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Assessment of scraped surface heat exchanger technology for the development of extended shlf-life meat products DAQ.071

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FINAL REPORT PART 1

ABSTRACT

DAQ.071 ASSESSMENT OF SCRAPED SURFACE HEAT EXCHANGER TECHNOLOGY FOR THE DEVELOPMENT OF EXTENDED SHELF-LIFE MEAT PRODUCTS

August, 1993

DPI QUEENSLAND

IFIQ

FINAL REPORT - PART 1

PROJECT SUMMARY

Project Title:

Assessment of scraped surface heat exchanger technology for the development of extended shelf-life meat products.

Project No.: DAQ.071

Research Organisation and Location:

Department of Primary Industries Queensland
International Food Institute of Queensland (IFIQ)
19 Hercules Street
HAMILTON QLD 4007

Commencement: 1 November 1990

Completion: 30 November 1993 (terminated on 7 June 1993)

Project Investigators:

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Objective:

To establish the feasibility of scraped surface heat exchanger technology in developing meat and vegetable particulate products which are shelf-stable when aseptically packed, and chilled extended shelf-life products.

Summary:

Scraped surface heat exchangers (SSHE) are used in the food industry to heat, cook, sterilise and cool food products which cannot be processed in plate or tubular heat exchangers. This includes products that are very heat sensitive, form a film on the heat exchange surface, are highly viscous or become highly viscous during processing. Aseptic processing involves sterilising the product and package separately, and filling under sterile conditions. Advantages include better product quality compared with canned products, lower transport and storage costs compared with frozen products, and virtually no restriction on package size. Problems include ensuring adequate heat penetration in particles to ensure sterility, preventing separation of particles from the carrier liquid, and retention of particle structure and shape.

The project aimed to establish the feasibility of the technology for aseptically packaged, beef-based particulate products and to compare it with conventional technologies. It also aimed to evaluate aseptically packaged, chilled pasteurised products.

A literature review and economic assessment of the aseptic packaging of food containing particulates were conducted. Discussions about product requirements were held by the commercial partner with Japanese and domestic food manufactures. From these meetings, meat-based particulate stew products were identified for the export market to Japan, and bolognaise sauce mainly for the domestic market. Formulations and processes were developed for canned, retort-pouched, chilled and frozen products.

Work on objective quality parameters was also performed. A potential rancidity test (the thiobarbituric acid test) was applied to a meat and vegetable stew, but proved unsuitable for this type of product. The main types of heat-resistant bacterial spores found in this product were identified, and their thermal characteristics were established. A method was developed to suspend bacterial spores in alginate gel cubes, for evaluation of process lethality in particulate products sterilised in scraped surface heat exchangers.

A product containing small-sized particles, bolognaise sauce, was sterilised (130°C/3.5 minutes) in a scraped surface heat exchanger, cooled in a tubular Spiroflo heat exchanger, and aseptically filled into sterile nylon-foil laminate Intasept bags. Quality was measured by microbiological plate counts, colour (Hunter L, a, b), particle content, and sensory evaluation. The aseptically packaged product had better flavour, colour and appearance then the canned product, and was only slightly inferior to frozen bolognaise for these attributes. However, the aseptic product received lower scores for consistency and particle size than canned and frozen bolognaise. A chilled pasteurised bolognaise sauce was also processed by aseptic packaging, and by hot-filling into Cryovac bags. The storage life of the chilled product was 2 weeks at 4°C.

Experiments were carried out on a model "stew", containing potato cubes and a modified starch "sauce". A sauce of high viscosity was found to be necessary to suspend the particles, and prevent problems of separation and slippage during heating. A maximum particle content of 30% was able to be pumped through the aseptic processing line. However, some pressure fluctuations were encountered.

The project indicated that production of a shelf-stable, meat-based particulate product by scraped surface heat exchanger technology and aseptic packaging is technically feasible. However further developmental work on a product with larger particles is required. In addition, more market research on such products will be necessary before these products can be commercialised.

FINAL REPORT PART 2

EXECUTIVE SUMMARY

DAQ.071 ASSESSMENT OF SCRAPED SURFACE HEAT EXCHANGER TECHNOLOGY FOR THE DEVELOPMENT OF EXTENDED SHELF-LIFE MEAT PRODUCTS

August, 1993

DPI QUEENSLAND

IFIQ

FINAL REPORT - PART 2

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Project No.: DAQ.071

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Background and Industry Context:

Scraped surface heat exchangers (SSHE) are used in the food industry to heat, cook, sterilise and cool food products which cannot be processed in plate or tubular heat exchangers. This includes products that are very heat sensitive, form a film on the heat exchange surface, are highly viscous, or become highly viscous during processing.

Aseptic processing involves sterilising the product and package separately, and filling under sterile conditions. Advantages include better product quality compared with canned products, lower transport and storage costs compared with frozen products, and virtually no restriction on package size. Problems include ensuring adequate heat penetration in particles to ensure sterility, preventing separation of particles from the carrier liquid, and retention of particle structure and shape.

A south-east Queensland meat processor has identified markets for aseptically packaged meat and vegetable "stew" (principally for export to Japan) and aseptically packaged bolognaise sauce (principally domestic). Aseptically packaged products have considerable potential in the above markets provided that their quality is as good as, or better than the

existing products.

Project Objectives:

1. Establish the feasibility of scraped heat exchanger technology in developing meat and vegetable products which are shelf stable when aseptically packaged.

2. Establish the feasibility of scraped surface heat exchanger technology in extending the shelf life of chilled meat and vegetable products for the domestic market.

3. Compare the microbiological, chemical, physical and sensory attributes of products manufactured using this technology and by conventional means.

4. Develop both Japanese and domestic markets for shelf stable meat and vegetable products.

5. Pilot produce a range of products by the most viable aseptic processing technology.

6. Present these products to selected Japanese and domestic enterprises.

Brief Methodology:

A literature review and economic assessment of the aseptic packaging of particulate low-acid foods was conducted. Discussions about product requirements were held by the commercial partner with Japanese and domestic food processors. Formulations and processes were developed for canned, retort-pouched, chilled and frozen products.

Work on objective quality parameters was performed. A potential rancidity test (thio-barbituric acid test) was applied to a meat and vegetable stew. The main types of heat-resistant bacterial spores found in this product were identified, and their thermal characteristics were established. A method was developed to suspend bacterial spores in alginate gel cubes, for evaluation of process lethality in particulate products, sterilised in scraped surface heat exchangers.

A scraped surface heat exchanger, aseptic filler, valves, and temperature controller were added to the aseptic pilot equipment at IFIQ. A product containing small-sized particles, bolognaise sauce, was sterilised (130°C/3.5 minutes) in scraped surface heat exchanger, cooled in a spiroflo heat exchanger, and aseptically filled into sterile nylon-foil laminate intasept bags. Quality was measured by microbiological plate counts, colour (Hunter L, a, b), particle content, and sensory evaluation. The aseptically packaged product was compared to canned and frozen bolognaise, from replicated batches.

Aseptic processing experiments were carried out on a product containing larger particles, model "stew", containing potato cubes and a modified starch "sauce". The effects of particle concentration, starch concentration, back-pressure, heating and cooling, were investigated.

Main Results and Conclusions:

The project indicated that scraped surface heat exchanger/aseptic packaging technology was technically feasible for bolognaise sauce, a meat-based product with small-sized particles. The product sterilised at 130°C for 3.5 minutes, had better flavour, colour, and appearance than canned bolognaise. However, textural parameters (consistency and particle size) were inferior to canned and frozen products. Although this indicates no overall quality advantage for the aseptically packaged product any disadvantages may be offset by the economic advantages of bulk packaging and reduced storage and transport costs.

Pasteurised (i.e. not sterilised) bolognaise had a shelf life for two weeks at 4°C. There was no quality advantage of aseptic packaging, over hot-filling and tumble-cooling for this storage time.

The main types of heat resistant bacterial spores found in this product, were identified as *Bacillus* species, and their thermal characteristics were established. This research showed that alginate gel cubes embedded with spores of *Bacillus stearothermophilus* could be used as indicators of heat sterilisation of particulate food, in scraped surface heat exchangers. However, heat penetration into gel cubes was more rapid than into some food particles. More data are needed to ensure gel cubes can be used to accurately establish a safe process for low-acid particulate foods.

An aseptically packaged "stew" containing larger particles required a sauce with high viscosity to suspend the particles and prevent problems of separation and slippage. The maximum particle content present which could be pumped through the aseptic processing system was 30%. However, some pressure fluctuations were encountered. Further research and development is required to complete the process development of an aseptically packaged beef and vegetable stew containing large particles.

Markets were identified for aseptically packaged beef-based stew/curry in Japan and aseptically packaged bolognaise in Australia. Provided that high product quality can be achieved, an economically viable aseptic processing operation could be established. Further market research including assessment of products by potential customers will be necessary before these products can be produced commercially.

FINAL REPORT - PART 3

DAQ.071 ASSESSMENT OF SCRAPED SURFACE HEAT EXCHANGER TECHNOLOGY FOR THE DEVELOPMENT OF EXTENDED SHELF-LIFE MEAT PRODUCTS

August, 1993

DPI QUEENSLAND

IFIQ

PROJECT DETAILS

Project title:

Assessment of scraped surface heat exchanger technology for the development of extended shelf-life meat products.

Funding body:

Meat Research Corporation

DAQ.071

Research Organisation and Location:

Department of Primary Industries Queensland
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Phone: (07) 268 8555 **Fax:** (07) 868 1853

Commencement date: 1 November 1990

Completion date: 30 November 1993 (terminated on 7 June 1993)

Project research team:

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CONTENTS

SUMMARY

Scraped surface heat exchangers (SSHE) are used in the food industry to heat, cook, sterilise and cool food products which cannot be processed in plate or tubular heat exchangers. This includes products that are very heat sensitive, form a film on the heat exchange surface, are highly viscous or become highly viscous during processing.

Aseptic processing involves sterilising the product and package separately, and filling under sterile conditions. Advantages include better product quality compared with canned products, lower transport and storage costs compared with frozen products, and virtually no restriction on package size. Problems include ensuring adequate heat penetration into the particles to ensure sterility, preventing separation of particles from the carrier liquid, and retention of particle structure and shape.

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A literature review and economic assessment of the aseptic packaging of food containing particulates were conducted. Discussions about product requirements were held by the commercial partner with Japanese and domestic food manufacturers. From these meetings, meat-based particulate stew products were identified for the export market to Japan, and bolognaise sauce mainly for the domestic market. Formulations and processes were developed for canned, retort-pouched, chilled and frozen products.

Work on objective quality parameters was performed. A potential rancidity test (the thiobarbituric acid test) was applied to a meat and vegetable stew, but proved unsuitable for this type of product. The main types of heat-resistant bacterial spores found in this product were identified as various species of *Bacillus*, and their thermal characteristics were established. A method was developed to suspend bacterial spores in alginate gel cubes, for evaluation of process lethality in particulate products sterilised in scraped surface heat exchangers.

A scraped surface heat exchanger, aseptic filler, valves, and temperature controller were added to the aseptic pilot equipment at IFIQ. Considerable testing and modification of the equipment was carried out, to achieve the conditions necessary to sterilise the product. A product containing small-sized particles, bolognaise sauce, was sterilised (130°C/3.5 minutes) and aseptically filled into sterile nylon-foil laminate Intasept bags. Quality was measured by microbiological plate counts, colour (Hunter L, a, b), particle content, and sensory evaluation. The aseptically packaged product had better flavour, colour, and appearance than the canned product, and was only slightly inferior to frozen bolognaise. However, the aseptic product received lower scores for consistency and particle size than canned and frozen bolognaise.

A chilled pasteurised bolognaise sauce was also packaged aseptically, and by hot-filling into cryovac bags. The storage life of the chilled product was 2 weeks at 4°C in both cases.

Aseptic processing experiments were carried out on a model "stew", containing potato cubes and a modified starch "sauce". A sauce of high viscosity was found to be necessary

to suspend the particles, and prevent problems of separation and slippage during heating. A maximum particle content of 30% was able to be successfully pumped through the aseptic processing line.

The project indicated that production of shelf-stable, meat-based particulate products by scraped surface heat exchanger technology and aseptic packaging is technically feasible. However further developmental work on product with larger particles is required. In addition more market research on such products will be necessary before these products can be commercialised.

1. BACKGROUND AND INDUSTRY CONTEXT

Aseptic processing involves sterilising the product and package separately, and filling under sterile conditions. This is in contrast to conventional canning, where the product is sterilised in the can. Plug *et al* (1990) have defined "aseptic processing" as the shorthand name for the food production system where product moves in continuous flow through a heat-hold-cool thermal process and is then filled into a sterile package. The package is sterilised, filled, and sealed in a sterile environment".

For the purpose of this report meat products will be considered to be low-acid (above pH 4.6) foods containing particulates. Low-acid UHT (ultraheat treated) products currently being produced in Australia include milk, cream, custard, milk puddings, stocks, and soft-serve mix (Zadow, 1993). Aseptic low-acid products of the future are likely to be products that are now frozen or canned (Hannigan, 1983) and demand for such products will increase in future as consumers turn to convenient and high quality products in alternative (cheaper) forms of packaging (Murray, 1985).

1.1 Principles of meat product sterilisation

The reason for heating meat products to sterilisation temperatures is to allow for their distribution, storage and consumption at ambient temperatures without spoilage or risk to public health from food poisoning. The time and temperature of heat processing to obtain sterility depends on the amount of heat required at the point in the product slowest to heat, on the chemical composition of the product, and on the types and numbers of microorganisms contaminating the product at the time of heat processing.

The most important compositional factor determining the heat processing requirements of a food is its acidity (or pH). Foods are classed as "high-acid" if the pH is 4.6 or less and "low-acid" if the pH is greater than 4.6. Acid foods include most fruits and tomato products while low-acid foods include most vegetables, meat, fish and some dairy products. Low-acid foods require a more severe heat treatment than acid foods to render them sterile because bacterial spores are more heat resistant under low-acid than under high-acid conditions.

Heat sterilisation processes for low-acid meat products are designed to inactivate spores of *Clostridium botulinum.* This organism will grow at ambient temperatures. If this organism survives the heat sterilisation process there is a risk that toxins will be produced, sometimes without swelling the food package or noticeably changing the nature of the product. As this organism presents a major public health risk, recommended heat processes for low-acid foods are designed to reduce the probability of a spore of *C. botulinum* surviving to one in a 10^{12} (Board, 1989).

Different time temperature relationships are used to achieve the same sterilising effect. Conventional canning utilises temperatures of 116°C-121°C (typically for 30 to 60 minutes, depending on the product and can size) while aseptic processing technology is performed at temperatures ranging from 130-150°C (typically for several minutes, depending on the product characteristics). A shorter holding time at these higher temperatures will result in a similar sterilising effect as conventional methods.

1.2 Advantages of aseptic processing

The advantages of using aseptic processing for meat products over conventional heat processing methods include:

- improved product quality (reduced loss of flavours, aromas, natural colours or volatiles);
- energy savings;
- consumer convenience;
- new marketing opportunities; and
- bulk packaging

(Wernimont 1983; Anon 1988)

1.3 Economic considerations

Heat processed products (canned, retort-pouched, and aseptically packaged) are stored at ambient temperature, and therefore storage costs are lower than for frozen foods. Aseptically packaged products have the additional economic advantage of virtually unrestricted package size. Aseptic bulk packaging is possible as the heat process is independent of pack size, unlike conventional canning.

Energy consumption during processing, packaging, storage, and transport has been compared for aseptically packed, canned, and frozen foods. (Gadsden Rheem, 1991). Comparative data in kWh/tonne for the aseptic "Combibloc" pack and conventionally processed foods, are shown below.

	Canned Foods		Frozen Foods		Aseptic
	Steel Cans	Glass Jars	Poly Bags	Cartons	Cartons
Processing	1 860	1 860	315	315	500 (approx.)
Packaging material	3 880	6 240	1 360	1 800	2 500 (approx.)
Storage	120	120	1 740	1 740	120
Transport (500 km)	230	230	160	160	160
Consumer storage	-	-	720	720	-
Total	6 090	8 450	4 295	4 735	3 280

(Source: Gadsden Rheem, 1991)

The data indicate that conventional canning incurs the highest processing and packaging energy use, but low storage consumption. Freezing has low processing and packaging energy use, but high energy consumption during storage. Energy consumption during aseptic packaging is lower than canning but greater than freezing for processing and packaging. Energy consumption during storage is lower than freezing, and similar to canning. Toledo and Chang (1991) compared steam and electricity consumption for a product throughput of 2 275 kg/hr. Steam consumption was 0.21 kg/kg of product for canning compared with 0.14 kg/kg of product for aseptic processing. This represented a saving of $US 1-20/hr. However, electricity costs for conventional canning were negligible compared with a power consumption of 0.0374 kWh/kg for aseptic processing. This represents a comparative loss of $US 5-91/hr for aseptic processing.

Overall, aseptic packaging appears economically viable for high throughout, bulk (institutional) packs. Advantages of low steam consumption, low package cost, and high quality have to be balanced against the disadvantages of high capital cost, and high electricity usage. The economic advantages would appear to favour exported bulk aseptic particulate products. However, for retail-pack, low-volume products, conventional technology may be more economic. The final decision has to be made on a combination of economic, technical and quality considerations.

1.4 Problems with aseptic processing of meat products

Heldman (1989) has highlighted critical factors affecting aseptic processing of foods containing particulates. Factors affecting heat transfer are the particle size, shape, thermal properties of the particle (thermal conductivity and specific heat) and the thermal properties of the carrier liquid (surface or convective heat transfer coefficient). There are also various factors affecting the residence time of particles in the heat exchanger used, and the configuration of the holding tubes (length and number of bends). Lee and Singh (1991) reported that particles travelled faster than carrier liquid in a horizontal scraped surface heat exchanger, but the opposite occurred in a vertical scraped surface heat exchanger. Flow rate, mutator speed, particle size and concentration all affected residence times.

Sastry *et al* (1987) have considered microbiological problems in continuous sterilisation of low-acid (pH 4.6) foods containing particulates. The product, including particle interiors, must receive a heat process adequate to inactivate spores of *Clostridium botulinum*. There is no reliable method to measure the internal temperature of particles flowing through a heat exchanger. However, computer modelling has been used to predict particle internal temperatures during aseptic processing (McKenna and Tucker, 1991; Manvell, 1990).

An alternative way of determining the lethality of the heat sterilisation process, is to inoculate the particles with heat resistant bacterial spores before processing, and test for sterility after processing. A method of immobilising bacterial spores in calcium alginate gel has been described by Dallyn *et al* (1977), who used *Bacillus stearothermophilus* as the test organism. The gel was formed into beads containing randomly distributed spores. The organism had high heat resistance, and the beads were robust enough to withstand passage through a scraped surface heat exchanger at temperatures up to 140°C.

Sastry *et al* (1988) considered that a suitable bioindicator should be in the form of a particle, possessing at least the following necessary and/or desirable characteristics.

- Large size (about 2.5 cm), containing immobilised bacterial spores throughout the interior, and especially at the slowest heating zones.
- Geometry, thermal properties and responses similar to real food particles.
- Visual distinguishability from real particles, permitting easy recovery from processed product.
- Retention of spores without leakage through all process steps.
- Shelf-stability, (this is more a desirable, rather than necessary characteristic).
- Physical durability, possessing the ability to withstand process stresses without disintegration.

According to Murray (1985) the widespread development of particulate thermal processing has been limited by a number of constraints.

These include:

- the different penetration rates for different particulates and for the carrier liquid phase. Therefore the liquid phase is often overprocessed;
- the possibility that although harmful microorganisms are destroyed, enzymes will survive that can be detrimental to the product;
- the fragile nature of particulate products once heat treated and the difficulty in transporting such products without damage; and
- the possible separation of particulate and liquid phases either during processing or in storage prior to packaging.

The last difficulty could be overcome by processing the particulates in a liquid of higher viscosity than the desired end product and blending back with a diluent at the filling stage. The first difficulty could be overcome by processing the solid and liquid phases separately.

1.5 Processing technology

Scraped surface heat exchangers (SSHE)

Scraped surface heat exchangers will continuously process products that:

- are very heat sensitive;
- form a film on the heat exchange surface;

- are highly viscous or become highly viscous during processing; or

- have a particle size or delicacy that cannot be accommodated by other heat exchangers. Products containing up to 40% particulate content, and the particle sizes up to 20 mm can be handled. (Anon 1989)

SSHE are expensive heat exchangers to buy, operate and maintain but are the most versatile. They can effectively handle any products presently batch processed in kettles or tanks, that can be pumped. The scope of application applies to heating, cooking, cooling, freezing or aseptics. Areas within the meat industry where scraped surface heat exchanger technology can be used are gravies and slurries, ground meats, soups and stews, stroganoff, paté, meat and fish spreads, pet food and blood plasma (Day, 1970; Volan and Ziemba, 1970; Hall, 1972, Hannigan, 1983; Anon, 1989). Applications include heating to either increase shelf life or achieve sterilisation. Therefore a processor who runs a range of products might install one SSHE system because it could do the work of several other simpler systems.

The SSHE consists of concentric product and media tubes, a rotating scraper (mutator) and a suitable mutator drive. The product tube contains the product, provides a heat exchange surface and an enclosure for the mutator. The media tube contains the heating or cooling media. The mutator continuously scrapes product from the heat exchange surface. In operation, the SSHE assures rapid heat transfer to a relatively small volume of product (Anon, 1989).

Information on processing conditions is scant. Generally products are preheated to approximately 50°C before pumping through the scraped surface heat exchanger where the product is heated to 130°-150°C. Murray (1985) states that the optimum process is based on a processing temperature of approximately 130°C. This requires a sterilising time of approximately 5 min for a 20 mm particulate.

Other aseptic processing systems

Fellows (1988), and Hersom and Shore (1981) have described the "Jupiter Process" which uses a double cone heat exchanger. In a sequence of microprocessor-controlled operations, solid pieces of food are fed into the double-cone vessel, which is then rotated slowly on a horizontal axis. Steam at 206 kPa is introduced and the product is tumbled through the steam. Steam in the jacket is at the same temperature to prevent the food from burning onto the cone. Liquor is added during sterilisation to prevent damage to the solids by the tumbling action. After sterilisation the product is rapidly cooled with cold water and sterile air, and the condensate-water-stock is removed. The liquid portion of the product is sterilised separately in a plate or tubular system and added to the solids. The cone then acts as a mixer. The blended solids-liquids are discharged to an aseptic filler using an overpressure of sterile air. This avoids pumping the softened product and further reduces damage to the food. Cooking liquor from the solids is used to make sauce, to top up containers, or to inject into solids during subsequent processing.

Another system is "ohmic heating". In ohmic heating a conducting fluid is heated directly by electrical energy. An alternating current is passed from electrodes, through the fluid which is contained in a non-conducting pipe. There is sufficient resistance in the fluid for energy losses to occur, and the fluid heats evenly. This process enables solid particles to

heat as fast as liquids, thus making it possible to use high temperature short time sterilisation techniques on particulate foods (Halden *et al*, 1990). Conversion efficiencies from electrical energy to heat of greater than 90% are claimed, and particulates may be processed without shearing forces associated with some other types of heat exchangers.

Another system, the "Stork Steripart" system (Anon, 1989), allows liquid and particulate fractions to receive different heat treatments. The liquid fraction can flow at a high velocity and is subjected to a heat treatment comparable to that of a Ultra High Temperature process. The particulates, which may vary in thermal size, can be held in the main flow during preset times and are subjected to a heat treatment suited to their relevant size. The system incorporates heat exchangers with one or more "Rota-Hold" type or "Spiral-Hold" type Selective Holding Sections and operates in conjunction with an aseptic buffering/delivery system. The particulates are added to the liquid with the help of a metering system, and the blend is conveyed through the heat exchanger system by means of a positive displacement pump.

