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FINAL REPORT

Project Armis No. 4531

High Pressure Technology in the Manufacture of Minimally-Processed Meat Products

The National Food Centre

RESEARCH & TRAINING FOR THE FOOD INDUSTRY

RESEARCH REPORT NO 47

Contents

HIGH PRESSURE TECHNOLOGY IN THE MANUFACTURE OF MINIMALLY-PROCESSED MEAT PRODUCTS

Authors:

Declan J Troy M.R.S.C. C.Chem. M.Sc.
Clodagh Crehan B.Sc. (Nutr Sci)
Anne-Maria Mullen B.Sc. Ph.D
Eoin Desmond B.Sc. Ph.D
The National Food Centre, Dunsinea, Castleknock, Dublin 15

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Teagasc
Agriculture and Food Development Authority

Teagasc 19 Sandymount Avenue Ballsbridge Dublin 4

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SUMMARY

High hydrostatic pressure processing was applied to raw minced meat prior to product formulation and the results indicate that with 50 MPa pressure it was possible to reduce the salt in frankfurters from 2.5% to 1.5% without compromising the safety and overall quality. Similarly the phosphate content of frankfurters could be reduced from 0.5% to 0.25% after pressure treatment. Cook loss from the treated frankfurters was significantly reduced indicating a higher yield of product due to the high pressure.

The effects of high pressure on the functional properties of breakfast sausages with reduced salt and reduced phosphate were examined. The salt level of the sausages could be decreased from 2.5% to 1.5% while improving cook yield. Sensory scores were highly acceptable and no significant difference in product texture was evident. Superior quality and acceptability were obtained in the breakfast sausages with 0.25% phosphate after the application of 150 MPa pressure.

Salt reduction below 1.5% had detrimental effects on both sensory quality and texture of breakfast sausages. Tapiocaline and KCl were added as functional ingredients to sausages with 1% salt. The added ingredients improved the stability and water-holding capacity of pressure-treated products containing 1% salt. However, the sensory attributes of the sausages were not enhanced by these ingredients and textural quality was decreased.

The optimum pressure required to increase the water-holding capacity and cooked yield of beefburgers was 300 MPa. Tenderness and juiciness were also enhanced by 300 MPa pressure. The fat level could be reduced to 15% in beefburgers with the application of 300 MPa pressure and the addition of tapiocaline.

High hydrostatic pressure processing was evaluated in a commercial sausage manufacturing plant. Seasoning was provided by the manufacturer for the high pressure treated product which was low in fat (15%) and had a reduced salt (1.5%) level. Consumer testing and other quality measurements were undertaken. Products treated with 150 MPa pressure were as acceptable as the typical commercial product. The shelf-life of the sausages was extended after the application of 600 MPa pressure.

MINIMAL PROCESSING

The convenience food industry is now one of the fastest growing in Ireland and demand for consumer-ready foods has increased dramatically over the last few years. In these food products, meat is one of the main ingredients and usually the most expensive. Today's increasingly health conscious consumer favours a reduction in preservatives such as salt and nitrite, which can in turn increase the risk of microbial contamination of meat-based convenience foods.

The meat industry has been encouraged to reduce excess fat, salt and additives present in formulated meat products in an effort to address consumers' negative perception of such ingredients. Salt is being increasingly targeted by the meat product industry in light of the role of sodium in the development of hypertension and coronary heart disease. Phosphates find diverse uses as functional additives in various food products and although permitted for use at inclusion levels of up to 0.5% in finished meat products by the USDA, additives of any type do not appeal to the consumer.

Minimal processing helps manufacturers produce foods that have the quality of fresh foods but convenience and profitability associated with shelf-life extension. Quality attributes that can be protected by application of minimal process technologies include flavour and odour, nutritional value and the reduced need for additives. This project investigated high hydrostatic pressure processing to produce minimally-processed meat products containing low levels of preservatives and high quality and safety.

HIGH PRESSURE PROCESSING

Processing of foods at high pressure and low or moderate temperature is being investigated to eliminate the effects of pressure on phase transitions of water and lipids, on protein denaturation, on texture modifications, on enzyme activation and inactivation and on microbial inactivation. The latter application is of special interest since pressure represents an alternative to thermal processing, especially for foods with nutritional and sensory characteristics which are thermosensitive.

