Sensory analysis: Beefburgers prepared with 20% meat extenders were compared with all-meat controls. Burgers were cooked from frozen by grilling, to an internal temperature in excess of 75°C. Cooking time was 20 min (10 min on each side). Sensory evaluation was carried out under controlled light and temperature conditions. A forced choice method was used. Fifteen panellists were recruited from the staff of The National Food Centre. Samples were labelled with random three-digit codes. Water was supplied as a palate cleanser during sessions. Each panellist was presented with three samples, two the same and one different. Panellists were asked to taste the samples in the order given on their forms and to identify the different sample. They were then asked to describe the difference between the samples. Assessors were also asked to state their confidence in their choice of odd sample and their sample preference. This ancillary information was only collected from assessors giving a correct response. Preference information can give some indication as to the nature of the difference between the samples if one sample is strongly preferred over the other.

Consumer pre-test study: On the basis of the sensory analysis, the meat extender containing 20% liver/soya (incorporated at a level of 20g of extender per 100g of beefburger) was selected for further investigation in a consumer pre-test study using students and staff from the Dublin Institute of Technology, Cathal Brugha Street. The survey was carried out in the sensory facility at Cathal Brugha Street College. 52 individuals took part, the majority in the age group 17yr to 30yr. Each person received one half of a fully cooked burger. As before participants were asked to comment on a number of attributes.

Results

The analyses of the meat extenders and the burgers can be seen in Table 9.

Water Uptake The extenders containing 40% liver (I) and 40% beef (G) displayed significantly poorer hydration qualities when compared to both their low meat counterparts (F, H) and the soya control product (J). The products containing the lower levels of meat (F, H) showed significantly greater water uptake when compared to the controls.

Bulk Densities The extenders containing 40% liver (I) and 40% beef (G) displayed significantly higher bulk densities when compared to both their low meat counterparts (F, H) and the soya control product (J).

Colour The extender containing 40% beef (G) had a higher brightness (L value) and redness (a value), and lower yellowness (b value) than those containing the lower level (F). The opposite was true of the products containing liver (H, I).

The low beef product (F) and the high liver product (I) were less bright (lower L value) than the control (J). All products yielded a significantly lower redness (a value) than the control (J). The product containing the low level of beef (F) was more yellow (higher b value), while the product containing the high level of beef (G) had more blue colour (negative b values); the opposite was true of the products containing liver (H, I).

Table 9: Colour, density and water uptake of meat extenders containing soya and beef or liver (F to J). Also, cooking loss of beefburgers manufactured using the meat extenders.

Extenders		F	G	H	I	J	Meat control	Sig.
	Colour L	49.5	81.4	76.7	43.8	71.4		***
	Colour a	5.1	6.7	6.4	5.3	9.4		***
	Colour b	16.5	-17.0	-6.1	14.8	-1.5		***
	Bulk density (g/cm^3)	157.1	348.3	147.9	312.8	121.6		***
	Water uptake (%)	385.8	135.2	357.9	139.3	448.6		***
Burgers	Cook loss (%)	46.5	34.2	46.5	39.9	45.9	47.0	**

F: Soya/20% beef G: Soya/40% beef H: Soya/20% liver I: Soya/40% liver J: Soya control.
Sig.: Level of significance: * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

Microbiology Total viable counts on meat extender products revealed no change in microbial load between 0 days and 30 days.

Texture The analysis revealed no significant differences between beefburgers with respect to hardness, stringiness, cohesiveness, gumminess and chewiness.

Cook Loss Losses were significantly lower in burgers containing extenders with 40% beef (G) compared to all other burgers, with the exception of those containing the 40% liver/soya meat extender (I).

Sensory analysis In triangle tests, panellists detected a difference between control meat burgers (meat control) and burgers containing meat extenders, except those containing 20% liver/soya extender (H). Where significant differences were observed, part-substitution of the meat by meat extenders resulted in detectable flavour and texture changes. Preference information indicated a preference for the control sample when test burgers contained 40% beef/soya (G) or 40% liver/soya (I) extenders, suggesting that extenders containing meat at the 40% level (G, I) may adversely affect the flavour and texture of the final product.

Consumer pre-tests Over 50% of panellists rated the burger containing the 20% liver/soya extender moderately acceptable or better. A similar proportion rated tenderness moderately acceptable or better. Overall flavour was rated as being moderately acceptable or better by 60%, however non meat flavours were also detected by the panellists and 50% of them scored it as being moderately intense or greater.