1.6 Packaging

Various types of aseptic packaging fillers are available, which can handle particulate materials. These include the "Intasept" and "Scholle" fillers which pack in laminate bags (Anderson, 1985) and the "Combibloc" filler, which packs in laminate cartons.

Foil laminates used for bulk catering service packs are sterilised by gamma irradiation. However, plastic thermoformed trays for use in retail packs would require sterilisation immediately prior to filling. Bockelmann (1985) found that extruded plastic products had microbial counts ranging from 0.3 to 10 microrganisms per 100 cm^2. On paper based laminates loads ranged form 2 to 5 microorganisms per 100 cm^2. Superheated or saturated steam could be used for sterilisation of packaging materials, and has been applied for the sterilisation of polystyrene cups.

1.7 Quality considerations

Colour

In canning, heat has to penetrate to the centre of can (the "cold" spot) to sterilise the product. Then, the heat has to be removed after processing. Low-acid foods, such as meat products require quite a severe heat process to ensure sterility. The time-temperature combinations used in heat-processing have a substantial effect on most naturally occurring pigments. In meats, the red oxymyoglobin pigment is converted to brown metmyoglobin, and purplish myoglobin is converted to red-brown myohaemochromogen. Maillard browning and caramelisation also contribute to the colour of sterilised meats. However, this is an acceptable change in cooked meats. In aseptic processing, meat pigments change colour, but there is little caramelisation or Maillard browning.

Flavour

In canned meats there are complex flavour changes (for example pyrolysis, deamination and decarboxylation of amino acids, degradation, Maillard reactions and caramelisation of

carbohydrates to furfural and hydroxymethylfurfural, and oxidation and decarboxylation of lipids). Interactions between these components produce more than 600 flavour compounds in ten chemical classes. In aseptically sterilised foods the changes are again less severe, and flavours are better retained.

Texture

In canned meats, changes in texture are caused by coagulation and a loss of water-holding capacity of proteins, which produces shrinkage and stiffening of muscle tissues. Myofibrillar protein shortening during heating results in meat toughening. Softening is caused by hydrolysis of collagen, solubilisation of the resulting gelatin, and melting and dispersion of fats through the product. Polyphosphates are added to some products to bind water. This increases the tenderness of the product and reduces shrinkage.

The relatively long time required for collagen hydrolysis and the relatively low temperature needed to prevent toughening of meat fibres are conditions found in canning but not in aseptic processing conditions. Toughening of meat is therefore likely under aseptic processing conditions (Hersom, 1984). Dawson *et al* (1991) found chicken breast meat was tougher and drier when aseptically processed at 145°C, than at 130°C and 121°C. The texture of meat purees is determined by size reduction and blending operations and is not substantially affected by aseptic processing.

Nutrition

Generally, canning results in greater nutritional losses than aseptic processing. Aseptic processing allows a substantial reduction in the time necessary to accomplish sterilisation and thus results in increased nutrient retention and food quality. Canning causes the hydrolysis of carbohydrates and lipids, but these nutrients remain available and the nutritive value of the food is not affected. Proteins are coagulated and, in canned meats, losses of amino acids are 10-20%. Reductions in lysine content are proportional to the severity of heating but rarely exceed 25%. The loss of tryotohan and, to a lesser extent, methionine, reduces the biological value of the proteins by 6-9%. Vitamin losses are mostly confined to thiamine (50-75%) and pantothenic acid (20-35%).

During storage, various changes occur including oxidative darkening, rancidity development and gradual nutrient losses. The rate of change will be affected by storage temperature, packaging material, and pack size. An advantage of aseptic processing is that bulk packaging is feasible. This means a high ratio of product to package surface area, and potentially decreased rate of changes during storage.

1.8 Industry context

Kudos Meat Products Pty Ltd, a south-east Queensland processor manufacturing frozen, chilled, and dried meat products for the domestic and export markets, is the commercial partner in this project. The company has identified markets for aseptically packaged meat and vegetable "stew" (principally for export to Japan) and aseptically packaged bolognaise sauce (principally for the domestic market). Mr Robert Beaver, a managing Director of Kudos, visited six Japanese processors in 1991.

The market in Japan which has been identified as having potential, is the quick or instant meal market. These meals are consumed at home, for lunch at hotels and in coffee shops. Two specific products are beef curry and beef stew. Currently Australian boiled beef is imported, and the products processed into 200 g retort pouch sachets for retail sale and into conventional A10 cans for food service use.

Retort-pouched beef stew sales have increased from 3 300 in 1988 to an estimated 4 850 tonnes in 1993. Retort-pouch beef curry has increased from 64 900 tonnes in 1988 to an estimated 78 200 tonnes in 1993.

A major restaurant chain has been identified as the domestic market for frozen and chilled bolognaise sauce, with a throughput of 300 tonnes in 1990/91 which has increased to 500 tonnes in 1992/93. This is projected to reach 638 tonnes in 1997/98.

Aseptically packaged products have considerable potential in the above markets, provided that their quality is as good as, or better than, the existing products.

2. PROJECT OBJECTIVES

- Establish the feasibility of scraped surface heat exchanger technology in developing meat and vegetable products which are shelf stable when aseptically packaged.

- Establish the feasibility of scraped surface heat exchanger technology in extending the shelf life of chilled meat and vegetable products for the domestic market.

- Compare the microbiological, chemical, physical and sensory attributes of products manufactured using this technology and by conventional means.

- Develop both Japanese and domestic markets for shelf stable meat and vegetable products.

- Pilot produce a range of products by the most viable aseptic processing technology.

- Present these products to selected Japanese and domestic enterprises.

3. METHODOLOGY

3.1 Thermal criteria of test thermoduric microorganisms

This experiment was aimed at establishing the heat resistance characteristics of spore-forming bacteria, which have significance in aseptically packaged meat products.

Organisms employed include *Bacillus stearothermophilus*, *Clostridium perfringens* and *Bacillus cereus*. *Clostridium botulinum* was not included because of a delay in obtaining a stock culture due to a necessity for quarantine clearance. The organisms selected were chosen for the following reasons: *Bacillus stearothermophilus* is regarded as the most heat resistant organism and criteria which would ensure its destruction would be more than adequate for other spore formers. It is, however, non pathogenic and an obligate aerobe which would restrict its ability to grow in canned or packaged food products. *Clostridium perfringens, C. botulinum and Bacillus cereus* are important spore-forming, pathogenic organisms commonly encountered in various food products. Of these, *Clostridium botulinum* would represent the most hazardous organism, not only because of its food poisoning potential, but also its ability to cause gas production and hence swelling of cans or packaged food products. Thermal criteria guaranteed to ensure destruction of this organism are commonly employed in many food products. Thermal death curves for *Bacillus stearothermophilus*, *Bacillus cereus* and *Clostridium perfringens* were plotted.

Materials and methods employed were as follows:

- Test organisms

Bacillus stearothermophilus UQM 298 was subcultured and enumerated on peptone yeast extract agar, incubated at 50°C for 2 days. Cultures for thermal death curve studies were incubated overnight in peptone yeast extract broth at 50°C.

Clostridium perfringens UGM 57 was subcultured on Oxoid cooked meat medium and enumerated using peptone yeast extract agar incubated anaerobically for 2 days at 37°C.

Bacillus cereus UGM 446 was subcultured and enumerated on peptone yeast extract agar incubated at 37°C for 24 hours.

- Electronically controlled oven

The time/temperature (T/t) treatments of *B. stearothermophilus* were conducted in the oven of a gas chromatograph model no. 3300 (Varian, Walnut Creek, co 94598, USA). The oven was fitted with a fan and temperature probe connected to a digital readout. Temperatures were set at a constant temperature for each T/t profile monitored. Samples were inserted and removed manually at each given time interval.

- Sample preparation

Forty µl of culture was drawn into 100 mm soda glass capillary tubes o.d. 1.24 mm, wall thickness 0.2 mm. The ends of the tubes were sealed by melting the glass with a bunsen flame. These tubes were placed end on in a sample rack, constructed mainly of a non

heat-conducting synthetic fibre, in front of the oven fan and temperature probe. It was assumed that the T/t profiles of both sample and oven would be similar because of the small volume of sample heated and the material and thickness of the sample tube. After heating for the desired period, samples were immediately cooled in ice water before serial dilution and pour plating, using standard methods.

The range of time/temperature exposures employed varied with the heat sensitivity of the organism in question. Minimum and maximum temperatures and times employed were 60 to 130°C and 5 sec to 30 min, respectively.

- Graphs

Graphs of the log of bacterial counts after exposure to given temperatures for various time intervals were plotted. Calculations of various parameters used in driving the required heat treatments were carried out using thermal death curves of *Bacillus stearothermophilus.*

3.2 Establishment of thermal criteria for thermoduric organisms isolated from meat and vegetable ingredients

The major ingredients of the stew product envisaged were meat, vegetables (including carrot, potato and onions) and starch. Meat, obtained from Kudos Meat Products Pty Ltd, was semi-cooked prior to arrival at the laboratory. A microbiological assessment of meat was conducted on this semi-cooked product rather than raw meat. Potatoes and carrots were blanched prior to processing and a microbiological assessment of blanched and unblanched vegetables was made. Onion was processed raw due to undesirable changes in texture which occur during blanching. Starches were also examined for the possibility of microbial contamination. Isolation and identification of organisms was conducted using standard methods. Spore suspensions for calculating thermal death curves were prepared using the following basic procedure: Broth cultures of individual organisms were grown and harvested by centrifugation; cells were resuspended in 0.15M phosphate buffer pH 7.0; vegetative cells were destroyed by heating the suspensions at 80°C for 10 minutes. The method of establishing thermal death curves was as described in 3.1.

3.3 Market and product identification

The criteria used to identify product markets and products were:

- a visit by Mr Robert Beaver, Managing Director, Kudos Meats to Japan to major food manufacturers and distributors;
- tasting of Japanese retort-pouched products brought from Japan by Mr Beaver;
- visits by technical managers of major Japanese food companies to the Kudos plant in Brisbane for discussions with Kudos management and IFIQ staff;
- discussions between a major domestic food distributor and Kudos and

- product formulation legal requirements were obtained from the Australian Food Standards Code for the domestic market.

Details on Japanese requirements for imported foods were obtained from the Trade and Investment Development Branch of the Department of the Premier, Economic and Trade Development, and JETRO (Japan External Trade Organisation). The following documents were obtained.

- Japanese Agricultural Standard for pre-cooked frozen foods AG 26.
- Jetro Short Market Surveys 1987 AGSMS-10.
- Food sanitisation in Japan AG 24.
- Guide Book to Japanese Agricultural Standards JASA 1986.
- Standards and Certification Systems in Japan.
- List of Japanese Associations of Agriculture, Fishery and Forestry AG 29.
- Meat Products in Japan AG 27.
- Brief Commentary on Japan's Laws and Regulations Relating to Food Additives 1983 AG 11.
- The Processed Foods.
- Guide to Japan Technical Regulations

3.4 Economic evaluation of aseptic packaging

A literature review to compare the costs of aseptic processing, canning, retort pouches and freezing was carried out initially.

A further evaluation of the economic feasibility was carried out in conjunction with Kudos Meat Products Pty Ltd and Mr Peter Firth of Gibson Associates. Market segment and size data for bolognaise sauce, stew, and curry particulate products was supplied by Kudos Meat Products. Estimates for supermarket chains, restaurant chains, and hospitals/institutions were made for both the Japanese and Australian markets in terms of market volume, market share, projected sales, expected selling price and sales revenue.

Manufacturing cost data (covering capital, operating, and ancillary costs) was obtained from equipment manufacturers, technical literature, freight forwarders, etc. Fixed costs covering market research and promotion/advertising were estimated by IFIQ marketing staff. Capital costs for an aseptic processing plant operating at 3 tonnes/hour were obtained from APV Baker Pty Ltd and Heat and Control Pty Ltd. Cost estimates for both a scraped surface exchanger plant, and an ohmic heating plant, were obtained. The cost of a commercial scale aseptic filler was obtained from Wrightcel Australia Ltd.

Variable costs included prices of ingredients, labour, packaging materials, import duties, delivery costs, and plant operating costs (steam, electricity, and maintenance). Ingredient costs for meat, vegetables, and other components were obtained from wholesalers, distributors, and the Brisbane Markets. Labour requirements were estimated from technical literature, and costs from Kudos. Costs of packaging materials were obtained from Wrightcel Australia Ltd. Delivery costs for ocean freight to Japan were obtained from Associated Customs Services Pty Ltd, and for domestic road freight from TNT Australian Road Freight. Data on import duties for Japan was supplied by the Japan Secretariat, Department of the Premier, Economic and Trade Development. Operating costs for steam and electricity were calculated from technical literature, and using data from SEQEB.

Market and cash flow spreadsheet projections to the year 2 000 were calculated by Peter Firth, based on the above estimates.

3.5 Product and process development (conventional technologies)

Formulations

A confidential commercial bolognaise formulation was obtained from Kudos Meat Products Pty Ltd. A meat and vegetable stew product was formulated to comply with the identified criteria. This is shown in Table 1.

Table 1 Meat and vegetable stew formulation

Component	% W/W
Meat cubes	20
Potato cubes	10
Onion pieces	5
Carrot cubes	5
Starch - Fieldclear 714	3
Starch - Mazacca 3401x	3
Soy sauce	2
Beef stock (cubes)	0.225
Salt	0.2
Garlic powder	0.2
Pepper	0.01
Water	51.36

Process development

Flow diagrams for canned and retort-pouched products are shown in Figure 1. Process flow sheets for frozen and chilled stew are shown in Figure 2.

- The formulation for a meat and vegetable stew was modified to ensure freeze - thaw stability of the stew. Freezing rate was determined by insertion of thermocouples into the centres of 2 kg bags, and monitoring temperature until through the latent heat period.

- Chilled stew and bolognaise products were prepared according to the US "Capkold 50" process. The process involves hot-filling into Cryovac bags, and tumbling in water at 1°C to rapidly chill the product (to 4°C in less than one hour for a 7.5 L bag). In order to simulate this process, stew was formulated as described for the frozen product, and hot-filled at 85°C into Cryovac bags. Bags were placed into a mixer tank with baffles, and filled with chilled water at 1°C. The mixer agitation was sufficient to ensure a tumbling motion of the bags, without damaging them. Water at 1°C was continuously pumped in, to ensure a constant temperature.

- For canning, the process time was determined by measuring heat penetration in several cans (size = 307 x 309). Thermocouples, attached to a digital thermometer, were inserted through the can walls, into meat cubes at the centres of cans. The thermocouples were held in place with a metal plug and rubber washers, and sealed with "Araldite" adhesive. Cans were then retorted at 121°C for 80 minutes and temperatures at the can centres were recorded. Temperatures were converted into lethality units, using appropriate Tables (Fellows, 1988). Temperature-time and lethality-time curves were plotted.

- Retort-pouched products were prepared by filling stew into 1 kg retort pouches. Pouches were supported in metal holders (20 cm x 28 cm x 2 cm) with 9 mm holes, 5 mm apart. Thermocouples were inserted into several pouches as described for canning, to monitor heat penetration. Pouches were sealed, placed in holders and retorted in water, with an air overpressure. They were processed at 121°C for 30 minutes, followed by pressure cooling. Temperature-time and lethality-time curves were plotted.

Quality of the products was determined by examining the appearance and integrity of the particles, and assessing flavour and texture, after processing. Formal sensory assessment of the canned and frozen stews was carried out, using a panel of 34 IFIQ staff members. Stew was warmed in a microwave oven, and served at 85°C in white bowls. Appearance criteria were rated under white light, while flavour and texture were assessed under red lights. The panel was asked to score samples for overall appearance, meat particle size, vegetable texture, sauce consistency, and overall acceptability. A specimen score sheet is shown in Figure 3.

The stability of the starch-based "sauce" was assessed as follows:

Starch solutions of equal amounts of Mazaca 3401 and Fieldclear 714 were prepared in three concentrations 1% + 1%, 3% + 3%, and 5% + 5%. Solutions were heated to 80°C to ensure gelatinisation. Sub-samples were canned and retorted at 121°C for 45 minutes,

and blast-frozen at -30°C. Viscosities were measured (at 20°C) with a Brookfield Spindle Viscometer, and expressed in centipoise (Spindle LVF#3, Rotation speed 20 rpm).

FIGURE 1: CANNED AND RETORT POUCH STEWS

PROCESS FLOW SHEET

(A) Component Preparation

(i) Sauce

6% starch + water → steam kettle (80°C) → salt, pepper, garlic, soy sauce, beef stock → mixing

(ii) Meat (ex Kudos Meats)

brisket → cooker → dicer($10mm^3$)

(iii) Vegetables

onions, carrots, potatoes → washer → abrasive peeler → onions to slicer; dicer ($10mm^3$) (3 mins) → steam blancher

(B) Processing Operations

meat cubes (20%) → mixing tank ← sauce (60%); ↑ vegetable cubes (20%) → jacketed steam kettle (cooking) → hot filling (90°C)

- cans (450g) → closer → retort (121°C/steam) → pressure cooling
- retort pouches (1kg) → heat sealer → retort (121°C/water with air over-pressure) → pressure cooling

Figure 2 FROZEN AND CHILLED STEW

PROCESS FLOW SHEET

(A) Component Preparation

(i) sauce

5% starch + water → steam kettle (80°C) → salt, pepper, garlic, soy sauce, beef stock → mixing

(ii) meat (ex Kudos Meats)

Brisket → Cooker → dicer (10 mm^3)

(iii) vegetables

Onions, Carrots, Potatoes → washer → abrasive peeler → onions to slicer; dicer (10 mm^3) → steam blancher (3 mins)

(B) Processing Operations

Meat Cubes (10%) → Mixing tank ← Sauce (60%); Vegetable cubes (30%) → Jacketed Steam kettle (cooking) → Bag filling → Heat sealing → Tumble Chilling (3°C) → Chilled Storage (1°C); Blast freezing (-30°C) → Frozen storage (-18°C)

Figure 3

IFIQ BEEF CASSEROLE SCORESHEET

Please assess the beef casserole for appearance, eating quality and overall acceptability. PUT A VERTICAL MARK THROUGH EACH HORIZONTAL SCALE TO MARK YOUR ASSESSMENT OF EACH ATTRIBUTE.

APPEARANCE

1. OVERALL APPEARANCE — Dislike extremely / Like extremely
2. MEAT SIZE — Too small / Too big
3. VEG SIZE — Too small / Too big
4. SAUCE COLOUR — Too light / Too dark
5. SOLIDS/SAUCE RATIO — Too low / Too high

EATING QUALITY

6. FLAVOUR — Dislike extremely / Like extremely
7. MEAT TEXTURE — Too tender / Too tough
8. VEG TEXTURE — Too soft / Too hard
9. SAUCE CONSISTENCY — Too thin / Too thick

OVERALL

10. ACCEPTABILITY — Dislike extremely / Like extremely

COMMENTS .....

.....

.....

.....

Name..... Date..... Time.....

CASS-R-1

3.6 Quality assessment methods development

Preparation of sodium alginate gels with imbedded spores of *Bacillus stearothermophilus*

Bacillus stearothermophilus has a greater thermal tolerance than any of the commonly occurring *Bacillus* species from meat, vegetable and starch ingredients. It was therefore decided to attempt embedding *Bacillus stearothermophilus* spores in a sodium alginate gel. Ideally, the gel could be cut to approximately the size of food particles and passed in a stew mixture through the heat sterilisation process. Particles would then be recovered post processing to test for spore survival.

- Spore preparation

Bacillus stearothermophilus was grown in broth culture for 3-5 days at 55°C and harvested by centrifugation. Cells were resuspended in 0.15 M phosphate buffer pH 7.0, vegetative cells were destroyed by heating this suspensions at 80°C for 10 minutes.

- Gel preparation

Gels were prepared by dissolving sodium alginate (3%), Oxoid agar no. 1 (1%) and methylene blue dye (0.01%). This mixture was sterilised by autoclaving and allowed to cool to approximately 70°C. At this stage, measured quantities of spore suspensions were added to give a final spore concentration of approximately 10^4/g. The gel mixture was then poured into moulds and allowed to cool to room temperature. Sodium alginate gel does not set at room temperature, but the agar component of the mixture did form a solid gel at this concentration. The set gel was then cut to the desired dimensions and placed in a 2% calcium chloride solution to cure the sodium alginate component of the gel matrix. The gel was stored at 5°C suspended in sterilised distilled water.

- Recovery of spores from the gel

Two methods of homogenising the gel were tested; using a Sorvall Omni Mixer and a Colwell stomacher. Several types of homogenising media including 0.1% peptone, 2% sodium citrate, ¼ strength Ringers solution, 0.85% sodium chloride and Tween 80 were tested. Gel particles were homogenised for various time intervals, the resultant suspension was diluted serially, and pour-plated in nutrient agar. Spore counts were expressed in colony forming units per gram of gel.

Development of the thiobarbituric acid test (TBA)

The thiobarbituric acid test has been used as a measure of the oxidative deterioration of meat products. (Witte 1970, Vyncke 1970).

Different methods for the determination of TBA values are reported in the literature. Hence comparisons between laboratories using different methods is difficult. Two basic methods exist, a distillation method and an extraction method. The approach that was followed in these investigations was that of an extraction method, in which distillation apparatus is not required.

The following is a modification of the method used by Witte, *et al.*, (1970), with use of E.D.T.A. and propyl gallate as recommended by Vyncke (1970).

- 20 $\pm$ 0.05 g blended stew was weighed into a Sorvall Omni Mixer container (100 mL).

- 50.0 mL of 20% trichloroacetic acid (TCA) solution in 2 M orthophosphoric acid (H_3PO_4), containing 0.1% disodium ethylene diamine tetraacetic acid (Na_2EDTA) and 0.1% propyl gallate (PG) was added.

- This was blended at speed "4" for 1.5 minutes using a Sorvall Omni-Mixer, with the blending vessel (stainless steel) partially immersed in an ice water bath.

- The mixture was then filtered through Whatman No. 1 filter paper into a plastic specimen bottle (70 mL).

- 5 mL filtrate was mixed with 5 mL of 0.01 M thiobartituric acid (TBA) (0.144 g/100 mL of distilled water) in a capped test tube by inversion.

- After storage in the dark for 17 hours, the sample was read at 532 nm, and a standard curve was prepared.

Preparation of standard curve was as follows.

- 0.2 to 0.3 g of 1, 1, 3, 3 - tetraethoxypropane (TEP) was weighed into a tared 25 mL volumetric flask - A* and the weight recorded to four decimal places.

- Standard A was diluted 1:100 (1 mL in 100 mL volumetric flask) - B*.

- Standard B was diluted 1:1000 (1 mL in 100 mL volumetric flask) or 2: 100 depending on the anticipated malonaldehyde concentration of the samples - C*.

* The diluent was 20% TCA in 2M H_3PO_4, containing 0.1% Na_2EDTA and 0.1% PG.

- 0, 1.0, 2.0, 3.0, 4.0, 5.0 mL standard C was mixed with 5.0, 4.0, 3.0, 2.0, 1.0, 0.0 mL 20% TCA in 2M H_3PO_4, containing 0.1% Na_2EDTA and 0.1% PG, respectively to give a total volume of 5 mL and then 5 mL 0.01M TBA was added. The test tubes were capped and mixed by inversion (x3).

Determination of recovery was as follows.

(i) 0.1 mL of standard B was added to a 200 mL volumetric flask and made up to the mark with 20% TCA in 2M H_3PO_4, containing 0.1% Na_2EDTA and 0.1% PG.

(ii) 2.0 mL of standard B was added to a 200 mL volumetric flask made up to the mark as above.

(iii) 3.0 mL of standard B was added to a 200 mL volumetric flask and made up to the mark as above.

(iv) The solutions prepared in (i), (ii) and (iii) were used to extract portions of the sample as in 1 and proceed through 1 to 7.

(v) % recovery was calculated from the following formula for each of (i), (ii) and (iii) and average the result.