The main advantage of pressure processing is the high quality of the treated products. It is also an efficient process. Once the desired pressure is reached, the pump or piston is stopped, the valves are closed and the pressure can be maintained without further energy input. It is a gentle process that affects only non-covalent bonds (hydrogen, ionic and hydrophobic) with little or no effect on covalent bonds thereby protecting the chemical constituents associated with food flavour, colour and nutritional content.

The strength of the bind between meat particles is an important consideration in the development of meat products (MacFarlane, 1984). Pressure treatment prior to heating has been reported to considerably enhance the thermal gelation capacity of proteins in a comminuted meat system (Ikeuchi *et al.*, 1992) favouring an increase in binding strength of meat patties (MacFarlane *et al.*, 1984) and in shear force of low- and high-fat burgers (Carballo *et al.*, 1996).

High hydrostatic pressure processing unit (EPSI, Belgium)

The importance of meat colour in consumer acceptance is well known. (MacDougall, 1997).

PROJECT AIMS

The aim of this project was to use high pressure technology to develop a range of meat products formulated with none or reduced levels of preservatives, non-meat ingredients and/or chemical additives (salt and phosphate) while maintaining high product quality and safety.

To achieve the objective, five studies were undertaken to examine:

(a) the effect of high pressure processing on the functionality of reduced-salt and reduced-phosphate frankfurters;

(b) the significance of high pressure processing on the quality of reduced-salt and low-phosphate breakfast sausages;

(c) the significance of high pressure processing and added functional ingredients (KCl and tapiocaline) in reducing salt levels of breakfast sausages below 1.5%;

(d) the ability of high pressure processing to compensate for fat reduction in beefburgers, and

(e) an industrial scale-up of the process to compare the research products with commercial brands of sausages, beefburgers and frankfurters, with the overall aim of developing high pressure processing as an exploitable technique, with benefits for both industry and consumer.

GENERAL METHODS

Indirect compression was used to apply pressure to raw minced meat using a 2 litre capacity warm isostatic press (Engineered Pressure Systems International, N.V., Belgium).

Texture profile measurements were taken using an Instron Universal Model 4464 testing machine with a compression attachment. Sensory analysis was

carried out using an internal trained panel according to the American Meat Science Association guidelines (AMSA, 1983). The panellists were asked to assess juiciness, saltiness, spiciness, tenderness, overall flavour, overall texture and overall acceptability using a six- or eight-point hedonic scale. Other methods can be found in Crehan *et al.*, (2000).

This pressure is about 400 mPa.

The effect of high pressure processing on the functionality of reduced-salt and reduced-phosphate frankfurters

Twelve batches of frankfurters were manufactured with targeted salt (1.5% and 2.5%) and phosphate (0.1% and 0.25%) levels and selected pressure treatments (0 MPa, 150 MPa and 300 MPa). The formulation of the batches is given in Table 1.

The effects of pressure treatment (150 and 300 MPa) on cook loss, emulsion stability, sensory quality, texture profile and colour of frankfurters with reduced salt and phosphate were investigated. Salt reduction from 2.5% to 1.5% had no effect on cook loss of frankfurters but increased the stability of the emulsion. Decreasing the salt content decreased sensory perception of saltiness, spiciness, overall flavour intensity and overall acceptability but no difference in juiciness, smokiness or overall texture was recorded. Textural attributes of hardness, springiness, cohesiveness, gumminess and chewiness were all improved by reducing the salt content of the products. Salt reduction significantly decreased redness and yellowness colour values.

Cook loss decreased when the phosphate content of the frankfurters was reduced. However, the stability of the emulsion was also reduced. Smokiness and spiciness increased due to phosphate reduction and other sensory characteristics remained unaffected. Texture profile analysis (TPA) indicated that phosphate reduction decreased hardness, adhesiveness, gumminess and chewiness but the other textural parameters were unaltered. Redness was the

Table 1: Formulation of frankfurters with varying salt and phosphate contents with and without high pressure application. All data are presented in kilograms.