MARKET STUDIES

Interviews were conducted with food manufacturers and consumers to determine their views on the development of extruded meat products. A full account of the results is contained in the report entitled Food Market Studies, in the section on extruded meats (The National Food Centre, 2001). The conclusions of the market study are summarised below:

- There is great potential for convenience foods, particularly for products which respond to consumer demand for improved product quality such as high quality chilled meat products. Extruded meat does not easily meet this demand.
- Meat based meals will decrease as a proportion of the total convenience meals market in the future. The main reasons are consumer perception of meat as an unhealthy food, and the growth in demand for ethnic and pasta based recipes.
- There is little potential for extruded meat as retailers find it difficult to position an extruded meat product. A mixture of meat and soya targets neither meat eaters or meat avoiders. It would be a source of confusion as a component in meat based convenience foods.
- Meat in convenience meals consists of approximately seventy per cent chicken, with minced beef making up a major part of the remaining meat-based dishes. The reason for the smaller beef component is a combination of consumer attitudes towards healthy eating and difficulties with quality control in meat dishes.
- Extrusion was not well understood by consumers and even after careful explanation consumer reaction to the concept was negative.

RECOMMENDATIONS TO INDUSTRY

Many opportunities are available in the snack market for the application of extrusion technology. Snack products produced using twin-screw extruders can be formed into a range of shapes, sizes, colours and textures by varying feed ingredient or by altering screw speed, feed rate, die design or screw configuration. High-fibre snack bars (Onwulata, 2000) and low-fat snacks (Faller, 2000) have also been prepared by twin-extrusion cooking. Snack pellets may also be produced which can subsequently be expanded using hot air, microwaves or immersion in hot oil (Berry, 2000). This sector also has potential in the manufacture of multi-textured products such as product with a crispy outer texture and soft centre (Berry, 2000). Addition of soya protein to corn based snacks to make products of nutritionally higher value has been found to be acceptable in consumer tests (Faller, 1999) and overcomes the problems encountered with soya products such as poor flavour. Restructured fruit products can also be prepared by extrusion processing (Akdogan, 2000).

There have been a number of developments in extrusion technology, which have increased the range of products that can be prepared (Berry, 2000 and Mermelstein, 2000). High-moisture extrusion cooking (HMEC) can be used to convert vegetable and animal protein into foods with meat-like textures (Swientek, 2000), producing such products as sandwich fillings, chicken nuggets and pizza toppings.

Cold extrusion (where the product is kept at low temperatures during its passage through the extruder) could be used to prepare comminuted meat product batters for products such as sausages and frankfurters. Using cold extrusion, the traditional mixing and size reduction operations could be performed in a single continuous process rather than as discrete batch operations. This in turn could reduce operating costs, increase energy efficiency, allow more automated control and reduce floor space requirements. Studies in this area were conducted as part of this project. With the appropriate processing conditions, it was found that products similar in quality to conventionally manufactured products could be produced. Costing analysis for a pilot scale sausage production system revealed that although the initial capital outlay for the cold extrusion system was higher than the conventional system, the production cost per kg extruded sausage was estimated to be 8% lower. Most of the cost saving came from a predicted reduction in labour costs.

Co-extrusion (which involves combining two materials that are usually dissimilar in nature in an extrusion die) could be used to replace traditional filling systems in the manufacture of meat products. Commercial full-scale co-extrusion systems are available for the preparation of sausages and frankfurters and involve the formation of a continuous string of meat, which is subsequently surrounded by a uniform collagen layer. Recent research indicates that such systems give processing advantages over conventional methods. These advantages include production of products with more even string diameters, reduced coagulation defects and weight consistency problems and also minimised handling of the product during its manufacture (van den Dungen, 2000 and Kobussen, 1999a,b). Co-extrusion may also be employed in the manufacture of bread and meat-filled bread products (Bencomo, 2000).

A hybrid process called super-critical fluid extrusion (SCFX) uses carbon dioxide under high pressure rather than steam to expand grain-based products (Berry, 2000). Because of the low temperature and low shear, heat sensitive ingredients such as vitamins and nutraceuticals can be extruded. The method should open up possibilities in the area of functional snack foods and breakfast cereals. Modification of extrusion technology allows preparation of texturised whey protein, an ingredient that can be used in the preparation of low-fat meat products instead of texturised vegetable protein that some consumers find unacceptable (Berry, 2000).

CONCLUSIONS

- A novel method for the manufacture of sausages and frankfurters by cold extrusion was devised.
- Frankfurters and sausages produced by extrusion were of comparable quality to those produced by bowl chopping. A consumer pre-test study revealed no significant difference in preference for bowl chopped and extruded sausages and frankfurters.
- Meat extenders were developed using cooker extrusion and incorporated into beefburgers. A consumer pre-test study revealed that over 50% rated burgers containing 20% liver/soya extender moderately acceptable or better. However, inclusion of 40% beef/soya or 40% liver/soya meat extenders in beefburgers may adversely affect burger flavour and texture.
- Expanded semolina and maize snack products containing 10% dried beef and flavoured with beef flavouring were favourably received in consumer pre-tests, the maize snack being significantly more acceptable.
- Although some food manufacturers expressed interest in the extrusion-cooked ingredients developed in this project and in the cold extrusion process for making sausages, nevertheless, the result of the trade and consumer market analysis suggests that it would be difficult to develop a market for extruded meat products because of poor perception of the quality of such products by manufacturers and consumers, and difficulty in identifying a target market.

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