- Formulae

$$R = \frac{\text{TBA (meat in TEP containing TCA solution)} - \text{TBA (meat in ordinary TCA solution)}}{\text{TBA (added)}} \times 100$$

R = % recovery

(100% Recovery) TBA g/100g = Fx (Equivalent mL from standard curve) x Standard curve g/mL)

$$F = \frac{\text{Total Volume}}{5} \times \frac{1}{20} \times 100$$

Total Volume = mL solution + mass of meat x moisture

TBA (added) = (Standard B) x (volume) x 5 (µg/100g)

$$\text{Actual TBA} = (100\%\ \text{Recovery})\ \text{TBA} \times \frac{100}{R}\ \mu g/100g$$

$$\text{MA value} = \frac{\text{Actual TBA}}{100}\ mg/kg$$

NOTE: Triplicate determinations on meat samples were performed, with each extract being tested in duplicate. Standard solutions were also tested at least in duplicate. A line of best fit was determined by means of a programmable calculator, and the values obtained used to calculate the "equivalent mLs".

3.7 Development of aseptically packaged products

- Equipment development

Discussions were held with several visiting technical experts, regarding equipment aspects of this project. Meetings were held with:

- Mr Chuck Meek, Sales Engineer, Cherry-Burrell Process Equipment, USA (scraped-surface heat exchangers);
- Mr Ian Anderson, Technical Manager, Wrightcel Australia Ltd (Aseptic filling equipment);
- Mr Adam Anderson, International Sales Manager, Marlen Research Corporation, USA (pumps for particulate products);
- Mr Wolfgang Duller, Product Manager - meat and seafood systems, Heat and Control Pty Ltd, Brisbane (scraped-surface heat exchangers and particulate pumps);
- Mr Ron Gilhome, Executive Director Sales, Scholle Industries Pty Ltd, Sydney (aseptic filling equipment);
- Dr Giulia Boerio, Area Manager, Bertuzzi Corporation, Italy (scraped surface heat exchangers and aseptic systems);
- Mr Ron Lindsell, General Manager - process engineering , APV Baker Pty Ltd, Melbourne (Heat exchangers);
- Mr James Cunich, General Manager - sales and marketing, Heat and Control Pty Ltd, Brisbane (scraped surface heat exchangers);
- Mr John Pain, Engineer, Functional Design, Melbourne (Tubular heat exchangers); and
- Mr Kel Cranston, Branch Manager, Alfa-Laval Engineering Pty Ltd, Brisbane (tubular heat exchangers)

The existing pilot plant equipment for aseptic processing of fruit purees consisted of a Cherry-Burrell scraped surface heat exchanger, Spiroflo tubular heat exchangers and a mono pump. This was augmented with a second Cherry-Burrell scraped surface heat exchanger, Waukesha model 16 and model 30 lobe pumps, wider holding pipes, back-pressure valve, pressure relief valves, temperature controller, and an Intasept "Pilot 32" aseptic bag filling machine. The layout of the aseptic processing line is shown in Figure 4 and major equipment in Figures 5, 6 and 7. The general procedure for each run was as follows.

> The system was pre-sterilised with water which was heated in the scraped surface heat exchangers to a minimum of 130°C, and circulated with no coolant flowing in the Spiroflo heat exchangers. During pre-sterilisation, with water the pressure in

the system was maintained with a pressure relief valve while a back-pressure pump was used to control product pressure.

Tap water was circulated through a single stage Spiroflo heat exchanger at the end of the line, to prevent steam "flashing" hot water.

The product was mixed and pre-heated to 60°C in a hot water-jacketed product feed tank. It was then pumped with a Waukesha pump through both scraped surface heat exchangers, with the product reaching a temperature of at least 130°C after the second stage. The product then flowed through insulated holding tubes (4 x 3 metres) to achieve the desired holding time, and was then cooled in a 3-stage Spiroflo heat exchanger, to ambient temperature (using water at 3°C as the coolant). Product then flowed through a second Waukesha pump, which maintained a back pressure in the system. Finally, it entered the Intasept filler and was aseptically packaged into sterile 5L nylon-foil laminate bags. In-between bags, the product flowed through a back-pressure valve, which opened and closed in sequence with the filler (i.e. the valve opened when the filler closed, and vice versa).

The system was cleaned by circulating detergent (U.I.M. "Cyclopower") through the system with a centrifugal pump. The filler had a CIP cycle, which ensured that all parts of the filling head were adequately cleaned. Lobe pumps were removed from the line, and cleaned manually, as they obstructed the flow of detergent during CIP.

Figure 4 Aseptic Processing Line

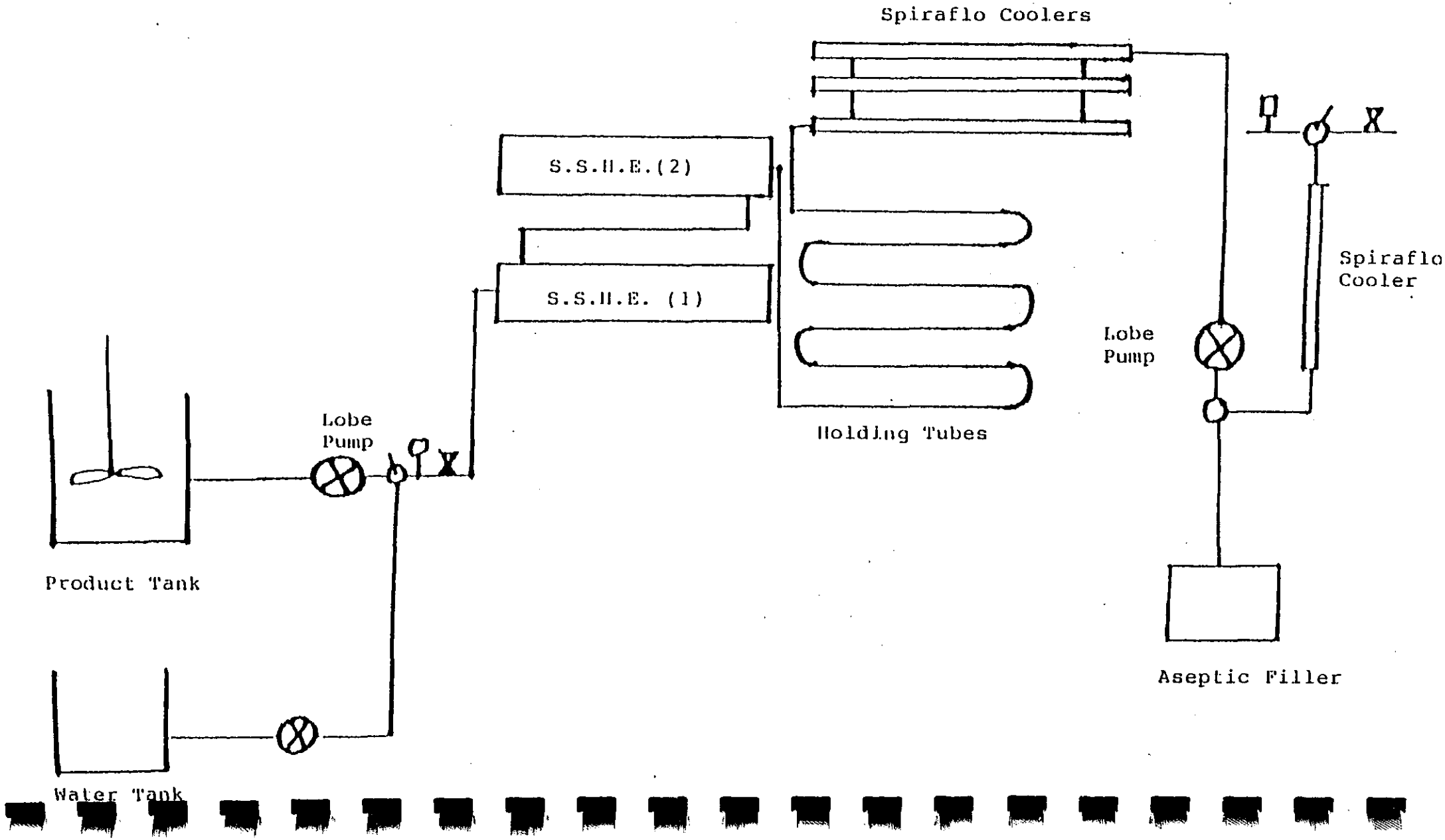


Figure 5 Scraped surface heat exchangers

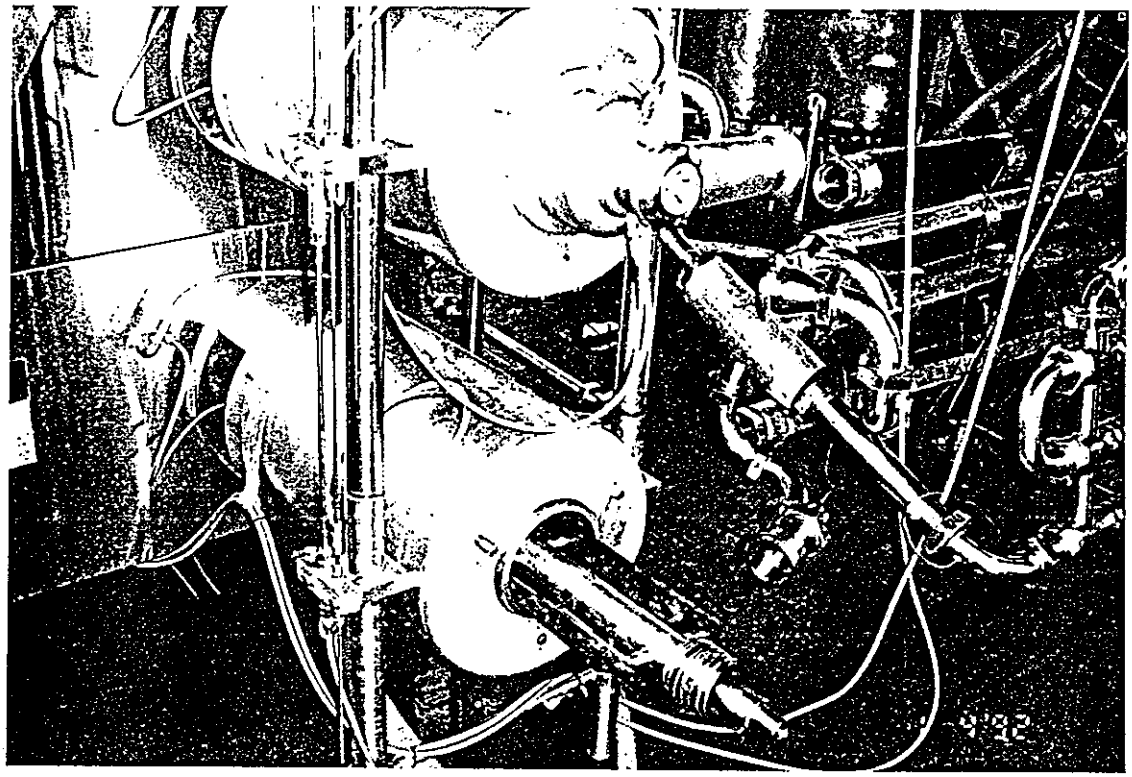


Figure 6 Intasept aseptic bag filler

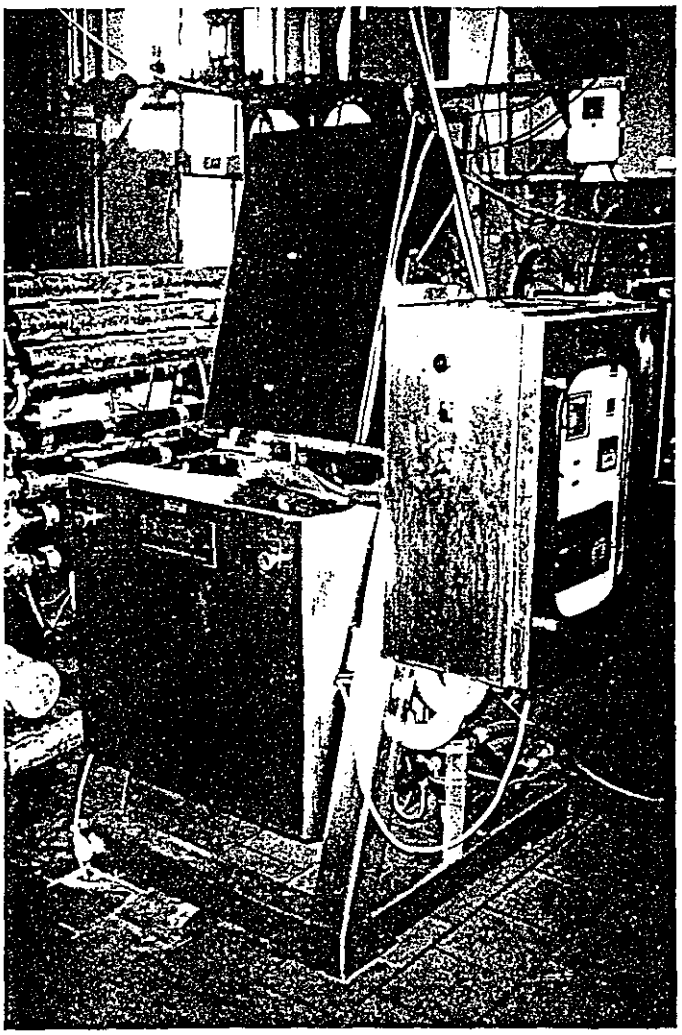
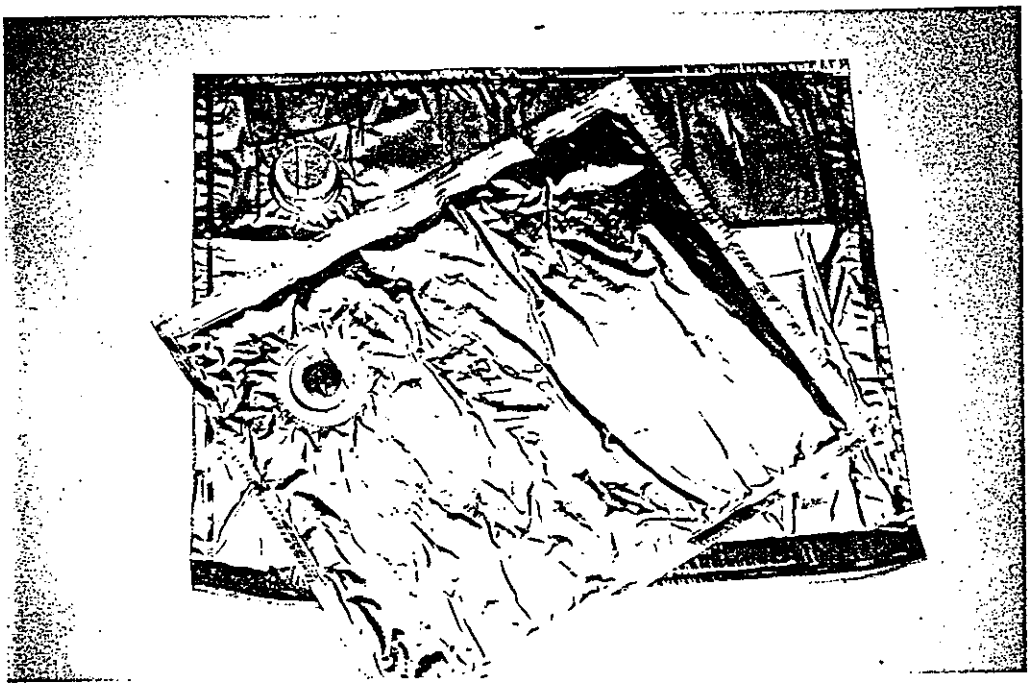
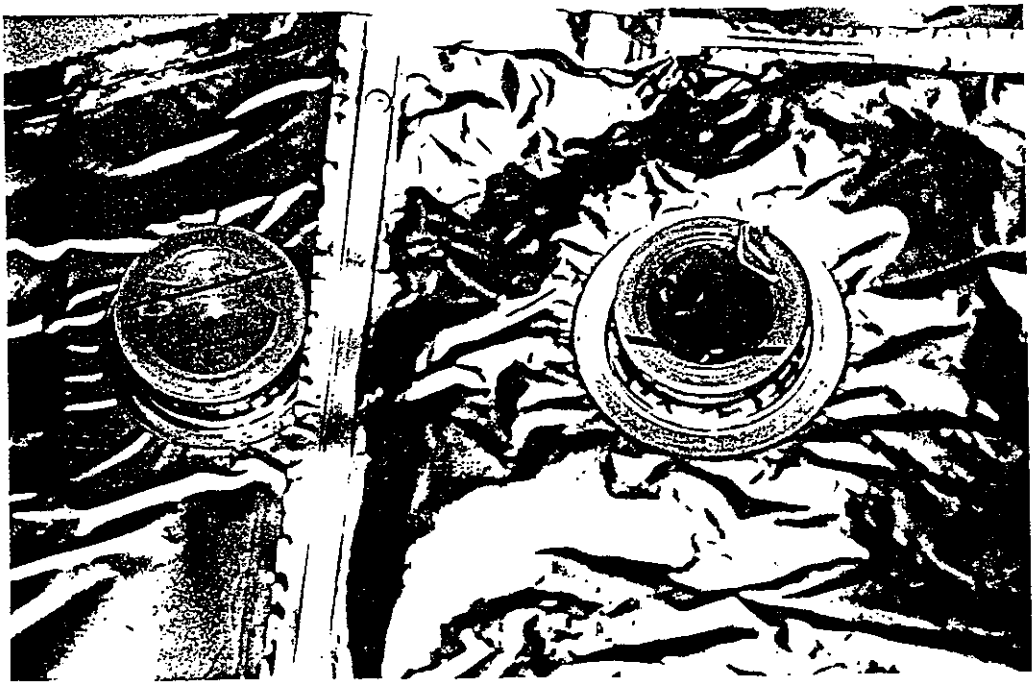


Figure 7 Intasept bags





Process monitoring was performed as follows.

- Pressures were measured with sanitary pressure gauges (with diaphragms to prevent particles becoming trapped) before the scraped surface heat exchangers, and after the back pressure pump at the end of the line.

- Temperatures were measured with thermocouples inserted into ports located after each scraped surface heat exchanger, the holding tube, the Spiroflo cooling heat exchanger and the back pressure pump. The readings were stored in an Anritsu 7001 data logger, and subsequently transmitted to a PC for graphing and printing. In addition, pre-sterilising temperatures at the filler head were read from the filler control panel.

- Flow rates in litres/minute were measured by timing the flow at the end of the line into a tared bucket, and weighing.

- A number of preliminary runs were carried out on water bolognaise sauce and a model "stew" of starch and potato cubes to test the system and determine whether the required operating conditions could be achieved.

Aseptically packaged bolognaise sauce

This trial was set up to compare bolognaise sauce processed in three forms: aseptically packaged (3.5 minutes at 130°C), canned, and frozen. Aseptic and canned samples were stored at 4°C and 25°C. Frozen bolognaise was stored at -18°C. Samples were examined immediately after processing, after 6 weeks at 4°C, and after 6 months at 25°C. Treatments were replicated over seven batches of bolognaise. Process conditions for the aseptically packaged products were as follows:

Presterilisation = 130°C/5 mins with water
Batch size = 180 kg
Feed temperature = 60°C
Flow rate = 6.24L/min
Steam pressure to SSHE = 500 kPa
Back pressure = 300 kPa
Product temperature = 130°C (3.5 mins holding time)
Product temperature after cooling = 30°C
Mutator speed = 150 rpm
Filler = Intasept aseptic filler
Bag Type = nylon foil laminate

A process sufficient to ensure adequate safety requires 12 decimal reductions of *Clostridium botulinum* spores. From earlier microbiological work, a 1D process = 0.2 min at 130°C. Therefore 12D = 2.4 mins at 130°C. To allow for heat penetration into bolognaise particles, an additional minute was added to the holding time. The process of 3.5 minutes at 130°C is 17.5D (for *Clostridium bolulinum*) or 3.5D (for *Bacillus stearothermophilus*. This gives a F_o = 27.1, for the liquid phase of the product.

For canning, bolognaise sauce from each replicate batch was hot filled into lacquered 307 x 309 cans, closed, and sterilised in a pilot scale retort for 80 minutes at 121°C. Cans were pressure cooled, dried and labelled.

For freezing, the bolognaise sauce was filled into 2 kg polythene bags, heat sealed and placed in a cross-draft blast freezer for 90 minutes at -30°C. Samples were then stored in a room at -18°C.

Quality of the products was measured as follows.

- pH

pH was measured with a "Metrohm" pH meter with glass and calomel electrodes.

- Colour

The colour of bolognaise (600 mL sample) was measured with a "Labscan" Hunter colour difference meter with a 44 mm diameter aperture. Results were expressed as L (brightness), a (redness), and b (yellowness). An average of 5 readings was recorded, with the beaker rotated between readings.

- Particle content

Bolognaise (100 g) was poured onto a weighed screen (2 mm mesh). The sauce was washed off with tap water, the particles were drained for 2 minutes, and weighed. The particle weight was expressed as a percentage of the sample weight. The washed particles were examined for physical integrity.

- Microbiological assessments

Each bag was shaken to mix the contents, swabbed with ethanol, and flamed to sterilise the surface. They were then placed inside a sterile transfer cabinet and cut open with sterile scissors. Samples of the product were removed with a sterile spoon, and weighed (1g) into sterile petrie dishes, in duplicate. Ten-fold dilutions were also made in sterile peptone water.

Aerobic plate counts were determined by the pour plate method, with nutrient agar. Plates were counted after incubation for 48 hours at 30°C for aerobic mesophiles.

Aerobic mesophilic plate counts were determined with pour plates of reinforced Clostridial agar, overlaid with 5 mL of agar. Plates were counted after incubation in an anerobic jar, with a gas pack and catalyst, for 48 hours at 30°C. Colonies which grew were Gram stained, and examined microscopically. Any bacteria exhibiting Gram positive rods with spores, were identified as *Clostridium* sp.

- Sensory assessment

Bolognaise samples, heated and held at 85°C in a bain maree, were assessed by a panel of 18 IFIQ staff. Flavour and textural parameters were assessed under dim red lights, to mask any colour differences. Colour and appearance were scored under white light.

The panel was asked to score samples for bolognaise flavour, saltiness, other flavours, sauce consistency, colour, particle size and general appearance. A specimen score sheet is shown in Figure 8.

Chilled pasteurised bolognaise

Chilled pasteurised bolognaise sauce was prepared by both aseptic packaging and hot filling. Process conditions for the aseptically packaged product were as follows:

Presterilisation	= 125°C/30 mins
Batch size	= 160 kg
Feed temperature	= 30°C
Flow rate	= 5.4L/min
Steam pressure to SSHE	= 500 KPa
Back pressure	= 250 KPa
Product temperature	= 80°C at end of holding tube (4.26 mins holding time)
Product temperature after cooling	= 15°C
Mutator speed	= 150 rpm
Filler	= Intasept aseptic filler
Bag type	= Nylon-foil laminate

For hot-filling, the "Capbold 50" process was simulated as previously outlined. Bolognaise was heated in a steam-jacketed pan to 85°C, hot-filled into Cryovac bags and tumbled in water at 1°C for 60 minutes. Samples from both processes were stored at 4°C, and examined after 0, 1, 2, 3 and 4 weeks. Quality was measured by recording colour (L, a, b), and microbiological counts. In addition, odour was assessed by four of the researchers, and consistency was measured with a Bostwick Consistometer. The instrument was levelled, filled with bolognaise, and the "gate" opened. The distance travelled after one minute was recorded. (The greater the consistency, the lower the reading).

Aseptically packaged stew

Preliminary pumping trial

This trial was conducted before all of the equipment in Figure 4 was available. It was aimed at providing preliminary information on stew pumping characteristics.