Treatment/ Formulation	Lean pork	Lean beef	Fat	Ice	Water	Sodium nitrite	Na Asc[a]	Salt	Phosphate	Spice mix
Control/1*	0.997	1.077	1.38	0.153	0.307	0.0003	0.002	0.06	0.004	0.02
Control/2	0.997	1.077	1.38	0.151	0.302	0.0003	0.002	0.06	0.01.	0.02
Control/3	0.997	1.077	1.38	0.140	0.279	0.0003	0.002	0.1	0.004	0.02
Control/4	0.997	1.077	1.38	0.138	0.276	0.0003	0.002	0.1	0.01	0.02
150MPa/1	0.997	1.077	1.38	0.153	0.307	0.0003	0.002	0.06	0.004	0.02
150MPa/2	0.997	1.077	1.38	0.151	0.302	0.0003	0.002	0.06	0.01	0.02
150MPa/3	0.997	1.077	1.38	0.140	0.279	0.0003	0.002	0.1	0.004	0.02
150MPa/4	0.997	1.077	1.38	0.138	0.276	0.0003	0.002	0.1	0.01	0.02
300MPa/1	0.997	1.077	1.38	0.153	0.307	0.0003	0.002	0.06	0.004	0.02
300MPa/2	0.997	1.077	1.38	0.151	0.302	0.0003	0.002	0.06	0.01	0.02
300MPa/3	0.997	1.077	1.38	0.140	0.279	0.0003	0.002	0.1	0.004	0.02
300MPa/4	0.997	1.077	1.38	0.138	0.306	0.0003	0.002	0.1	0.01	0.02

[a] Sodium ascorbate.

*The first number refers to the treatment (Control;150MPa pressure; 300MPa pressure) and the second to the ingredient mix.

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only colour attribute to be affected by phosphate with a decrease being recorded.

Application of 150 MPa pressure decreased cooking losses of the frankfurters and resulted in a more stable emulsion. Panellists found that the juiciness of the products was increased by the application of 300 MPa pressure and there was a slight but significant decrease in overall texture and overall acceptability scores. Overall flavour intensity and colour were not affected by pressure processing. Texture characteristics, as measured by TPA, of reduced-salt and reduced-phosphate frankfurters were altered after application of 300 MPa pressure with an increase in hardness and improved cohesiveness.

The results demonstrate that high pressure processing at either 150 or 300 MPa partially offset some of the negative effects of reducing salt and phosphate levels in frankfurters.

The significance of high pressure processing on the quality of breakfast sausages with reduced-salt levels and 0.25% phosphate

The above work showed that high pressure processing (150 MPa) yielded highly acceptable results when frankfurters were formulated with low phosphate (0.25%). This process was adopted in the present trial to reduce the salt level in the preparation of breakfast sausages while maintaining sausage functionality and overall product acceptability.

A 5x1x2 factorial design was used to test 5 salt levels (0.5%, 1.0%, 1.5%, 2.0% and 2.5%), 1 phosphate level (0.25%) and 2 pressure treatments (0 MPa and 150 MPa). Cook loss, water holding capacity, emulsion stability, sensory and texture measurements were taken to assess the significance of high pressure processing and salt reduction on the sausage quality and yield.

Cook loss was significantly decreased by 150 MPa pressure. In addition, salt could be reduced from 2.5% to 1.5% without affecting cook loss, which is advantageous to the processor when considering cook yield. The water holding capacity of the sausages was not affected by salt content or pressure treatment, indicating the potential for salt reduction. Percentage total

expressible fluid (TEF) was unaltered by salt reduction to 1.5% or by the application of high pressure (150 MPa), implying a stable sausage emulsion.

Sensory analysis revealed highly acceptable sensory traits for sausages formulated with reduced (1.5%) salt (Table 2). Pressure application did not affect the overall acceptability of the sausages and it was interesting to note that highest overall acceptability scores were evident in sausages containing 1.5% salt.

From a textural viewpoint, hardness, springiness, gumminess and chewiness were unaffected by pressure (150 MPa) application and it was possible to reduce the salt level to 1.5% without affecting these characteristics.

In conclusion, the results proved the viability of reducing salt levels from 2.5% to 1.5% with the use of high pressure processing in fresh breakfast sausages without negatively affecting the quality characteristics of the sausages.

Table 2: Sensory characteristics of reduced-phosphate sausages with and without high pressure application and varying salt concentrations.