A model stew was used as the product for pumping. The product formulation was meat (20%), potato (15%), carrot (10%), onion (5%) and starch-based sauce (50% w/w.). Potato and carrot were diced (12 x 12 x 2 mm) and steam blanched. Each onion was cut into 16 segments. Meat was supplied by Kudos Meat Products Pty Ltd as 12 x 12 x 15

Figure 8

FIQ BOLOGNAISE SAUCE SCORESHEET

Please taste the samples in the order shown below and rate them for the listed attributes. Fill in the ranking section and then take your scoresheet into the kitchen to rate appearance.

SAMPLE ORDER:-1. _____ 2. _____ 3. _____

FLAVOUR

4. BOLOGNAISE — None — V.high

5. SALTINESS — None — V.high

6. OTHER(Describe) — None — V.high

Other:- _____

MOUTHFEEL

7. SAUCE CONSISTENCY — V. thin — Ideal — V. thick

8. Rank the samples in order of preference (1 = most liked).

Rank	1	2	3
Sample code			

NOW please take this scoresheet into the kitchen and rate the samples for APPEARANCE. Then rank them again .

9. COLOUR — Unacceptable — V. acceptable

10. PARTICLE SIZE — V. small — Ideal — V. big

11. GENERAL APPEARANCE — Unacceptable — V. acceptable

12. Rank the samples in order of preference (OVERALL)

Rank	1	2	3
Sample code			

COMMENTS _____

_____

_____

_____

Taster number _____ Date _____ Time

mm cubes (clod, flank, brisket) and 1 x 27 x 80 mm strips (rib meat).

Each meat type was supplied in a raw and a cooked (boiled) form. The sauce comprised a 5% solution of Maps 40 (Goodman Fielder Starches). The sauce was gelatinised to obtain higher viscosity before use in the product.

- Processing equipment

A feed tank was connected by 35 mm internal diameter piping to a Waukesha Model 30 rotary pump fitted with twin alloy rotors. The pump was set at a flow rate of 5L/min (based on water flow).

- Experimental design

Experimental variables for the cubed meat trial were meat type (3), meat form (2) and sauce temperature (2). For the meat strip trial, experimental variables were meat form (2) and sauce temperature (2). Treatments are summarised in Table 2.

Table 2 Pumping variables

Treatment	Meat type	Meat form	Sauce temperature (°C)
A	clod	raw	50
B	clod	raw	60
C	flank	raw	50
D	flank	raw	60
E	brisket	raw	50
F	brisket	raw	60
G	clod	cooked	50
H	clod	cooked	60
I	flank	cooked	50
J	flank	cooked	60
K	brisket	cooked	50
L	brisket	cooked	60
M	rib	raw	50
N	rib	raw	60
O	rib	cooked	50
P	rib	cooked	60

- Measurements

Size distribution - the average meat particulate size for each meat type and form was determined by randomly selecting 18 particulates, measuring the sides of each particulate as indicated, and determining the average.

To determine if particulates were significantly larger or smaller than the dice and strip specification, the following statistical formula was used.

$$\frac{x-u}{SE} > t_{n-1} \quad (P<0.025)$$

It was assumed that for cubed meat the size specification for measurements 1, 3, 4, and 5 was 12 mm and for measurement 2, 15 mm. For strip meat, the specification for measurements 1 and 3 was 27 mm, for measurement 2, 80 mm and for measurements 4 and 5, 1 mm. The ratio of sauce to particulates, and of meat to vegetables was determined by separating the components and weighing. Particulate integrity was assessed visually on the drained particulates after pumping.

Aseptically packaged stew

Test runs on a model "stew" (made of gelatinised starch solution and potato cubes) were carried out using the complete aseptic processing line.

Run 1 Effect of particle concentration

Formulations were (A) 40% 8 mm potato cubes + 3% Fieldclear 714 + 3% Mazacca 3543 x and (B) 30% 8 mm potato cubes + 3% Fieldclear 714 + 3% Mazacca 3543 x. In both cases, the starch was first gelatinised in the feed tank by heating to 70°C, prior to mixing in the potato cubes. The "stew" was then pumped through the system (without steam heating in the scraped surface heat exchangers).

Run 2 Effect of starch concentration

Formulations were (A) 30% 8 mm potato cubes + 2% Fieldclear 714 + 2% Mazacca 3543 x and (B) 30% 8 mm potato cubes + 3% Fieldclear 714 + 3% Mazacca 3543 x. Operating conditions were as described above.

Run 3 Effect of the back-pressure pump and bag filler

The formulation used was 30% 8 mm potato cubes + 3% Fieldclear 714 + 3% Mazacca 3543 x. This was pumped through the system without heating. Several bags were filled with the Intasept filler, and pipes were opened at several points in the line to examine the potato cubes.

Run 4 Effect of changing from water to product

Water was first circulated through the system with a mono pump to simulate normal presterilisation. "Stew" was then pumped through with a lobe pump. Back pressure for the water was controlled with a pressure relief valve.

Run 5 Effect of heating and cooling

This run was aimed at testing the effect of heating the "stew" to 130°C, holding and cooling to ambient temperature. Coolant was circulated through the Spiroflo heat exchanger before steam was admitted to the scraped surface heat exchangers.

4. RESULTS AND DISCUSSION

4.1 Thermal criteria of test thermoduric microorganisms

Graphs of the log of bacterial counts after exposure to a given temperature for various time intervals are presented in Figures 9 to 11. Calculations of various parameters used in deriving the required heat treatment for various food products were carried out using the thermal death curves of *Bacillus stearothermophilus*.

The suspending medium was at pH 5.0, although different thermal tolerances could be expected to occur at different pH values. Decimal reduction times (D values) i.e., the time necessary at a specific temperature to reduce the number of organisms to one tenth of the original count were as follows: 100°C, 162 sec; 110°C, 3.3 sec; 120°C 1.8 sec. Values for *Clostridium perfringens* and *Bacillus cereus* at 100°C were 1.7 sec and 0.66 sec respectively.

The D value is also influenced by a number of variables including pH. At a pH of 5.0 the reduction in counts of *B. stearothermophilus* at 130°C and higher was too rapid to allow an accurate determination. If the concentration of a particular organism in a product and its D values, for various temperatures, were known, this parameter could be used to calculate a minimum time/temperature treatment to ensure elimination of this organism.

From the thermal death curves presented, a number of different parameters used to calculate T/t exposures for various foods were calculated. These included:

F value. This represents the time needed to reduce a given initial plate count to a given final plate count. For *Bacillus stearothermophilus*, the F values for reducing the count from 10^3/mL to zero were as follows:

F at 100°C 486 sec
F at 110°C 9.9 sec
F at 120°C 5.4 sec

The F value can also be expressed as a number of D values, in this case 3.

Lethality factor (r). This denotes the contribution to the total lethality per minute at a given temperature.

$r = 1/F$

r at 100°C = 1/8.1 = 0.123
r at 110°C = 1/.165 = 6.06
r at 120°C = 1/.09 = 11.1

i.e. for a count of 10^3/mL of *Bacillus stearothermphilus* under these conditions, 1 min at 100°C would result in the destruction of 0.123 of the population; 1 min at 110°C 6.06 times the population present and 1 min at 120°C 11.1 times the population present.

Figure 9 Log cfu/ml Bacillus stearothermophilus vs time at 90, and 100°C

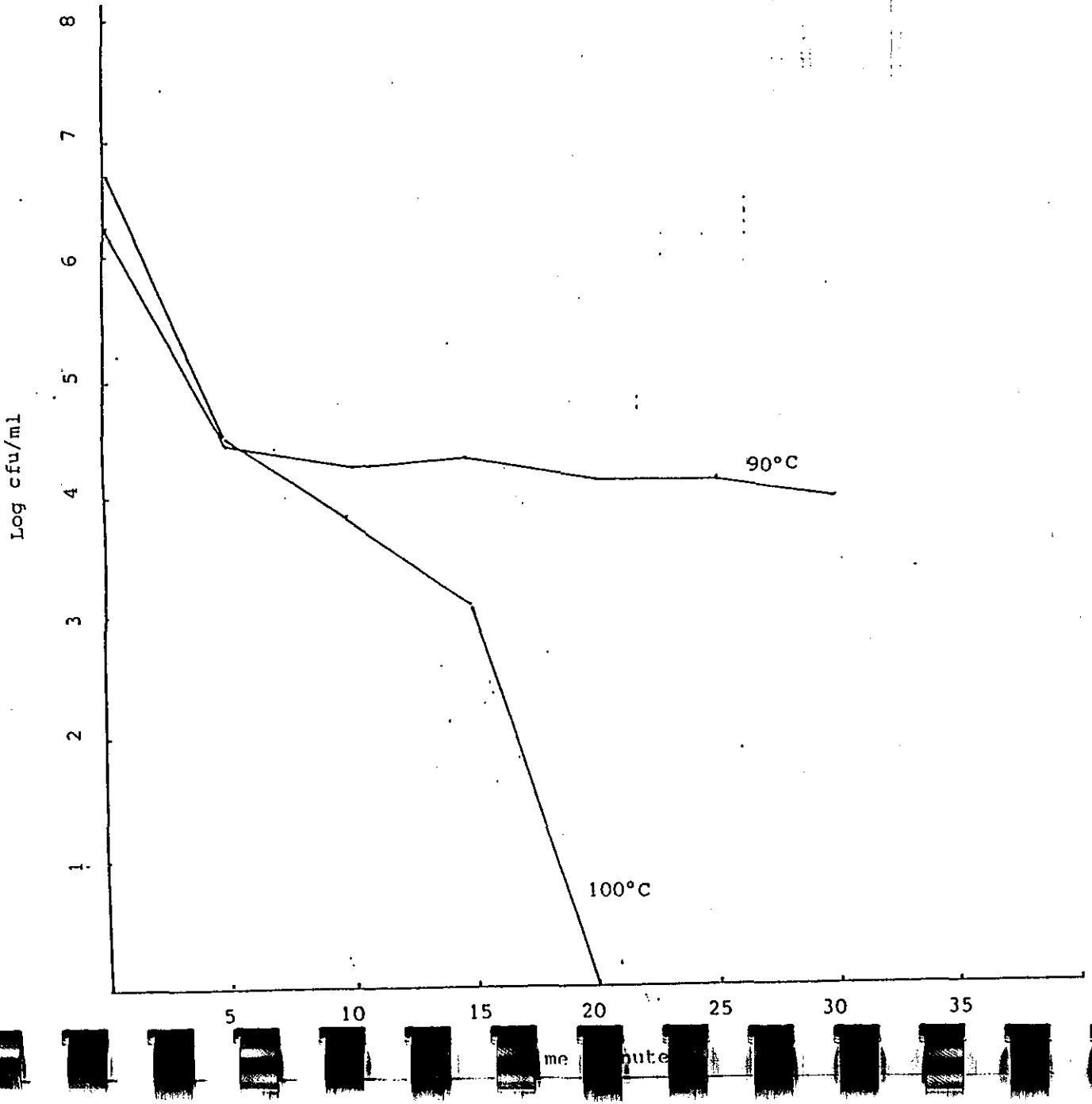


Figure 10 Log cfu/ml Bacillus stearothermophilus vs time at 110 and 120°C

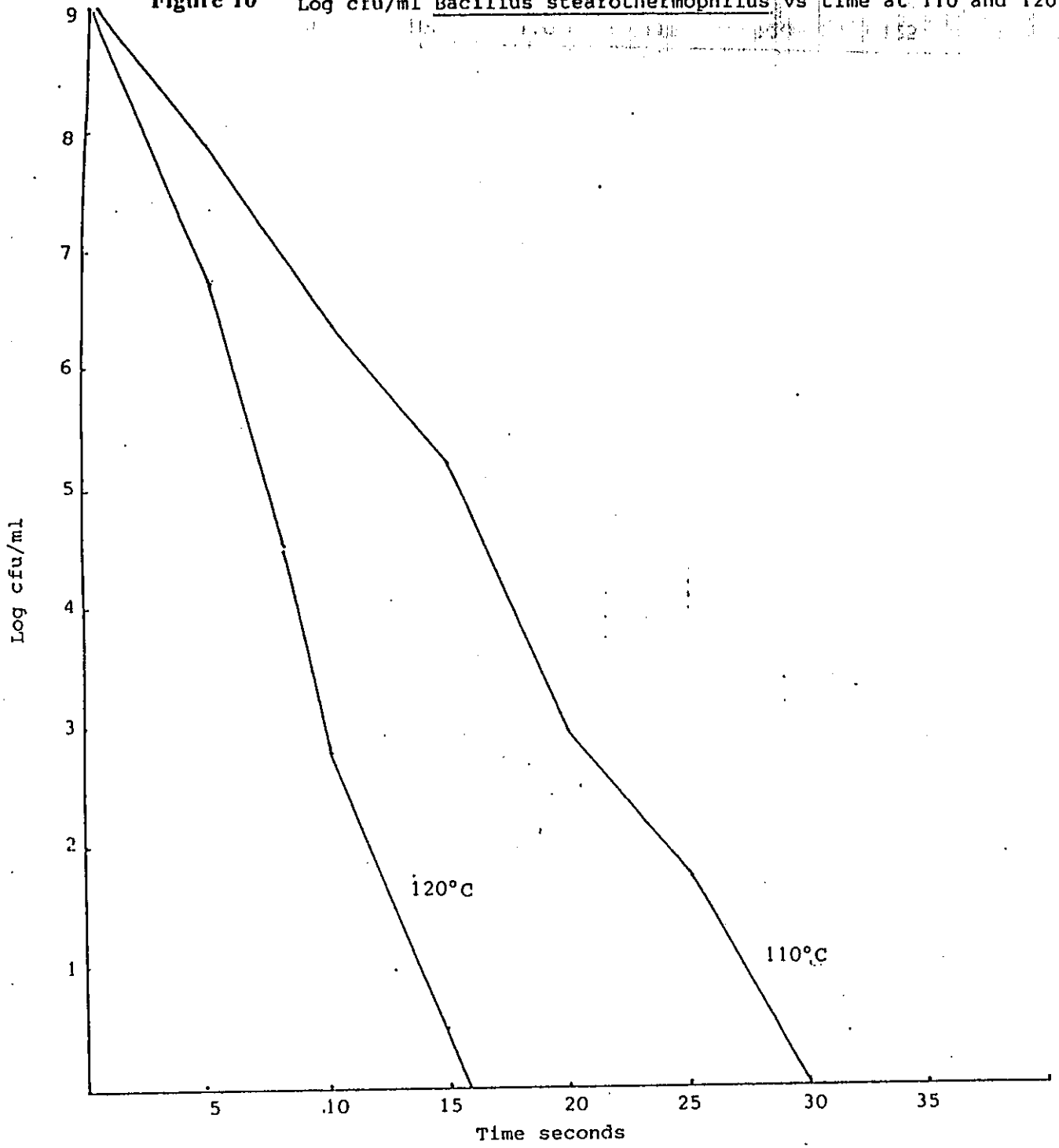
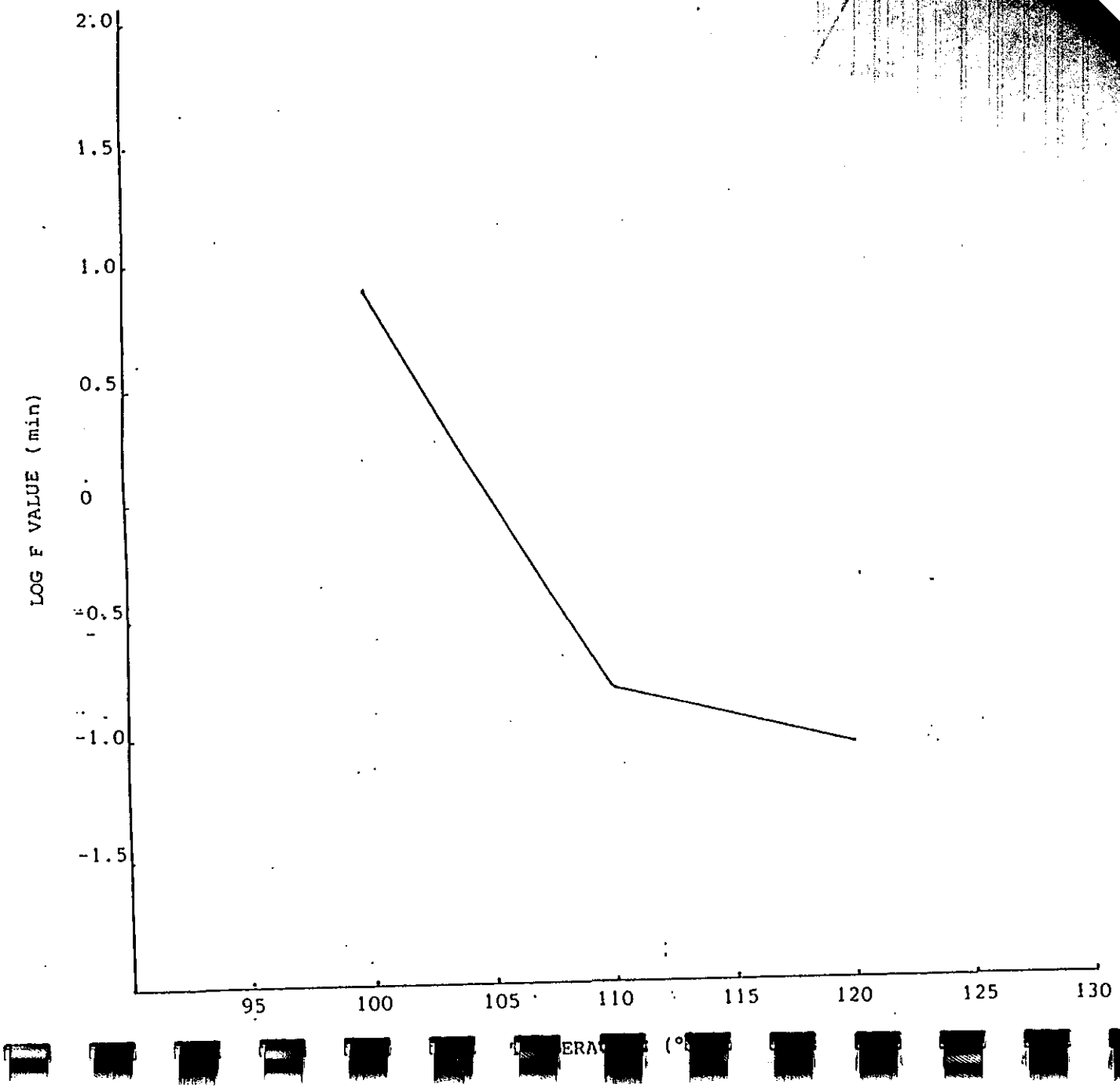


Figure 11 Log F value vs Temp.



Two concepts that denote the relationship between temperature and F value are as follows.

Q10 value. This denotes how many times the destruction of bacteria is accelerated or decelerated by a 10°C temperature increase or decrease respectively. From Fig. 11, Q10 for *B. stearothermophilus* at 100°C is 49.09.

Z value. This indicates the temperature increase or decrease that will cause the destruction of bacteria to proceed 10 times faster or slower respectively. From Fig. 11, z value at 100°C is 7°C.

The values for these parameters have been presented to give a generalised estimate of the type of heat treatment required for elimination of strongly thermophilic organisms.

Summary

The heat resistance characteristics of spore-forming thermoduric bacteria were established. Decimal reduction times for *Bacillus stearothermophilus* were 162 sec/100°C, 3.3 sec/110°C, and 1.8 sec/120°C. F values were 486 sec/100°C, 9.9 sec/110°C, and 5.4 sec/120°C.

4.2 Establishment of thermal criteria for thermoduric organisms isolated from meat and vegetable ingredients

- Microbial flora of meat

The microbial composition of a sample of partially cooked beef obtained from Kudos Meat Products Pty Ltd is presented in Table 3. In this sample, the predominant flora consisted of *Pseudomonas* species, *Lactobacillus* species and *Brochothrix thermosphactum.* As these organisms are not spore formers or markedly heat resistant, the counts suggest a relatively mild heat treatment or contamination post cooking. Neither aerobic nor anaerobic spore formers were detected at a dilution of 10^{-1}.

Spore-forming organisms are the organisms of most concern for the aseptic packaging process and it would appear that the meat samples were not a major source of them. Anaerobic spore formers (usually clostridial species) were not detected at a level of 10^{-1}/g in six meat samples tested. Aerobic spore formers (usually *Bacillus* species) were detected in only two of six meat samples. In these samples, which had total counts of 20 x 10^2 and 100 x 10^4/g, aerobic spore formers were present at levels of 50/g and 10/g respectively. Meat therefore, does not appear to be a major source of *Bacillus* species although the levels of this genus could vary considerably between batches.

Although clostridial species were not detected in the meat samples tested, it could be assumed to occur in meat samples from time to time. For this reason, thermal death curves of stock cultures of clostridial species were conducted and presented in Table 3. In Table 4, D values of commonly occurring, non-spore-forming bacterial species in meat are presented. Comparison between this Table and Table 8 demonstrates the much greater thermal tolerance of spore-forming genera than non-spore farmers and that thermal criteria designed to eliminate spores of *Bacillus stearothermophilus* would be more than adequate to eliminate these species.

- Microbial flora of vegetables

The microbial flora of a sample of vegetables is presented in Table 5. The Table presents counts of potato and carrots before and after blanching and for onions prior to blanching (onions were not blanched due to textural changes). The Tables demonstrate that the predominant flora of raw carrots, potato and onions consisted of Gram -negative species (i.e. non-spore-forming genera). Identification of representative colonies from the total count plates indicated that the predominant genera present were *Pseudomonas*, *Altermonas*, *Enterobacteriaceae* and *Acinetobacter*. The next major group were lactobacilli. In the blanched carrots, the total count was reduced to insignificant levels and was found to consist of lactobacilli, micrococci and *Bacillus* species. In the potato sample, blanching reduced total counts to undetectable levels. Other samples of potato, post blanching, were found to have *Bacillus* species surviving. The number of *Bacillus* species present after blanching was generally found to represent less that 0.1% of the total count of raw potato.

Aerobic and anaerobic spore formers were not encountered in either the raw or blanched vegetables (Table 5) indicating further that *Clostridium* or *Bacillus* species were not major contaminants of the vegetables. Three samples each of raw and blanched carrots and potatoes and raw onions were tested for the presence of spore formers. Anaerobic spore formers were not detected in any of these samples. Aerobic spore formers were detected in a third of blanched potato and raw onion samples. Average total counts and aerobic spore- former counts of these samples are presented in Table 5.

Tables 5 and 6 indicate that *Bacillus* species were not always present in vegetable samples and, when present, represented only a small proportion of the total flora. Identification of bacterial genera indicated, that post blanching, the predominant genera present were *Bacillus*, *Lactobacillus* and *Micrococcus*. Aerobic spore former counts, i.e. the count obtained after heating a sample at 80°C for 10 minutes, indicated that only a small proportion of the microflora, both before and after blanching, occurred in the form of spores. *Bacillus* species isolated from vegetables included *B. subtilis*, *B. circulans*, *B. megaterium* and *B. brevis*.

- Microbial flora of starch

Starches employed, Goodman Fielder maize starches codes 714 and 3401X, were also tested for total counts and the presence of aerobic and anaerobic spore formers. Levels of organisms encountered are presented in Table 7. These results demonstrated substantial total counts and aerobic spore former counts in the starches. In both starches, the main isolates obtained were *Lactobacillus* or *Bacillus* species which were present in approximately equal proportions. All aerobic spore former isolates were *Bacillus* species and included *B. subtilis*, *B. circulans*, *B brevis*, *B. megaterium* and *B. licheniformis*.

- Thermal criteria of spore forming isolates

The D values of spore suspensions from a selection of spore forming isolates and stock cultures are presented in Table 8. D values, i.e. the time required at a given temperature to produce a 10 fold reduction in spore numbers, were calculated for temperatures of 100, 110, 120 and 130°C.

Comparison of D values in this Table with those of non spore forming bacterial species commonly present in meat (Table 4), demonstrated the much higher thermal tolerance of the bacterial spores. Results presented in this Table also demonstrate the much greater thermal tolerance of *B. stearothermophilus* (stock culture) when compared to the thermal tolerance of spore forming isolates. For this reason, *B. stearothermophilus* was used as a test organism in the project.

Summary

Thermoduric bacteria in meat, vegetable and starch were identified. Anaerobic spore-formers were not detected, while aerobic spore-former counts ranged from 10 to 50/g. Spore-forming bacteria were not found in either raw or blanched vegetables, but *Bacillus* spp. were isolated from the starch. Decimal reduction times were established for several *Bacillus* and *Clostridium* isolates at 100°C, 110°C, 120°C and 130°C. They ranged from 32 to 1056 minutes at 100°C and from zero to 60 minutes at 130°C.

Table 3 The microbiological flora (cfu/g) of a sample of cooked beef from Kudos Meat Products Pty Ltd.

Total counts	20×10^2
Psychotrophs	7×10^2
Gram-ve organisms	10×10^2
Pseudomonas species	6×10^2
Aeromonas hydrohila	$<1 \times 10^2$
Brochothrix thermosphactum	3×10^2
Lactobacillus species	15×10^2
Staphylococcus aureus	$<1 \times 10^2$
Enterococcus species	$<1 \times 10^2$
Bacillus cereus	$<1 \times 10^2$
Coliforms	$<1 \times 10^1$
Clostridium perfringens	$<1 \times 10^1$
Yeast and moulds	14×10^1
Aerobic spore formers	$<1 \times 10^1$
Anaerobic spore formers	$<1 \times 10^1$
Salmonella presence	-ve
Listeria presence	-ve

Table 4 Decimal reduction time (D) values of commonly occurring, non spore forming isolates from meat. D values are expressed in seconds.

Meat isolate		D values
	60°C	70°C
Pseudomomuas	7	
Brochothrix thermosplactum	15	
Enterococci	61	
*Klebsiella ozaenae**	ND**	12
*Enterobacter salmazahrii**	ND	13
*Lactobacillus plantarum**	ND	10
Staphylococcus aurens	22	

* These organisms were selected for their ability to grow at 50°C i.e. thermophilic properties.

** ND not destroyed at this temperature.

Table 5 The microbiological flora (cfu/g) of washed and diced carrots and potatoes before (B) and after (A) blanching, and washed and diced raw onion.

	Carrot		Potatoes		Raw onion
	B	A	B	A	
Total Counts	$50x10^4$	$2x10^2$	$10x10^4$	$<1x10^2$	$5x10^2$
Psychrotrophs	$16x10^4$	$<1x10^2$	$4x10^2$	$<1x10^2$	$1x10^2$
Gram-ve organisms	$25x10^4$	$<1x10^2$	$9x10^4$	$<1x10^2$	$1x10^2$
Pseudomonas sp	$62x10^3$	$<1x10^3$	$9x10^4$	$<1x10^2$	$1x10^2$
Aeromonas hydrophila	$<1x10^2$	$<1x10^2$	$<1x10^2$	$<1x10^2$	$<1x10^2$
Lactobacillus sp	$<1x10^2$	$5x10^1$	$1x10^3$	$<1x10^1$	$4x10^1$
Staphylococcus sp	$<1x10^2$	$<1x10^2$	$<1x10^2$	$<1x10^2$	$<1x10^2$
Enterococcus sp	$<1x10^2$	$<1x10^2$	$<1x10^2$	$<1x10^2$	$<1x10^2$
Bacillus cereus	$<1x10^2$	$<1x10^2$	$<1x10^2$	$<1x10^2$	$<1x10^2$
Coliforms	$<1x10^2$	$<1x10^2$	$3x10^2$	$<1x10^1$	$<1x10^1$
Clostridium perfringens	$<1x10^1$	$<1x10^1$	$<1x10^1$	$<1x10^2$	$<1x10^2$
Yeast and moulds	$<1x10^1$	$<1x10^1$	$8x10^2$	$5x10^1$	$5x10^1$
Aerobic spore formers	$<1x10^1$	$<1x10^1$	$<1x10^1$	$<1x10^1$	$<1x10^1$
Anaerobic spore formers	$<1x10^1$	$<1x10^1$	$<1x10^1$	$<1x10^1$	$<1x10^1$

Table 6 Average total counts and aerobic spore-former counts (cfu/g) in vegetable samples in which aerobic spore formers were detected.

	Carrot		Potato		Onion
	raw[(1)*]	blanched[(1)]	raw[(2)]	blanched[(1)]	raw[(1)]
Total count	$5x10^4$	40	$15x10^4$	$12x10^1$	$12x10^4$
Aerobic spore former count	30	10	25	10	10

* no. of samples out of three in which aerobic spore formers were detected.

Table 7 Total counts and aerobic spore former counts (cfu/g) of maize starches.

Starch	Total count	Aerobic spore formers
714	23×10^2	19×10^1
3 401x	35×10^2	17×10^2

Table 8 Decimal reduction time (D) values of ingredient isolates and stock cultures at selected temperatures. D values are expressed in seconds.

Organism	Source	D values			
		100°C	110°C	120°C	130°C
B. licheniformis	onion	220	136	70	19
B. circulans	onion	330	135	16	13
B. megaterium	onion	120	75	57	27
B. megaterium	carrot	225	75	34	15
B. coagulans	carrot	330	50	24	12
B. licheniformis	potato	255	40	20	10
B. licheniformis	potato	435	200	50	9
B. brevis	potato	337	307	40	16
B. megaterium	starch	255	65	33	9
B. brevis	starch	210	48	22	14
B. cereus	stock culture	102	84	44	8
B. circulans	meat	420	120	53	-
C. botulinum	stock culture	78	15	-	-
C. perfringens	stock culture	32	14	-	-
B. stearothermophilus	stock culture	1 056	595	108	60

(organisms were suspended in 0.15M phosphate buffer pH 7.0).

4.3 Market and product identification

Based on meetings between Kudos Meat Products Pty Ltd and six Japanese food processors, the basic product should contain cubes of beef, potato, carrot and onion in a gravy sauce. The meat content should not exceed 20%, and a cube size of approximately one cubic centimetre is preferred.

Kudos obtained several packets of Japanese retort-pouched products, and these were examined. Packet labels were translated from Japanese into English, by the Department of the Premier, Economic, and Trade Development (Japan Secretariat). Details are as follows.

- "Lee" Glico curry

Potato, carrot, onion, beef, wheat flour, lard, gravy sauce, curry powder, bouillon, sugar, honey, tomato puree, salt, chutney, seasoning, caramel colouring, whey.

- "Draft" Glico beef and garlic

Pumpkin, onion, carrot, tomato, garlic, ginger, beef, oil, wheat flour, butter, skim milk powder, curry powder, salt, sugar, beef bouillon seasoning, chicken bouillon, yeast, spices, seasoning, caramel colouring, sweetening (licorice).

- "Donburi" gydon pack

Onion, carrot, mushroom, noodles, starch, beef strips, soy sauce, sugar vinegar, egg, lard, sale, bonito stock, seaweed stock, salt, seasoning.

From the meetings Kudos Meats Pty Ltd indicated that aseptically packaged meat and vegetable stew products should be developed for the export market to Japan. An aseptically packaged bolognaise sauce was identified principally for the domestic market.

It was considered that chilled products would be unsuitable for either market, due to their short shelf-life, and strict temperature control required through the distribution chain, from the processor to the consumer.

The export product would have a basic formulation containing beef cubes, potato cubes, carrot cubes, onion cubes/slices, and a starch-based sauce. A commercial formulation for a bolognaise sauce for the domestic market was obtained. The formulations both complied with the requirements of the relevant food legislation.

Key points were:

- the product must contain at least 51% meat, if it is first-named in the label;
- not more than 20% fat of total meat content; and
- not more than 6% starch of total content.

A report from Kudos Meat Products on their Japanese visit is included in Appendix 1.

Summary

An aseptically packaged meat and vegetable stew product was identified for the export market to Japan. An aseptically packaged bolognaise sauce was identified for the domestic market.

4.4 Economic evaluation

A review of the literature indicated that aseptic packaging appeared economically viable for high throughput, bulk (institutional) packs. This is detailed as Appendix 2 of this report. Market and cash flow projections for aseptically packaged bolognaise sauce, and meat and vegetable stews, indicated that provided a high quality product can be achieved, commercial production at Kudos Meat Products Pty Ltd should be economically feasible. It should be noted that this plant was assumed to operate at 3 tonnes per hour, utilising scraped surface heat exchangers. Ohmic heating was an alternative technology considered. It is reported to be more efficient in heating large particles, and cheaper to maintain than SSHE technology. However, capital costs are approximately 30% higher. Operating costs especially energy consumption, are also reported to be higher, although no data were available to confirm this. Also, there is no ohmic heating equipment in Australia, so any trial work would need to be conducted in the U.K. at considerable cost. (APV Baker trial facilities were $30 000 - 35 000 for a three day trial).

4.5 Product and process development (conventional technologies)

Freezing times for 2 kg bags in a blast-freezer at -30°C were 70 to 75 minutes and freezing curves for the meat and sauce components of the stew are shown in Figure 12.

Physical integrity of the products was assessed after thawing. In the stew the meat, carrot, and onion retained their structure. The sauce retained its consistency and opacity, with no syneresis or gelation problems. However, some breakdown of the potato cubes was indicated by small flecks of potato in the stew. A gentler mixing of the components and slight reduction of the blanching time for potato cubes solved this problem. The physical integrity of the bolognaise sauce was unaffected by freezing and thawing.

Mean sensory scores for the frozen stew are shown in Table 9. These indicated that appearance and flavour were well retained during freezing and thawing. The texture of the meat was considered too tough, and longer cooking prior to freezing was required. The consistency of the sauce was assessed after freezing and thawing for three different starches - Mazacca 3401X, FTD176, and Fieldclear 714, at 4% and 5% concentrations. The 4% concentrations were unacceptable due to a thin, watery consistency. 5% Mazacca 3401X was unacceptable due to a pasty consistency and opaque appearance. Five percent FTD176 was too gelatinous. Five percent Fieldclear 714 retained adequate consistency after freezing and thawing to suspend particulates, and was considered an acceptable sauce base.

Figure 12 Stew Freezing Curve

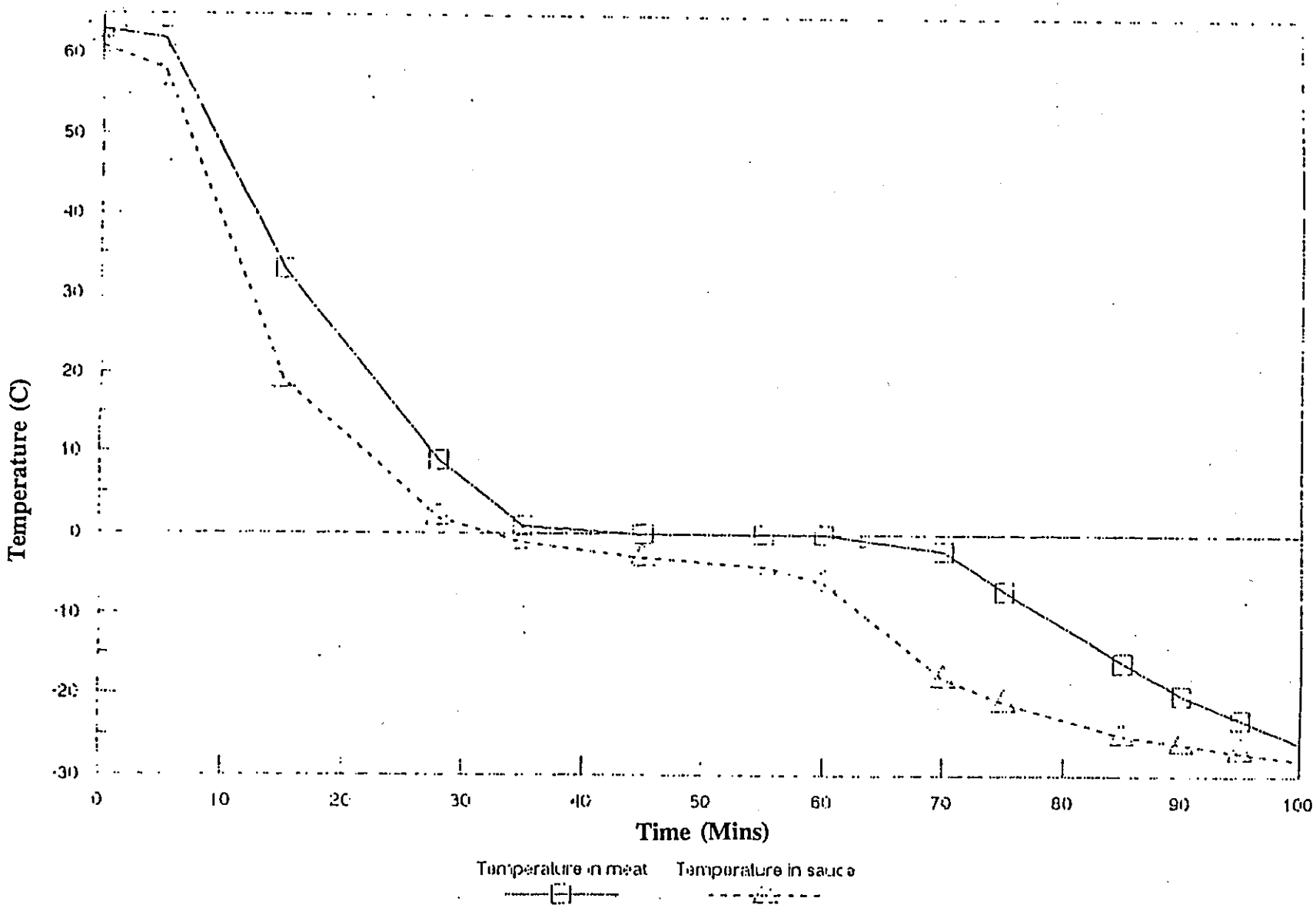


Table 9 Stew sensory data (mean scores of 34 panellists)

Parameter	Frozen	Canned
Overall appearance (0 = dislike extremely, 100 = like extremely	50.3	52.7
Meat particle size (0 = too small, 100 = too big)	51.1	35.6
Vegetable particle size (0 = too small, 100 = too big)	44.4	47.3
Sauce colour (0 = too light, 100 = too dark)	33.6	39.8
Solids/sauce ratio (0 = too low, 100 = too high)	39.9	38.3
Flavour (0 = dislike extremely, 100 = like extremely)	47.5	50.4
Meat texture (0 = too tender, 100 = too tough)	87.1	55.9
Vegetable texture (0 = too soft, 100 = too hard)	42.0	42.8
Sauce consistency (0 = too thin, 100 = too thick)	43.9	31.4
Acceptability (0 = dislike extremely, 100 = like extremely)	44.1	50.2

Freezing and thawing had no adverse effects on the physical integrity or sensory quality of the bolognaise sauce product.

- For the chilled stew

After one hour the temperature in the centres of meat pieces was 4°C. Physical integrity of both stew and bolognaise was similar to the frozen products. Sensory quality (assessed by the experimenters) was also similar both immediately after chilling, and after two weeks at 1°C.

Chilled low-acid foods require strict temperature control through the entire food distribution chain, to ensure both safety and quality retention. It may be commercially difficult to ensure a chilled distribution system at the temperatures specified by the "Capkold" process. In a recent survey of chilled "sous-vide" meat and vegetable products in Melbourne retail outlets, Sumner (1990) showed product temperatures in excess of 10°C (well above the maximum specified temperature of 3°C).

- Heat penetration

Heat penetration data for canned stew (307 x 309 cans) are given in Figures 13 (can centre temperature versus time) and Figure 14 (lethal rate versus time). The process of 80 minutes at 121°C gave an Fo = 16.15, which exceeded the minimum requirement of Fo = 8 to 10 for canned meat products. From the data collected, the process time could be reduced to 70 minutes, with an Fo = 9.39.

Cans were opened after processing and the contents examined. Physical integrity of the meat and vegetable pieces was well retained. The sauce showed no evidence of separation or syneresis. Overall, flavour was considered acceptable. Mean sensory scores for the canned stew are shown in Table 9.

Texture of vegetables and meat was considered reasonable, but a little soft. This could be overcome by decreasing the precooking time for the meat, and reducing the retort time. Sauce colour was considered a little pale for a canned stew. This was overcome by addition of 0.12% caramel as a colorant. Curry powder (0.48%) was also added to improve the flavour.

- Retort-pouched stew

Heat penetration data for retort pouched stew (1 kg bags) are given in Figure 15 (bag centre temperature versus time) and Figure 16 (lethal rate versus time). The process of 35 minutes at 121°C gave an Fo = 17.68. From the data collected, this could be reduced to 25 minutes, with an Fo = 9.69, and still be assured of a safe process.

After processing, the physical integrity and overall quality were similar to those of the canned stew.