	Saltiness*	Juiciness*	Firmness*	Flavour*	Texture*	Accept*
Pressure						
0 MPa	3.06	3.98^{a}	3.53	3.44	3.79	3.50
150 MPa	3.15	3.75^{b}	3.68	3.45	3.64	3.40
Significance	ns	P<0.05	ns	ns	ns	ns
Salt						
0.5%	1.91^{a}	3.48^{a}	2.30^{a}	2.44^{a}	2.66^{a}	2.45^{a}
1.0%	2.87^{b}	4.08^{b}	3.74^{b}	3.34^{b}	3.80^{b}	3.58^{b}
1.5%	3.47^{c}	4.19^{b}	3.98^{bc}	3.75^{c}	4.17^{cd}	3.99^{c}
2.0%	3.43^{c}	3.80^{c}	3.93^{bc}	3.78^{c}	3.94^{bd}	3.72^{b}
2.5%	3.83^{c}	3.76^{c}	4.08^{c}	3.91^{c}	3.92^{bd}	3.50^{b}
Significance	P<0.05	P<0.05	P<0.05	P<0.05	P<0.05	P<0.05
Interactions						
Pressure x salt	ns	ns	ns	ns	ns	ns

* Six point hedonic scale (e.g. 1 = not salty, 6 = extremely salty, etc)
Different subscripts within the same column imply significant differences
ns = not significant

The significance of high pressure processing and added functional ingredients (KCl/tapiocaline) in reducing salt levels of breakfast sausages below 1.5%.

Results from the previous study on low-salt sausages revealed that salt reduction below 1.5 % had detrimental effects on both sensory and textural aspects. Tapiocaline and KCl were selected as texture and flavour enhancing ingredients based on previous findings (Daly *et al.*, 1997). Tapiocaline is a pre-gelatinous starch from cassava and is commercially available.

A 3x2x1 factorial design was used to formulate fresh sausages with 3 salt levels (0.5%, 1.0% and 1.5%), 2 ingredients (0, no added ingredient; 1, added KCl and tapiocaline) and 1 pressure level (150 MPa) .

The addition of KCl/tapiocaline decreased total expressible fluid thus improving the stability of the emulsion irrespective of the salt level in the sausages. Similarly, salt level could be reduced to 1.0% without negatively affecting the water holding capacity of the sausages, provided tapiocaline and KCl were present in the formulation.

Texture profile analysis (Table 2) revealed that salt level could be reduced to 1.0% using tapiocaline and KCl without affecting hardness or springiness. Cohesiveness decreased with decreasing salt level and the presence of tapiocaline and KCl. Gumminess decreased with decreasing salt level but no effect of added ingredients was observed.

Added tapiocaline and KCl did not significantly alter the saltiness, juiciness, overall flavour intensity, firmness, overall texture or overall acceptability as perceived by the trained sensory panel. However, reducing the salt level below 1.5% resulted in disimproved sensory attributes.

In conclusion, high pressure and addition of KCl and tapiocaline did not compensate for loss of sensory properties in reduced salt sausages (below 1.5%). Yield was unaffected at 1 and 1.5% salt levels and significantly improved at 0.5%.

Table 3: Texture of low-salt breakfast sausages formulated with (1) and without (0) added tapiocaline and KCl.

	Hardness	Springi-ness	Adhesive-ness	Cohesive-ness	Gummi-ness	Chewi-ness
Salt						
0.5%	84.0[a]	6.90	0.22[a]	0.50[a]	45.0[a]	298.0[a]
1.0%	104.0[b]	6.77	0.26[b]	0.53[b]	55.0[b]	369.0[b]
1.5%	110.0[b]	6.66	0.26[b]	0.58[c]	61.0[c]	400.0[c]
Significance	P<0.05	ns	P<0.05	P<0.05	P<0.05	P<0.05
Ingredients						
0	97.0	6.81	0.24[a]	0.54[b]	54.0	355.0
1	101.0	6.74	0.26[b]	0.52[a]	53.0	357.0
Significance	ns	ns	P<0.05	P<0.05	ns	ns
Interactions Salt x Ingredients						
0.5/0	90.0	6.82	0.22	0.52	46.0	312.0
1.0/0	97.0	6.86	0.25	0.54	53.0	361.0
1.5/0	106.0	6.76	0.25	0.56	59.0	397.0
0.5/1	79.0	6.99	0.23	0.49	44.0	285.0
1.0/1	110.0	6.78	0.28	0.51	57.0	378.0
1.5/1	115.0	6.56	0.28	0.55	62.0	403.0
LSD	13.0	0.42	0.03	0.03	5.0	39.0
Significance	P<0.05	ns	ns	ns	ns	ns