Figure 13

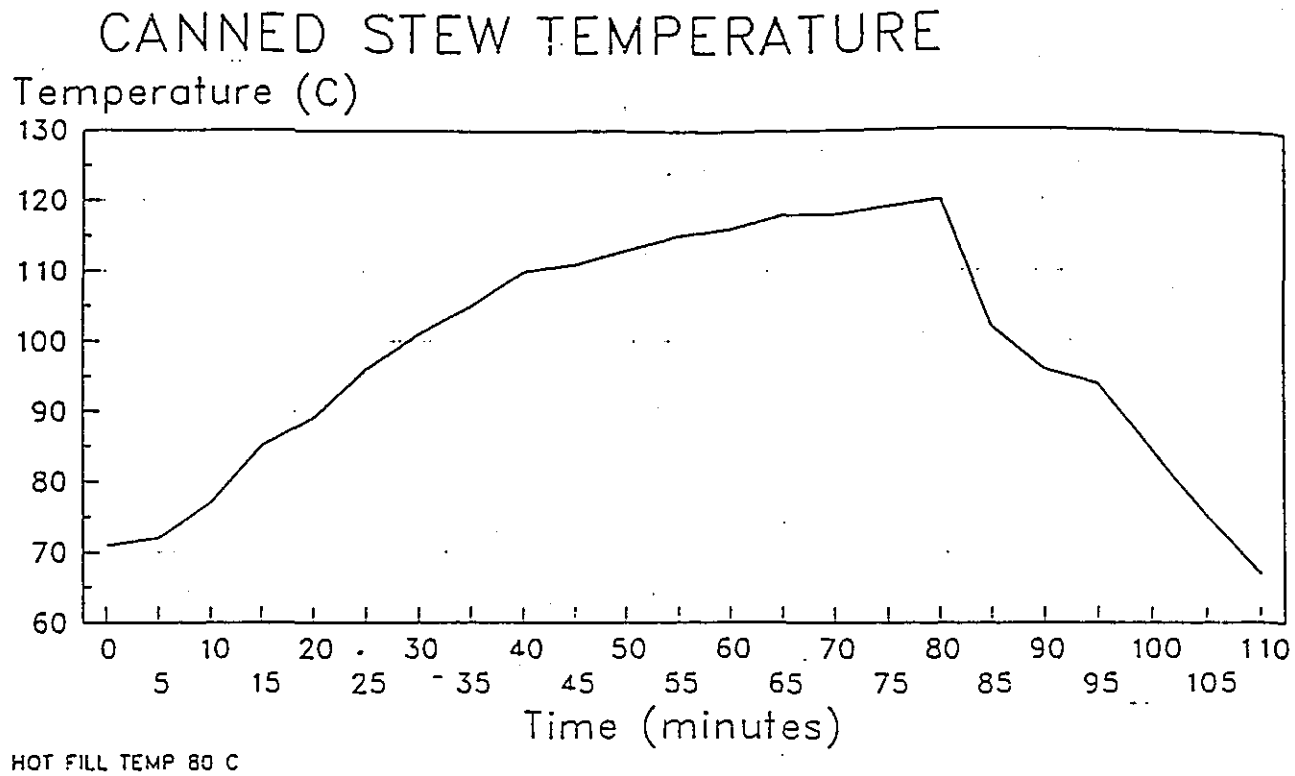


Figure 14

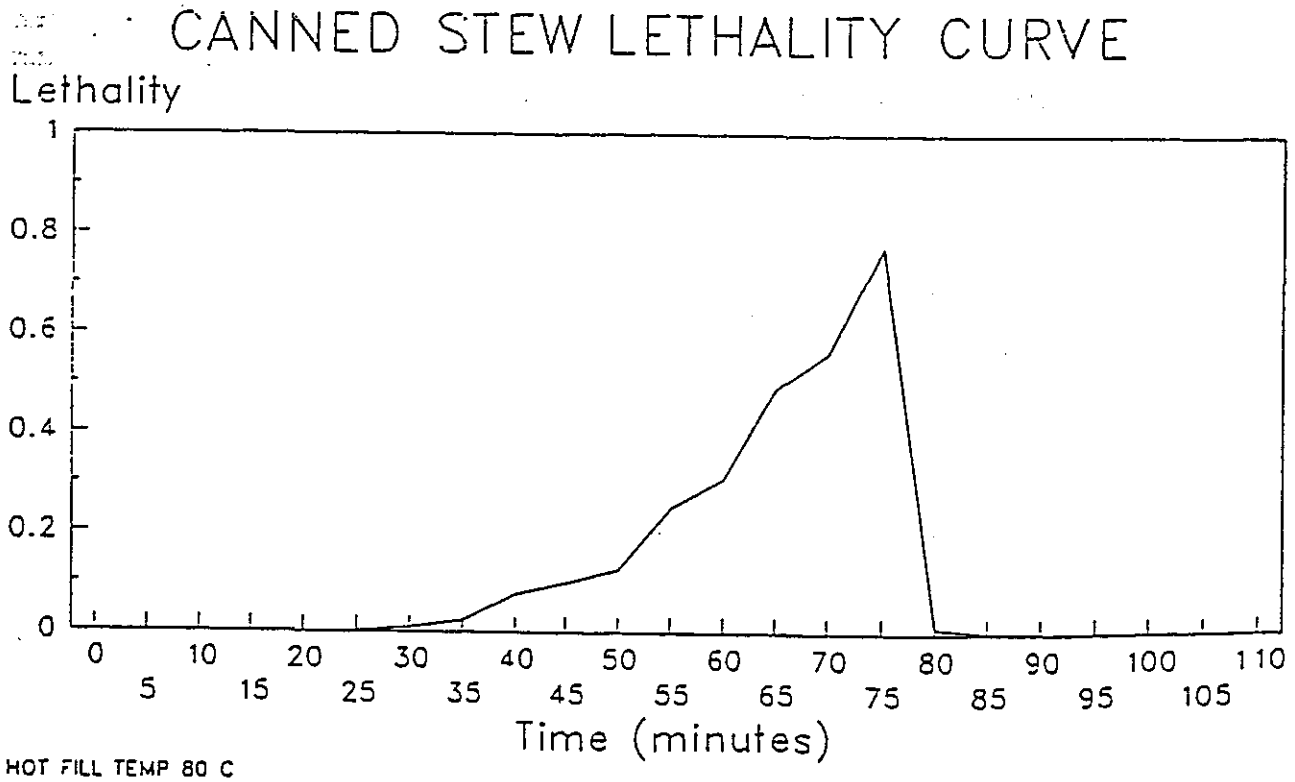


Figure 15

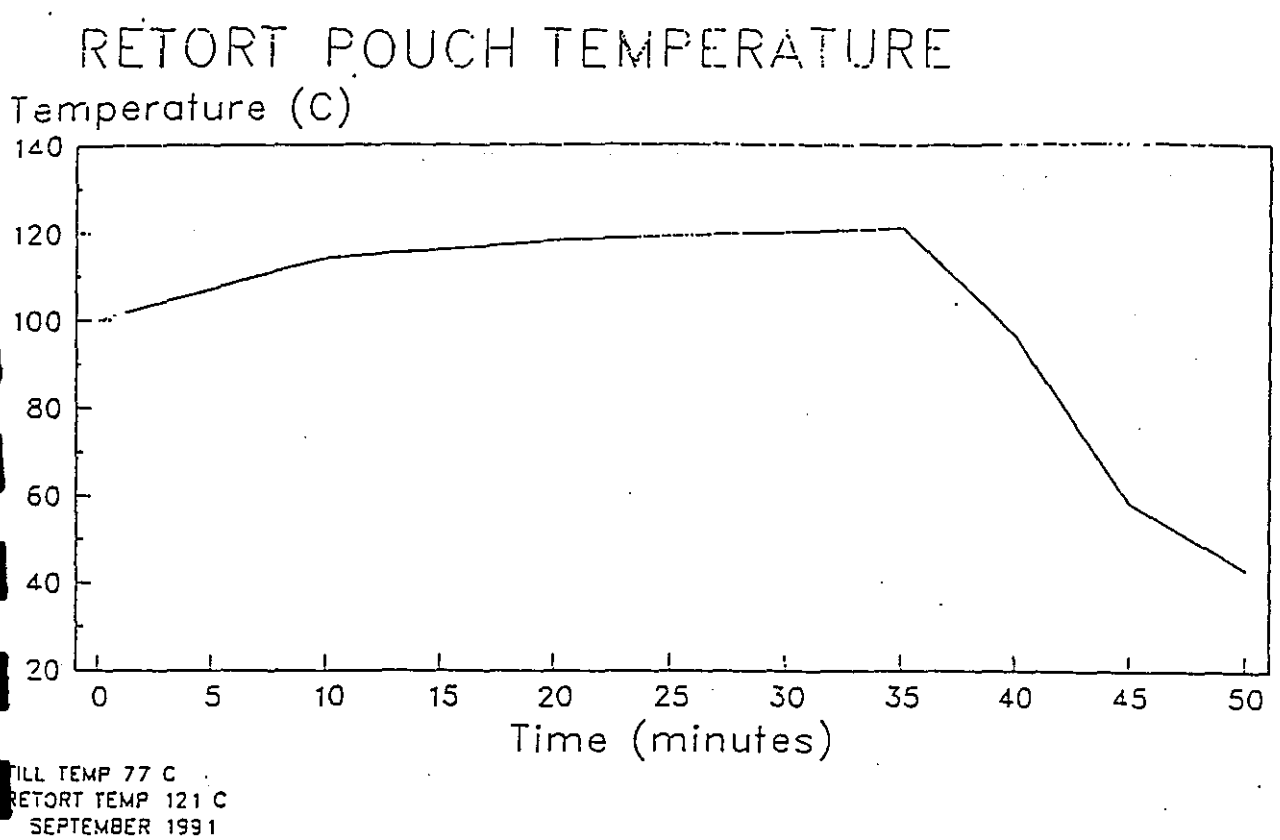
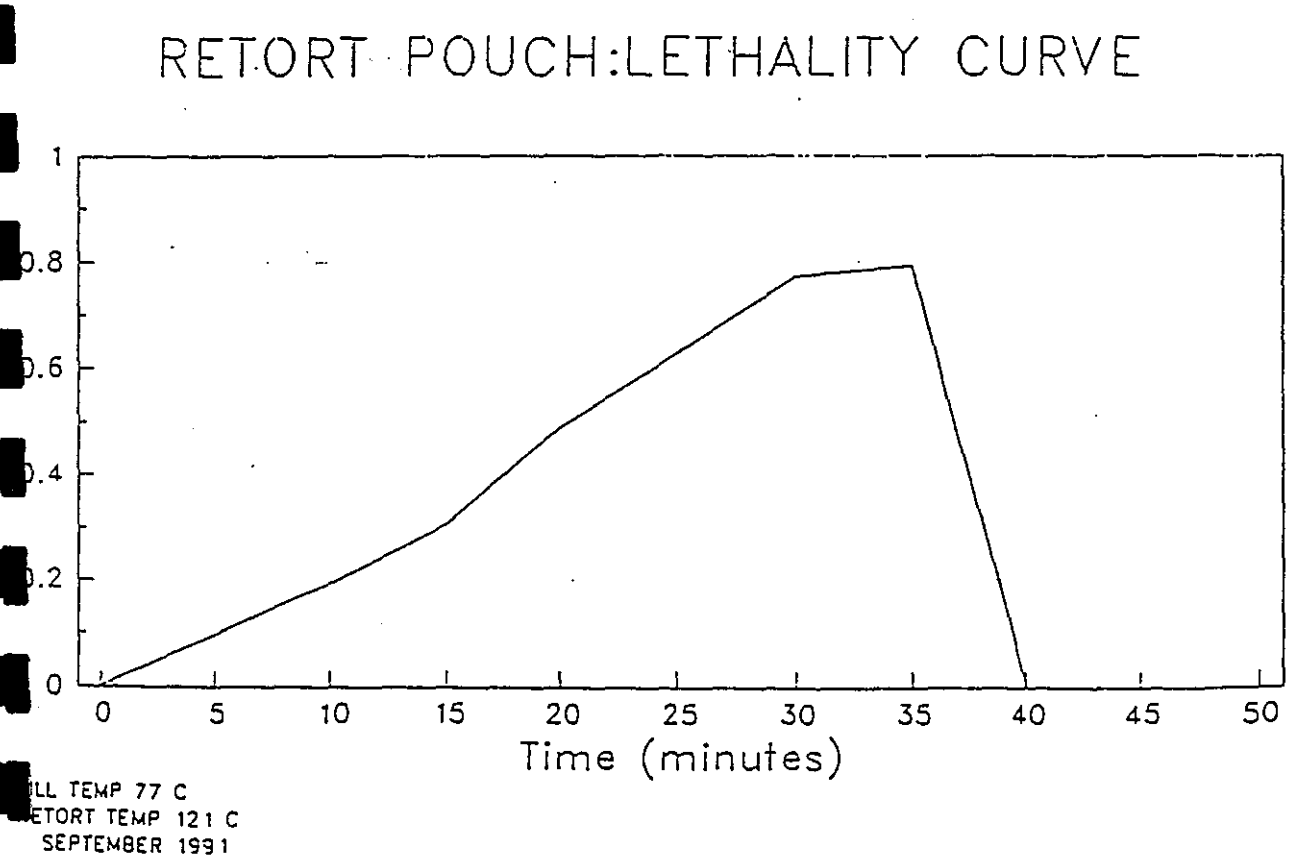


Figure 16



- Viscosity

Viscosity of the modified maize starches (Mazacca 3401X and Fieldclear 714) after processing is shown in Table 10.

Table 10 Starch viscosity (CP) at 20°C*

Treatment	1% + 1%	3% + 3%	5% + 5%
Control	20	550	1 300
Retorted	16	450	1 100
Frozen	8	250	1 700

(* Measured with a Brookfield viscometer, Spindle LVF # 3, angular velocity = 20 rpm)

The 1% + 1% was very watery, and unsuitable for suspension of particulates. The 3% + 3% was thick enough to suspend particulates, while the 5% + 5% was excessively thick. Retorting and freezing reduced viscosities (except for the frozen 5% + 5% concentration).

Summary

Meat and vegetable stews were processed by conventional technologies - frozen, chilled, canned and retort-pouched. Process conditions were established. Freezing times for 2 kg bags were 70-75 minutes in a blast-freezer at -30°C. Chilling times were 60 minutes to reach 4°C. The canned product, packed in 307 x 309 cans, required 70 minutes retorting at 121°C, while the retort-pouched product in 1 kg bags required 25 minutes retorting at 121°C. Sensory data were obtained for a range of quality parameters.

4.6 Quality assessment methods development

Preparation of alginate gels with embedded spores of Bacillus stearothermophilus

A comparison of counts using the Sorvall Omni Mixer and the Colwell stomacher is presented in Figure 17. Both 0.1% peptone and 2% sodium citrate water were used as homogenising media. The Figure demonstrates that the Sorvall Omni Mixer was more efficient in homogenising the gel particles and that sodium citrate was a more effective homogenising media. The effectiveness of sodium citrate is probably due to the fact that it is a chelating agent which can remove calcium ions from the gel matrix, thus solubilising it.

In Figure 18, a comparison was made of the counts obtained using several homogenising media in a Sorval Omni Mixer. These results again demonstrated the greater effectiveness of sodium citrate in solubilising gel particles.

In Figure 19, results are presented of counts of *Bacillus stearothermophilus* in gel which had been placed in boiling water for various time intervals. This graph demonstrated the

heat stability of the spores at 100°C.

Figure 20 demonstrates the stability of spores in the gel when stored in distilled water at 5°C. No reduction in spore counts occurred over a one-month period, indicating that the spore containing gels can be stored for extended periods of time, without loss of spore viability.

Further improvements were made as follows.

- Use of 2% EDTA and 2% tetra sodium pyrophosphate for homogenisation of gel particles. These two chelating agents were compared with sodium citrate (2%) for their ability to break down beads of gel. No advantage in using these agents rather than sodium citrate was noted. It was found that uniform distribution of spores within the gel could be achieved by mixing with a Sorval blender prior to setting.

  The heat stability of the gel, made with and without 0.5% agar was tested by boiling gel particles for various periods of time, and by canning them at 121°C for various time intervals. This demonstrated:

- expression of water from the gel and subsequent loss of weight, was not greater in gel containing agar;

- loss of spores from the beads during heating is negligible;

- discussions with a biometrician led to the conclusion that there was so little variation in replicate counts of spores extracted from gel beads that statistical analysis of spore count data was unnecessary. Three to five replicates were considered satisfactory.

The most desirable characteristics of the gel are as follows.

- Gel needs to have similar heat penetration characteristics to food particles.
- Gel should be able to be produced in a size and shape similar to food particles.
- Even distribution of the spores within the gel matrix.
- Spores should be readily recoverable from the gel matrix.
- Gel should have sufficient strength to withstand passage though an aseptic processor e.g. scraped surface heat exchanger.
- Needs to be easily recoverable from the food product post processing.
- Leaching of spores from the gel should be minimal.
- To be able to store the prepared gel beads for extended periods of time prior to use.
- The pH of the gel should be adjustable to that of the food product.

Figure 17 Spore counts from alginate gel beads homogenized in a Sorval blender or Colwell stomacher in 0.1% peptone (x-x) or 2% sodium citrate (o-o).

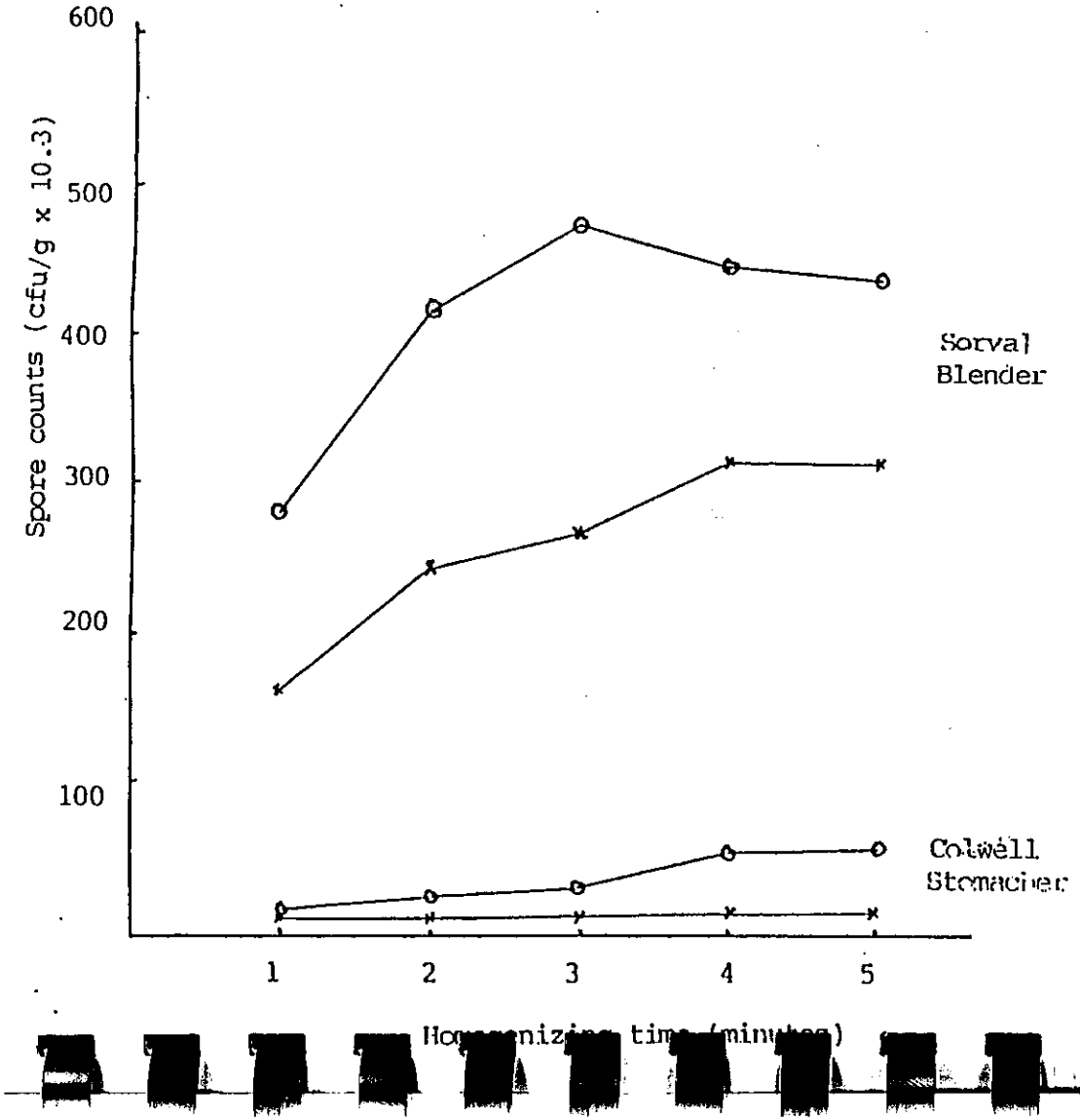


Figure 18 The effect of different homogenizing media on counts of Bacillus stearothermophilus spores in alginate gel. Samples were blended in a Sorval blender for various time periods.
o-o 2% sodium citrate, x-x 1/4 strength ringers solution;
▲-▲ 0.1% peptone, ● - ● 0.85% sodium chloride;
△-△ 2% tween 80.

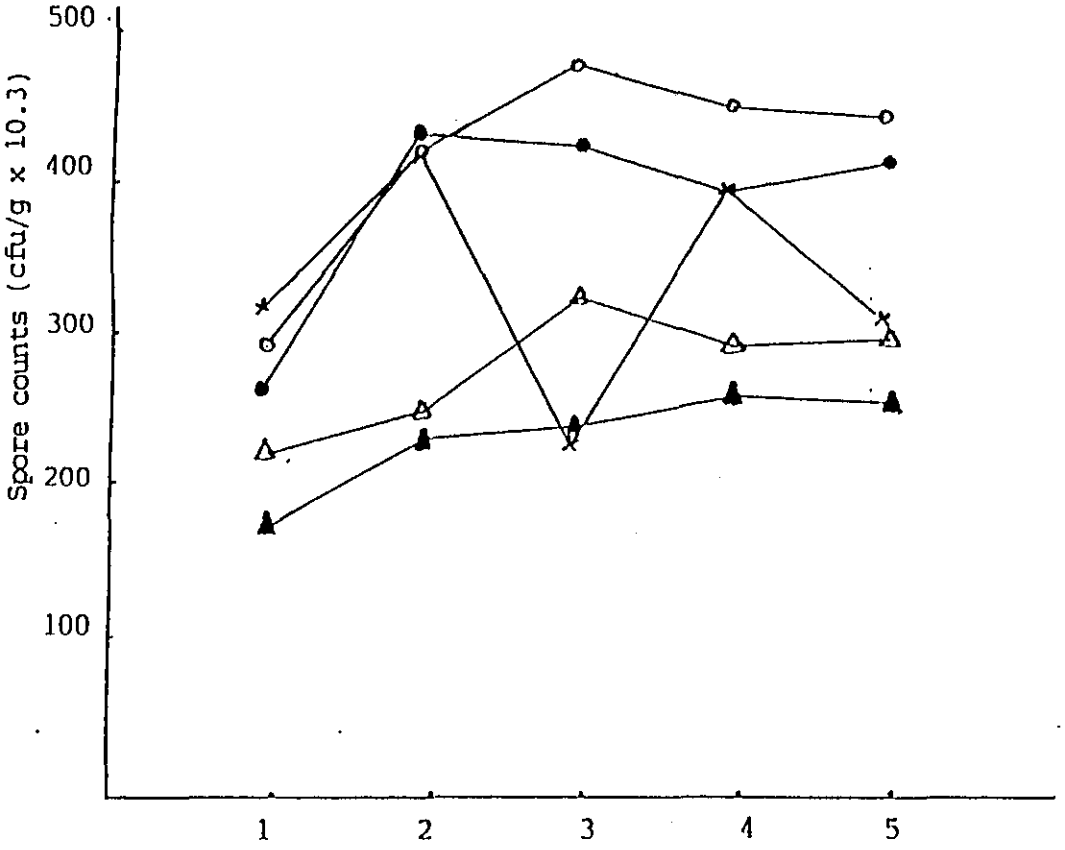


Figure 19 Counts of Bacillus Stearothermophilus in sodium alginate gel at 100°C for various time intervals.

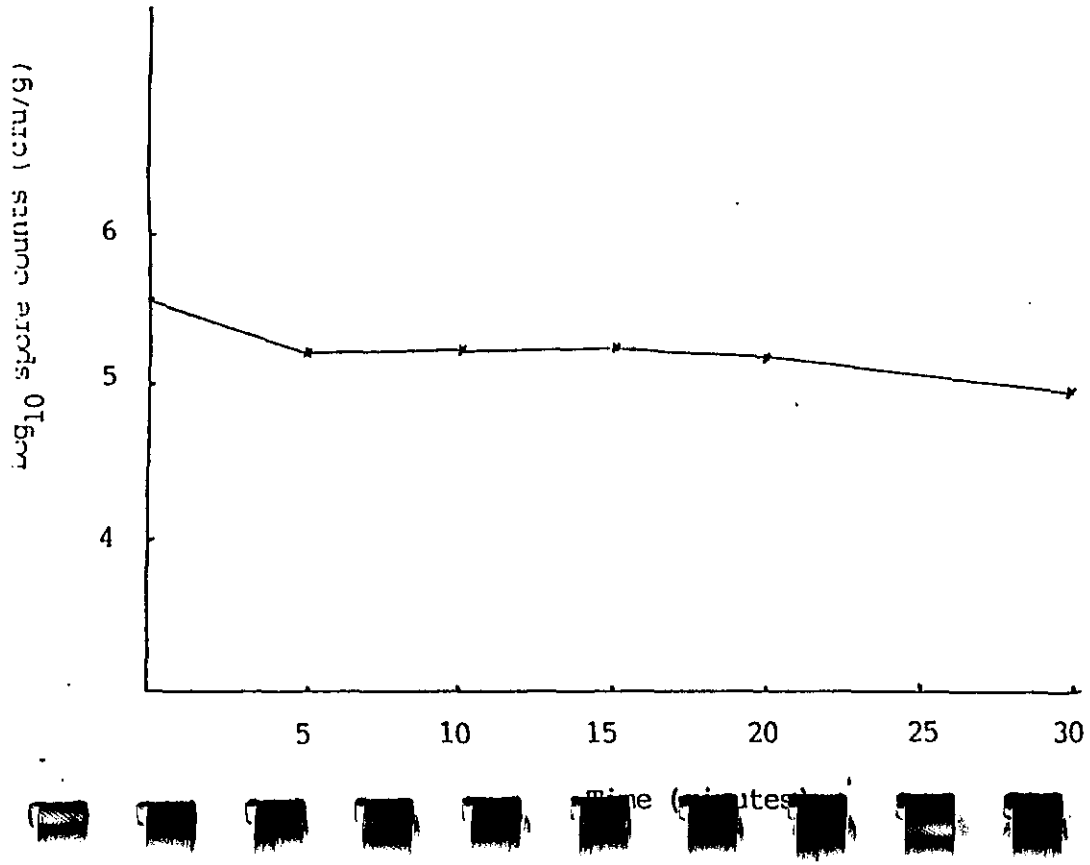
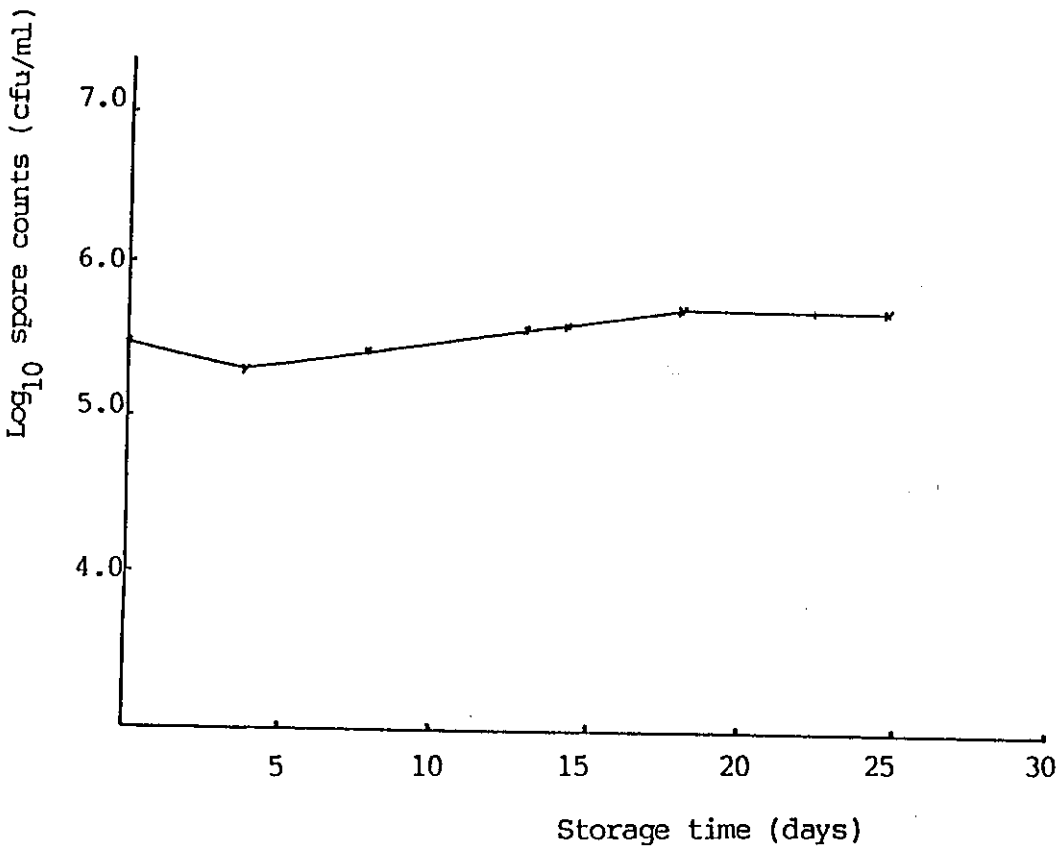


Figure 20 Counts of Bacillus stearothermophilus spores during storage of sodium alginate gel in distilled water at 5°C.



All of these characteristics except 1 and 5 were satisfactory. Additional tests were conducted to establish these characteristics.

- Mechanical strength of gels

The mechanical strength of the gel particles was tested by passing them through the scraped surface heat exchanger at temperatures up to 130°C. Approximately 70% recovery of undamaged gel particles was obtained, and this is considered to be more than satisfactory.

- Comparison of heat penetration data for the beads and for food particulates.

Technical difficulties occurred during this work for the following reasons.