LSD = least significant difference

Different subscripts within the same column imply significant differences

The ability of high pressure processing to compensate for fat reduction in beefburgers

Typical commercial beefburgers contain 23-25% fat, which is too high in view of consumers' demands for healthier meat products. However, the reduction of fat content in meat products is at the expense of their organoleptic properties, texture and appeal. Therefore technological ways are needed to compensate for fat reduction. One such way is the application of high pressure to raw ground beef. This study examined the acceptability of beefburgers containing 15% fat with and without the application of 300 MPa pressure to the ground beef component of the beefburgers. The study also

examined tapiocaline as a functional ingredient for low-fat beefburgers. Six beefburger formulations were used to determine whether high pressure and/or tapiocaline can maintain the quality of low-fat burgers (Table 4).

Where fat was reduced to 15%, it was replaced by water or a combination of water and tapiocaline according to the formulation presented in Table 4.

Highest cook yields were recorded in beefburgers with 15% fat and 300 MPa pressure and/or a combination of high pressure and added tapiocaline. The percentage water-holding capacity was similar for all of the products and the 15% fat beefburgers with tapiocaline and 300 MPa pressure were acceptable in this regard.

The reduced fat (15%) beefburgers showed optimum sensory scores with or without high pressure when tapiocaline was used. Overall flavour, overall texture and juiciness scores were enhanced. In addition, the combination of pressure treatment and tapiocaline gave less reduction in diameter of the beefburgers on cooking.

It was concluded that high pressure processing and added tapiocaline improved the quality characteristics of reduced-fat beefburgers.

Table 4: Formulation for reduced-fat beefburgers with added ingredients and high pressure (HP) processing. Data are presented in kilogrammes.

	Beef	Fat	Spice	Water	Tapiocaline
20% fat control	2.6	0.75	0.15	0.04	-
20% fat + HP	2.6	0.75	0.15	0.04	-
15% fat control	2.6	0.61	0.15	0.14	-
15% fat + HP	2.6	0.61	0.15	0.14	-
15% fat control + tapiocaline	2.6	0.61	0.15	0.105	0.035
15% fat + HP + tapiocaline	2.6	0.61	0.15	0.105	0.035

Raw beefburger mix before (on paper plate) and after (in pouches) application of 300MPa pressure.

Industrial application of high pressure processing in the manufacture of a reduced fat, low salt and low phosphate breakfast sausage

The aim of this experiment was to examine the application of HPP on the raw meat material used in the manufacture of a reduced fat, low salt and low phosphate breakfast sausage. 150 MPa pressure was applied to the raw meat material from which breakfast sausages having reduced fat (15%), low salt (1.5%) and low phosphate (0.25%) were made. A typical commercial seasoning was incorporated into the HPP sausages. They were compared with a commercial brand containing fat, salt and phosphate at levels of 25%, 2.5% and 0.5% respectively. Both types of sausages were cooked and compared using sensory analysis and texture profiles.

Sensory analysis revealed similar scores in overall flavour, but established that the HPP product had a more 'salty' taste. This may be due to the decreased masking effect of the lower level of fat in the HPP product. Overall texture

scores were significantly higher for the HPP sausages. However juiciness was rated lower possibly because of the lower level of fat. Some panellists preferred these sausages which were less greasy or mushy. Instrumental texture profiles suggested that the HPP samples were harder overall and more chewy.

When the samples were presented to 50 members of a user group who regularly eat sausages, 34.8% preferred the HPP compared with 45.7% who preferred the commercial sausage. 37% of members recorded that the HPP was just as good or better than their normal brand. 52% of members rated the commercial brand as good or better than their normal brand.

It is concluded that a reduced fat, low salt and low phosphate sausage can be produced using HPP, but some modifications are needed to increase its juiciness.

Generally, pressure above 400 MPa can kill bacteria. A shelf-life study on the breakfast sausages produced from raw meat subjected to 600 MPa was carried out. A control batch consisted of the same formulation except that the raw meat material was not subjected to HPP. The bacterial content was determined by total viable counts (TVC) over a two week storage period at +4°C and the results are presented in Figure 1. This demonstrates that HPP can lower the TVC during storage.