- Because it was difficult to accurately place a thermocouple in the centre of the gel particle.
- Experiments were restricted to testing heat penetration in a medium at temperatures up to 100°C.
- Thermocouples often dislodged or partly dislodged from gel cubes thus allowing entry of heated water and therefore inaccurate readings.

These problems were overcome using different procedures. Temperature penetration data for 2.5 cm cubes of food and 3% alginate are presented in Figure 21. These results demonstrate that heat penetration was more rapid in the gel than in meat or potato but not carrot.

Thermal criteria of Bacillus stearothermophilus spores embedded in alginate gel

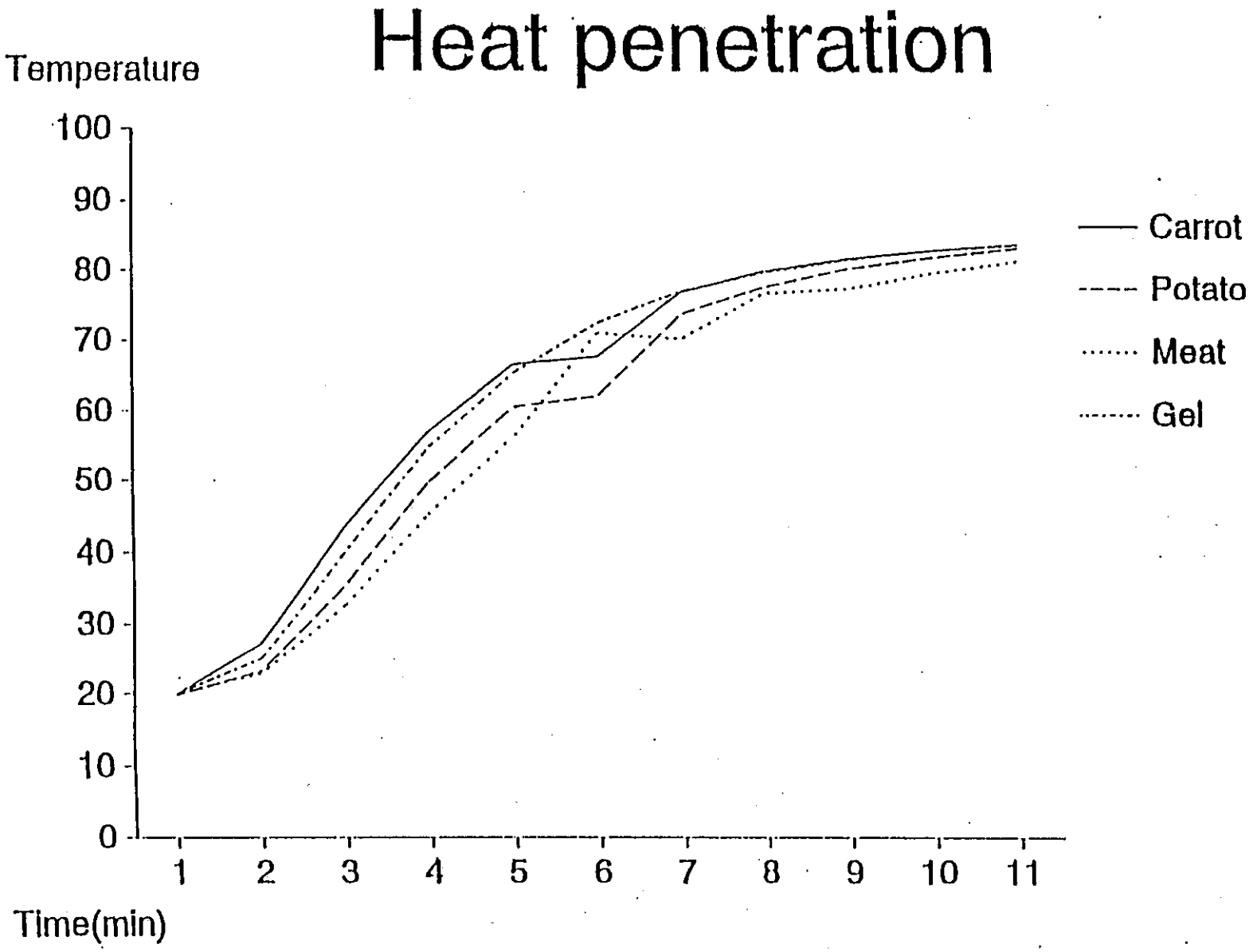
A comparison was made of the thermal death curves of spores of *B. stearothermophilus* embedded in gel with those of suspensions in phosphate buffer pH 7.0. D values obtained are as follows. Values expressed in seconds (i.e. no. of seconds for a 10 fold reduction in numbers) are shown in Table 10.

Table 11 D values for *Bacillus stearothermophilus* spores

Suspension medium	100°C	110°C	120°C	130°C
spores in gel	1 004	348	78	4.3
spores in phosphate buffer pH 7.0	1 056	595	108	60

These results demonstrated that the spores were less temperature resistant in the gel than in phosphate buffer at pH 7.0. This needs to be taken into account in calculations of Fo values for the product.

Figure 21


Heat penetration
Temperature
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
Time(min)
Carrot
Potato
Meat
Gel

Development of the thiobarbituric acid test (TBA)

The thiobarbituric acid test (TBA) measures lipid oxidation, and may be useful as a rancidity test for the meat component of aseptically packaged stews. The modified TBA extraction procedure applied to blended stew samples proved very variable. The average recovery in these tests was 81%. Factors affecting the reliability of this procedure were as follows.

- The TBA values obtained may have been affected by time and heating temperature considerations, so that reliable results were difficult to obtain.
- The sample tested must be homogenous so that truly representative sub-samples can be taken for analysis. (A sample of meat stew released a yellow-coloured fatty substance that was difficult to reincorporate into the stew completely).
- The low volume of meat in the stew.
- The presence of interfering substances in the stew mixture.

It was concluded that the TBA test was not suitable for the purpose of determining oxidative rancidity in meat stews or similar products.

In view of this, initial quality assessments for this product were based on sensory evaluation. If rancidity proves to be a problem, an improved analytical methodology may need to be developed.

Summary

A method was developed to suspend spores of *Bacillus stearothermophilus* in alginate gel cubes, for evaluation of process lethality in particulate products sterilised in scraped surface heat exchangers. When passed through a scraped surface heat exchanger at 130°C, approximately 70% recovery of undamaged gel particles were obtained. Spores were less temperature resistant in gel then in phosphate buffer at pH 7.0.

The thiobarbituric acid (TBA) test was unsuitable for determining oxidative rancidity in meat stews or similar products.

4.7 Development of aseptically packaged products

Equipment development

- Presterilisation

Work on presterilisation of the aseptic processing system was carried out. The aim was to circulate water at 125°C for 30 minutes. In initial tests, results were inconsistent. This appears to have been caused by trapped air in the system, resulting in "flashing" of water to steam. The problem was solved by increasing the flow rate and initial temperature of the sterilising water, and changing the layout of the holding tubes. The required

presterilisation conditions were successfully achieved using the following conditions.

Mono pump flow rate = 6L/min
Mono pump speed = maximum (1,311 rpm)
Feed water temperature = 85°C
Back pressure = 300 KPa
Mutator speed = 300 rpm
Temperature after heating SSHE = 134°C
Temperature after cooling tubes 126°C
(no coolant circulating)
Steam setting = ¼ turn (500 KPa)
Holding tube length = 12 m

A graph of temperature (°C) versus time (mins) is shown in Figure 22 (channel 5 = temperature after the heating SSHE; 4 = temperature after holding tubes; 3 = temperature after SSHE cooler; 2 = temperature after Spiroflo cooler; and 1 = temperature after the back-pressure pump).

For the above tests, the first scraped surface heat exchanger was used as a heater, (with steam as the heating medium) and the second as a cooler (with water at 3°C as the coolant).

Several modifications were made to the system by:

- increasing the initial flow rate and temperature of water to pre-warm the system;
- reducing the number of elbows and bends to a minimum;
- raising the level of the holding tubes above the SSHE (heater) to prevent air pockets; and
- increasing the number of locations of thermocouple ports and using thermocouples with greater temperature sensitivity.

A large capacity (10 000L/hr) centrifugal pump was connected to the system to ensure efficient cleaning-in-place (CIP) before and after product runs. An "Intasept" aseptic filler was installed in September 1992.

- Product sterilisation

This work was aimed at achieving a sterile, aseptically packaged, bolognaise sauce product.

To obtain a sterile aseptic product the system was first presterilised with water at 130°C for 5 minutes. This was followed with product which was held for 5 minutes at 130°. The product was then cooled to ambient temperature, and aseptically packaged. For a chilled extended shelf-life product, the product requires a much milder heat process (90-95°C for 5 minutes) to eliminate psychrotrophic spoilage bacteria.

Attaining the conditions needed to produce a sterile low-acid particulate product proved very difficult. Problems included:

- Worn rotors on feed pump; there was a delay of 6 weeks in obtaining new rotors from the USA.

- Water presterilisation heat losses and flashing of water to steam; this was overcome by the following measure.

  - Increased water flow rate
  - Reduced number of elbows and bends
  - Holding tubes raised to minimise air pockets
  - Improved insulation
  - Use of a monopump for water sterilisation
  - Steam in Spiroflo jacket during presterilisation

Time-temperature curves are shown in Figures 23 and 24.

- Insufficient heating capacity to sterilise the aseptic filler; the manufacturer was requested to modify an exhaust valve to allow a faster water flow rate during presterilisation.

- Increased flow rates of bolognaise with the new lobe pump rotors, resulted in insufficient heating capacity to sterilise the product; this problem was solved by reconfiguring the process flow such that both scraped-surface heat exchangers were used for heating. This equipment configuration supplies sufficient heat for product sterilisation.

  Although water presterilisation was able to be achieved successfully with a single heating stage, when bolognaise was introduced (Figure 24), the product temperature fell to about 105°C. However with the use of both SSHE for heating (Figure 25) a product temperature of 130°C was achieved.

- Instability when changing from water to product; changing over from water to bolognaise and maintaining constant conditions proved difficult because of the different viscosities and heat transfer characteristics of these fluids.

  Measures to solve this problem were as follows.

- Use of two valves during the change over from water to bolognaise. During water presterilisation, the pressure in the system was controlled by a pressure relief valve. This is because the back-pressure pump has wide clearance rotors, and was unable to hold back pressure on water. Once bolognaise came through, pressure was controlled by a back pressure pump. Pressure after the back-pressure pump was controlled by a back-pressure valve, which opened and closed in sequence with the filler valve. (In this case, the back-pressure pump was able to hold back pressure).

- Installation of a temperature controller. This enabled steady state conditions to be achieved. However, pressure still had to be controlled manually, with the back-pressure pump speed controller. There was also a need to install a flow diversion

valve in the system, to ensure that any product not up to the sterilisation temperature, was automatically directed to the feed tank.

A request was made to the MRC for additional funds, for purchase of a pressure controller and flow diversion values. Funds were also requested for the appointment of a temporary engineer, to install and test them in the pilot plant. Funding was not approved.

Figure 22 Water Presterilisation (one heating stage)

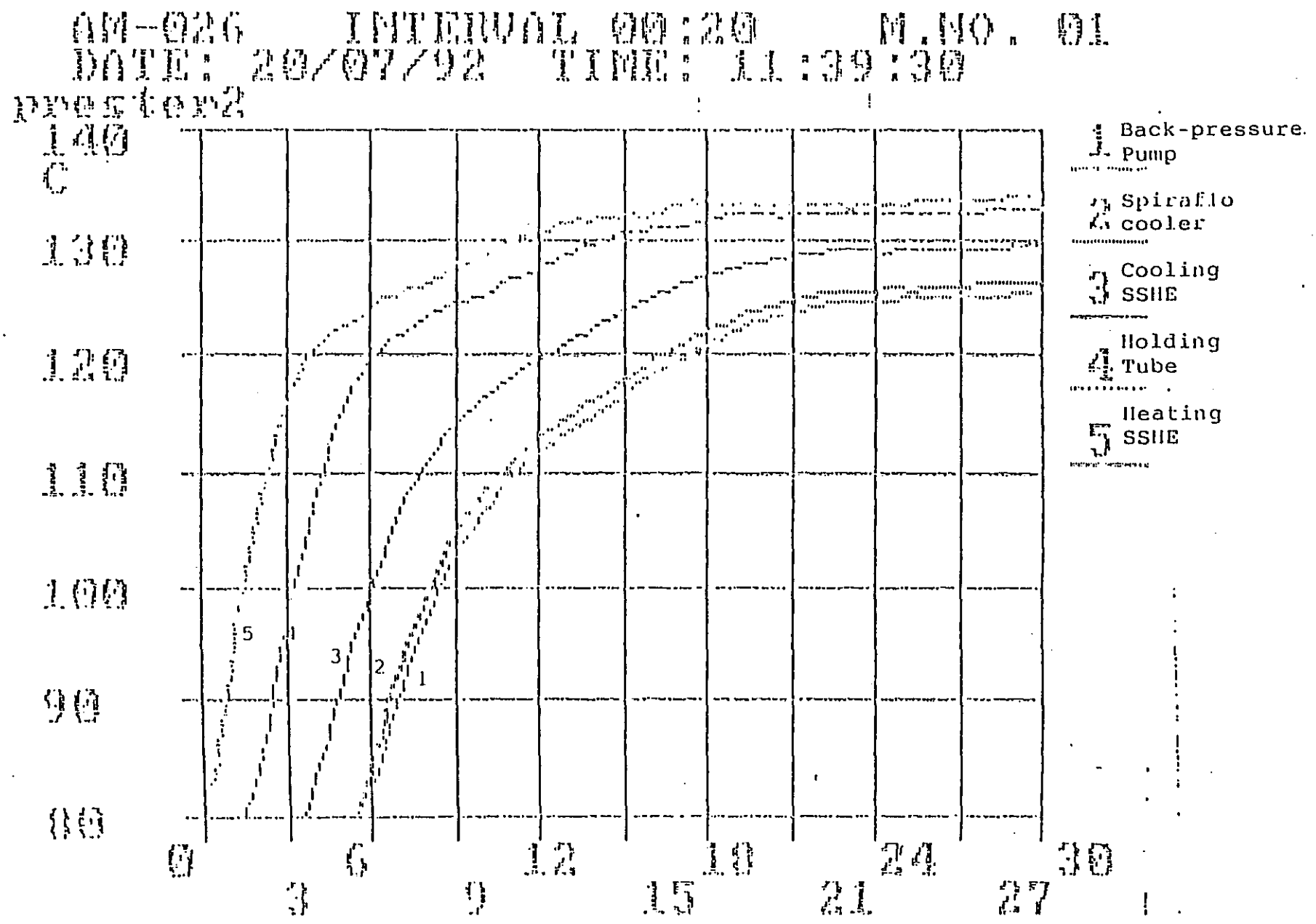


Figure 23

Water Presterilisation

(2 heating stages, and steam in Spiraflo jacket)

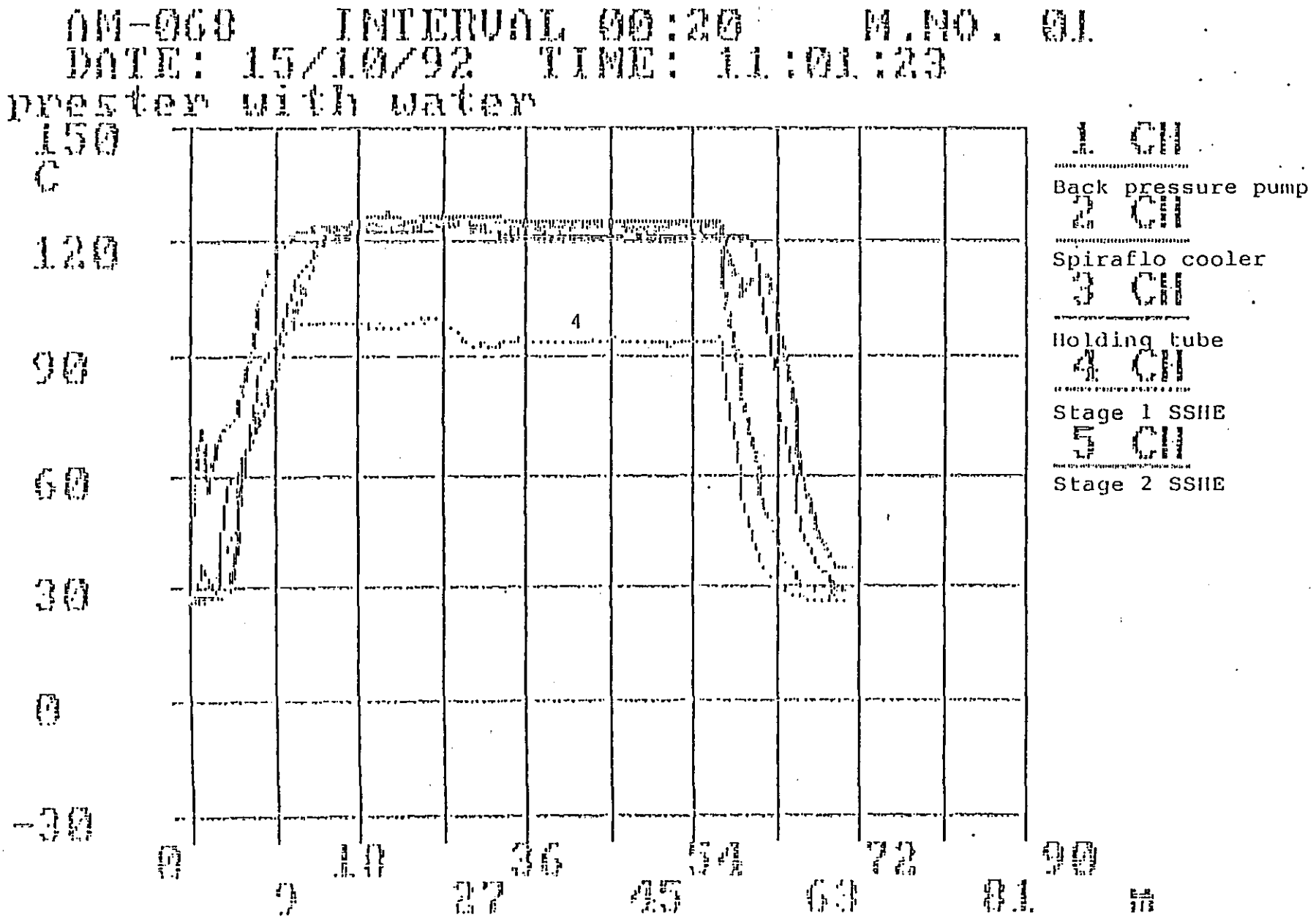


Figure 24 Bolognaise sterilisation (one heating stage)

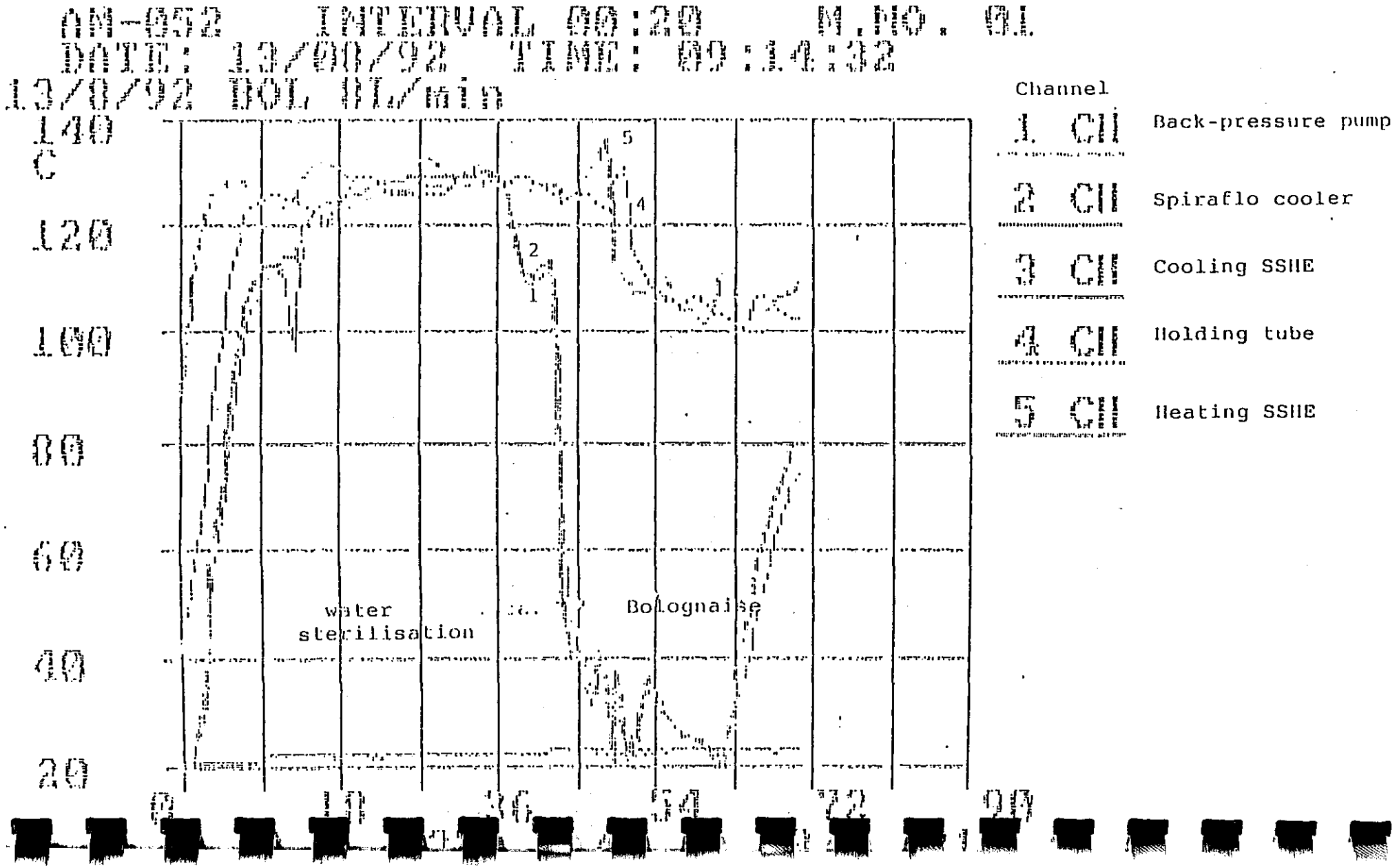
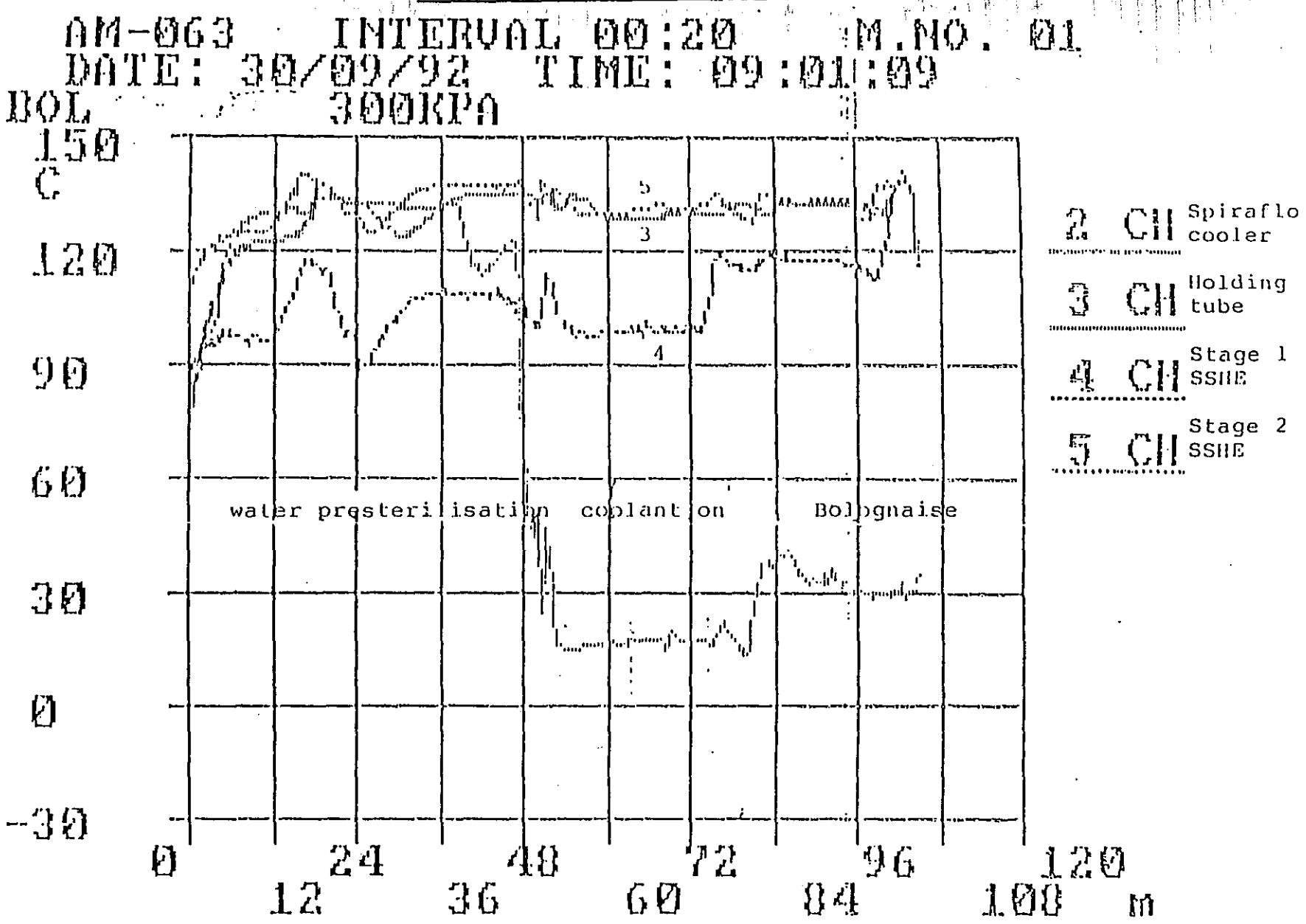