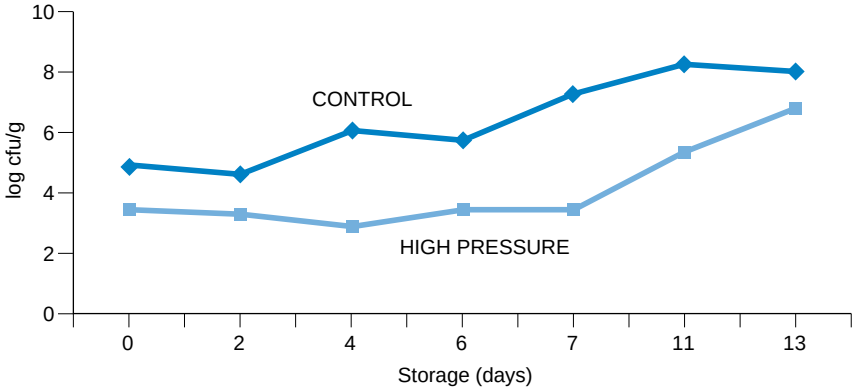

Figure 1: Total viable counts (in logarithm) of bacteria in commercial breakfast sausages with or without high pressure treatment. Product was stored for 13 days at +4°C.

Industry views on nutritionally enhanced processed meats

Interviews were carried out by the Market Research Group at The National Food Centre on the development of nutritionally enhanced processed meat products. The conclusions are summarised below:

The demand for the reduction in additives and preservatives in processed meats is retailer driven. However, Irish meat processing companies are committed to meeting these demands.

The industry needs assistance in developing processes that can lead to additive-free and preservative-free products (reducing or in some cases removing nitrites, phosphates and mono-sodium glutamate (MSG)).

Salt is viewed as a flavour enhancer and is no longer used as a preservative. Processors believe that salt flavour is a necessary consumer requirement.

The development of low-fat products is considered to be achievable but not economically viable for low-margin meat products. All the companies agreed that low fat is an issue that requires continual monitoring.

There are market growth opportunities for novel, nutritionally-enhanced meat products among the adolescent market.

There was a high level of awareness of high pressure processing but none of the companies had considered its potential in meat processing.

Processors' reservations on the potential viability of high pressure included high capital costs and a poor return on investment.

The National Food Centre's research objective of finding processing alternatives to the use of additives and preservatives reflects industry needs.

More details on the marketing research may be found in The National Food Centre report No. 39 (2001) entitled "Food Market Studies" in the section on nutritional meat products.

CONCLUSIONS

- High pressure processing (HPP) has many beneficial effects on meat product quality.
- HPP reduced the need for fat, salt and phosphate in meat products without significantly altering their quality.
- HPP improved the water-holding capacity and decreased cooking losses of low fat beefburgers.
- HPP was successfully used in conjunction with meat extenders to reduce the negative impact of reducing fat.
- HPP breakfast sausages with reduced fat, low salt and low phosphate were acceptable to consumers.
- HPP reduced the bacterial content of meat products.

RECOMMENDATIONS TO INDUSTRY

While the potential for high pressure processing of foods has been known since the late 19th century, only recently has suitable equipment been made available. The main applications are in the production of jams, fruit juice, soaps and more recently processed meats such as hams. The product range is increasing and spreading from Japan, USA and now into Europe.

The most suitable meat products for high-pressure treatment are both cured and/or cooked meat products because, unlike fresh meats, their colour is not affected by the treatment. High-pressure meat products commercially available in France, Spain, United States and Japan include hams, deli-style meats and ready-cooked meats. The high-pressure process is seen to have many advantages such as inactivating spoilage organisms, destroying food poisoning organisms, increasing shelf-life of product, reducing the need for additives and retention of texture and taste. Conventional heat treatments generally affect texture and taste adversely.

Disadvantages are capital costs and initial outlay on equipment, which is very expensive. Industrial scale vessels can cost from 0.5 to 4 million euro. Batch and semi-continuous systems are available. In the cooked meat and meat-based ready meals sector, high-pressure treatment offers a major opportunity to produce a fresh tasty product with minimal preservatives, which is safe and has a significantly longer shelf life. The growing market of this sector suggests that the initial investment costs may be worthwhile. Consumers are willing to pay extra for new products which have higher quality and are more convenient than the existing range. High-pressure technology can deliver on both these aspects. It is important that thorough testing is carried out in terms of eating quality, safety and cost benefits, before the technology is embraced.

It is recommended that manufacturers of processed meats and ready meals should closely monitor developments in high pressure processing.

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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