Figure 25 Bolognaise sterilisation (two heating stages)



Aseptic Bolognaise

Time/Temperature Graphs (Figure 26 to 32)

Channel codes in each graph are:

Channel 1 = temperature after back-pressure pump
Channel 2 = temperature after Spiroflo cooler
Channel 3 = temperature after holding tube
Channel 4 = temperature after 1st stage SSHE heater
Channel 5 = temperature after 2nd stage SSHE heater

Figure 26

Test: Bolognaise Rep 1
DATE: 01/12/92 TIME: 10:16:03
INTERVAL TIME: 20 SEC.
1 CH1
2 CH2
3 CH3
4 CH4
5 CH5
0
7
14
21
28
35
42
49
56
63
70
SEC

Figure 27

Figure 28

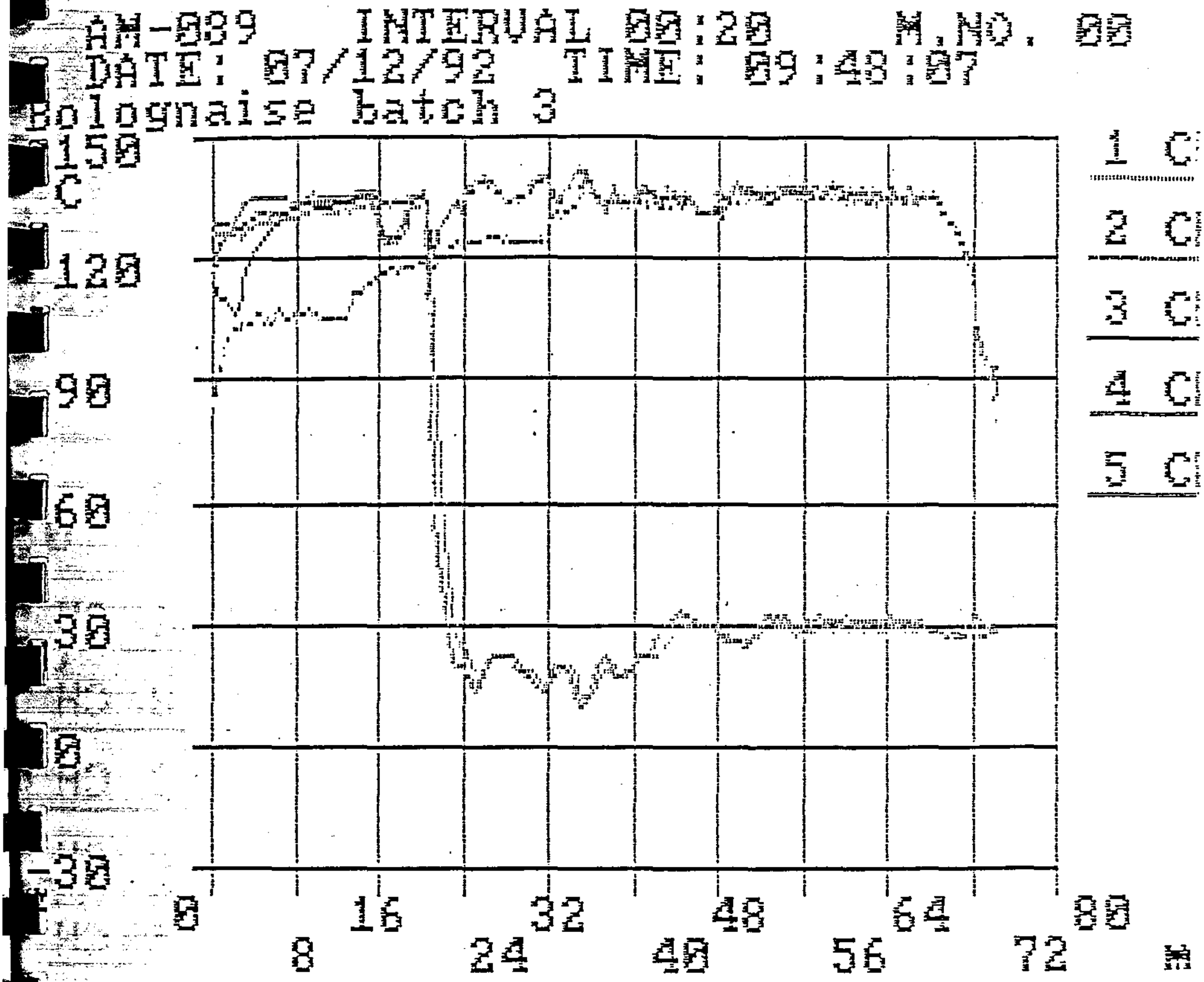

AM-039 INTERVAL 00:20 M.NO. 00
DATE: 07/12/92 TIME: 09:48:07
Bolognaise batch 3
150
C
120
90
60
30
0
-30
0
8
16
24
32
40
48
56
64
72
80
1 C
2 C
3 C
4 C
5 C

Figure 29

Figure 30

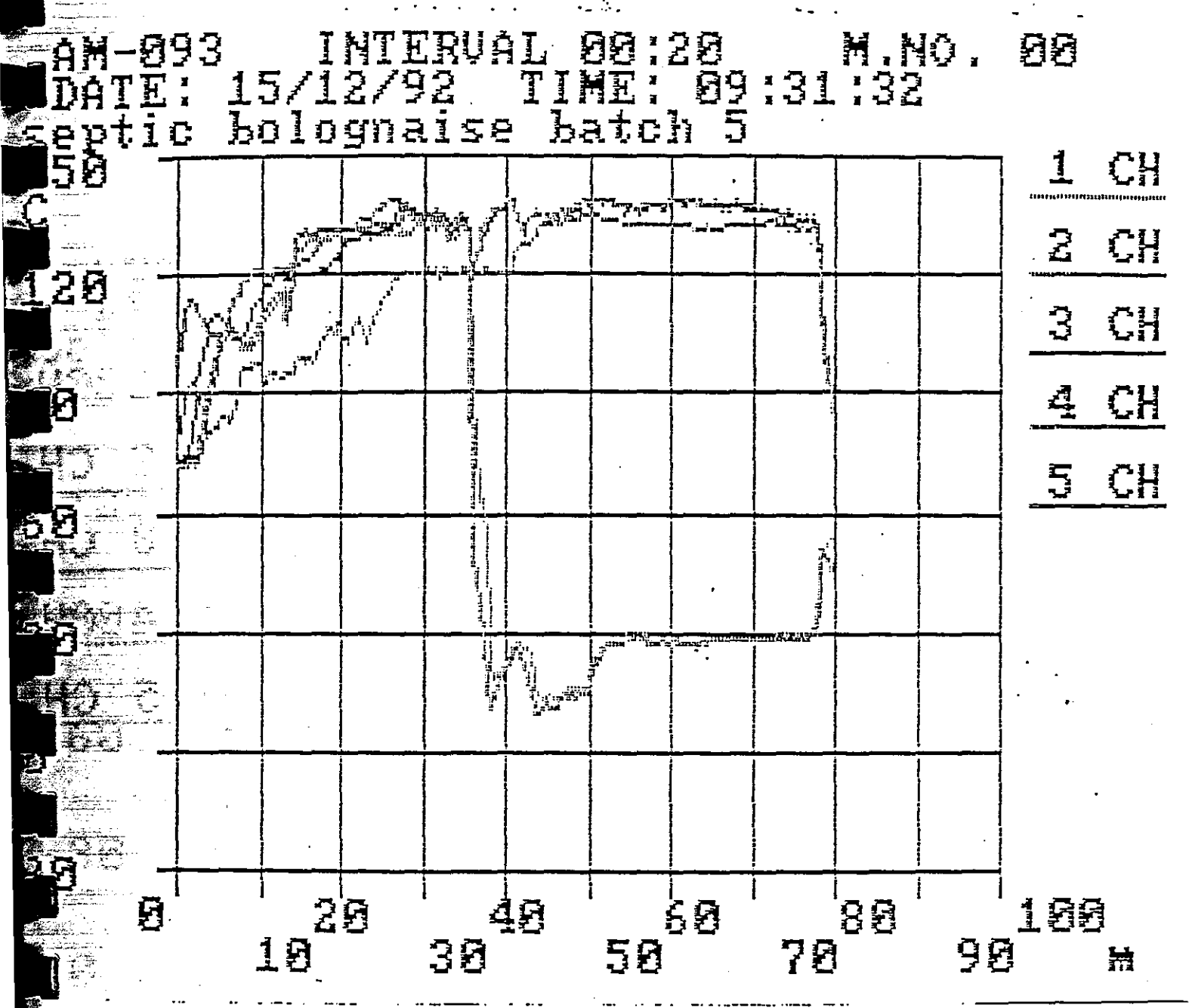
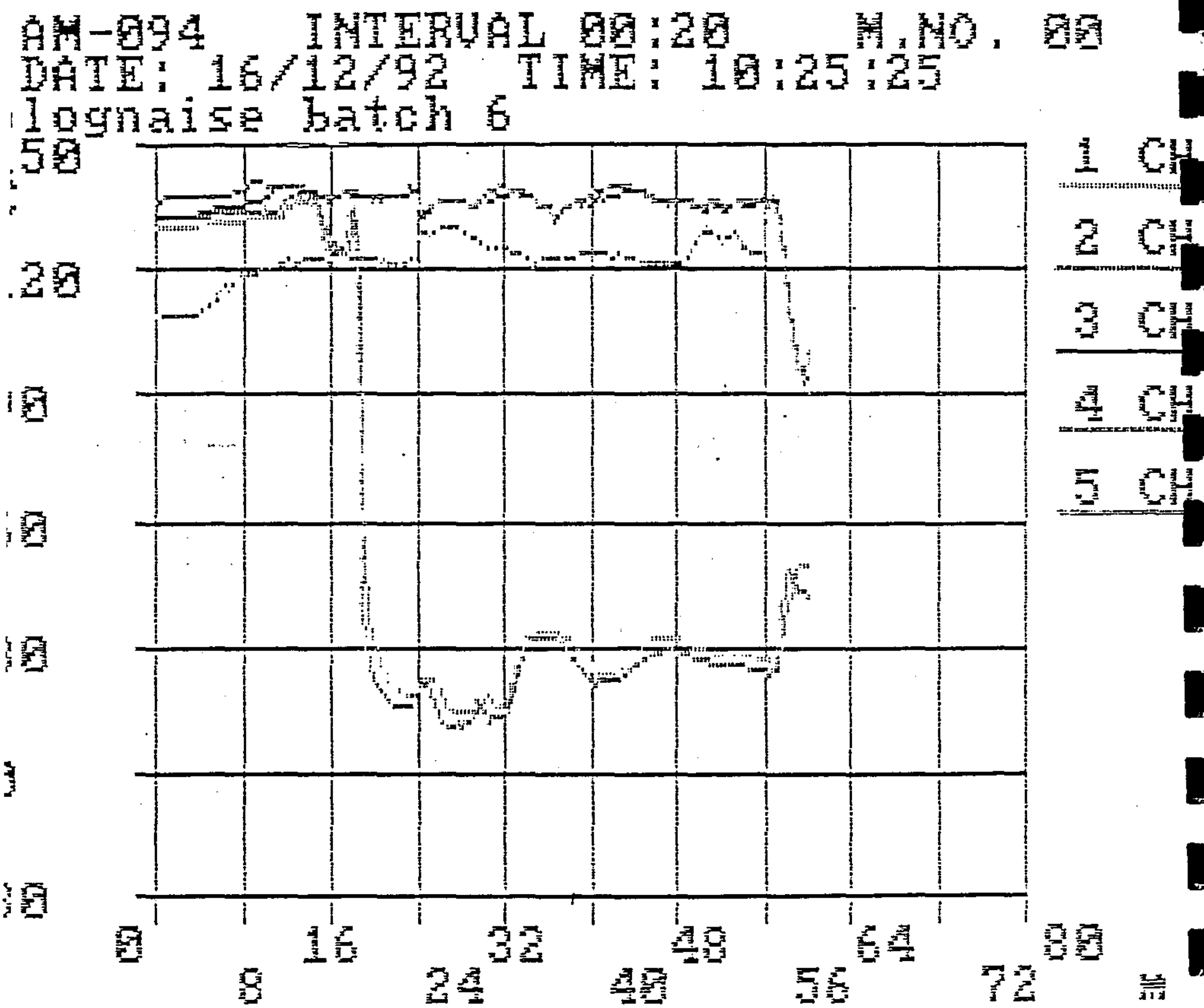
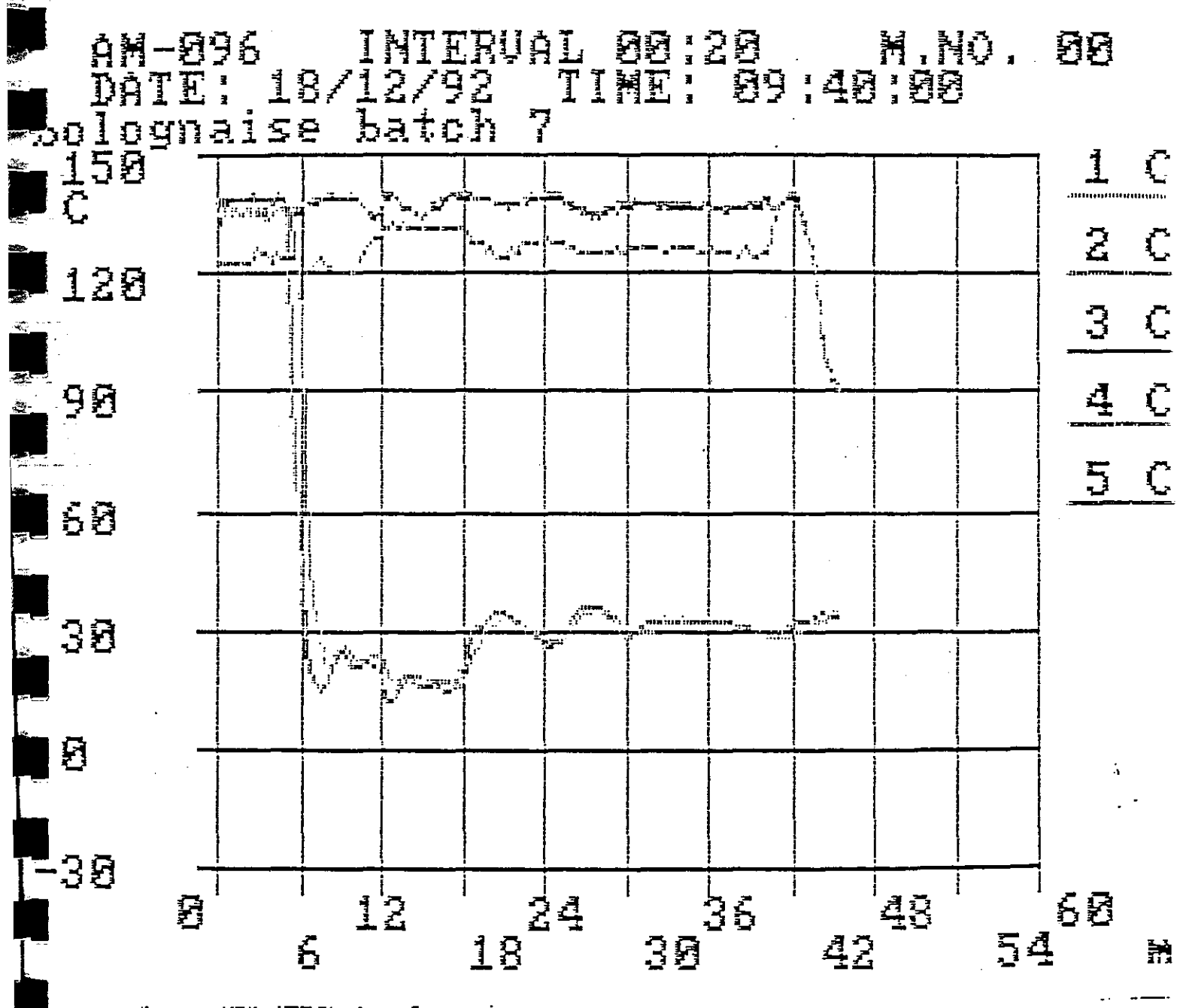

AM-093 INTERVAL 00:20 M.NO. 00
DATE: 15/12/92 TIME: 09:31:32
septic bolognaise batch 5
50
C
20
0
5
0
5
0
5
1 CH
2 CH
3 CH
4 CH
5 CH
0
20
40
60
80
100
10
30
50
70
90
m

Figure 31



AM-094 INTERVAL 00:20 M.NO. 00
DATE: 16/12/92 TIME: 10:25:25
lognaise batch 6
1 CH
2 CH
3 CH
4 CH
5 CH
0
8
16
24
32
40
48
56
64
72
80

Figure 32


AM-896 INTERVAL 00:20 M.NO. 00
DATE: 18/12/92 TIME: 09:40:00
Denaise batch 7
150
C
120
90
60
30
0
-30
6
12
18
24
30
36
42
48
54
60
1 C
2 C
3 C
4 C
5 C

The Intasept aseptic filler developed a mechanical problem caused by the lifting of the lining on the inside of the filler's volumetric controller. This was sent to the manufacturer in Melbourne for replacement (under warranty). However, the volumetric controller had to be redesigned in Sweden and this resulted in a delay of four months.

Upon its return the flow controller was still not functioning properly, although the filler was able to be manually operated, using the "fill interrupt" button. However, manual operation resulted in variation of bag volumes. The problem appears to have been caused by the hot water during presterilisation.

Microbial sampling of bolognaise sauce both prior to and post processing test runs was conducted on a regular basis. These samples included ones with and without the addition of spores embedded in alginate gel. Generally, the results indicated a low level of contamination even prior to scraped surface heat exchange treatment, and little contamination post processing. Results with spore beads indicated that the heat treatment the product received was sufficient to cause a 6-log reduction in *B. stearothermophilus* spore counts. Some break up of the gel beads occurred in the system, but meaningful spore counts were still able to be made.

Aseptically packaged bolognaise sauce

A Johnson lobe pump was used as the feed pump for the first batch of bolognaise. This proved unsatisfactory due to pressure fluctuations, caused by the slow speed of the pump. Subsequent runs were carried out using a smaller Wauhesha lobe pump, which resulted in greater pressure stability. Time-temperature data for each replicate batch are given in the attached graphs (Figure 26 to 32).

All samples received 3.5 minutes at a minimum of 130°C (equivalent to a minimum F_o = 27.1 for the liquid phase).

Several bags from each batch were sampled and plated for aerobic mesophiles and thermophiles, and for anaerobic mesophiles. The data are summarised in Table 12. The first two batches were suspect due to large pressure fluctuations during production, and because water was circulated through the secondary Spiroflo cooler to stop flashing, during presterilisation, which may have resulted in inadequate sterilisation. In subsequent batches, water was not circulated in the secondary cooler until sterilisation was complete.

Bacteria were absent in most samples from batches 3 to 7. Aerobes were detected in low numbers in several bags, and were identified as *Bacillus* species. Swabs of the filling gland surface of Intasept bags were free of microorganisms.

Initial examination of samples immediately after processing, indicated that the aseptic products were comparable to the frozen products in colour and flavour, but showed a loss of particle integrity and lower viscosity. This textural breakdown appears to be due to a combination of the effects of pumping, and the shearing action of the mutators in the scraped surface heat exchangers. It may also have been due to a changed source of supply of the tomato pulp, which had a lower viscosity. The canned product had a darker colour than the aseptic and frozen products, and also exhibited a "cooked" flavour.

Samples stored at 4°C for six weeks, showed no viable microorganisms in almost all samples. Counts for thermophilic and mesophilic aerobes, and mesophilic anaerobes are given in Table 13.

Objective data for particle content and colour (Hunter L, a, b values) are presented in Table 14 for five replicate batches of aseptic, canned, and frozen bolognaise.

Particle content was highest for the frozen product, while the canned and aseptic products had similar values. Examination of washed particles on a drained weight screen indicated that the aseptic particles appeared as intact as the particles in the canned and frozen products. However, the sauce was less viscous in the aseptic product. The Hunter measurements indicated that the aseptic bolognaise was lighter in colour than the canned product as shown by its higher L value. It was also more red and yellow as evidenced by the higher a and b values.

Table 12 Aseptically packaged bolognaise (unstored)

Microbiological counts (CFU/g)			
Bag Codes	**55°C (Aerobes)**	**30°C (Aerobes)**	**30°C (Anaerobes**
Batch 1 1/12/92			
13	<1	84	61
14	<1	2	<1
15	<1	1	<1
16	<1	Sp	4
17	1	<1	<1
18	<1	Sp	<1
Batch 2 2/12/92			
13	1	1	<1
14	<1	<1	<1
15	<1	6	<1
16	7	Sp	1
17	<1	<1	<1
18	1	<1	<1
Batch 3 7/12/92			
5	<1	18	<1
10	<1	<1	<1
15	<1	<1	<1
19	<1	<1	<1
25	<1	<1	<1
30	6	<1	<1
Batch 4 8/12/92			
1 (sample) (swab)	<1 <1	<1 <1	<1 <1
4 (sample) (swab)	<1 <1	1 2	<1 <1
10 (sample) (swab)	<1 <1	<1 <1	<1 <1
11 (sample) (swab)	<1 <1	<1 <1	<1 <1

Microbiological counts (CFU/g)			
Bag Codes	55°C (Aerobes)	30°C (Aerobes)	30°C (Anaerobes
20 (sample) (swab)	<1 <1	<1 <1	<1 <1
21 (sample) (swab)	<1	<1	<1
29 (sample) (swab)	<1 <1	<1 <1	<1 <1
30 (sample) (swab)	<1 <1	<1 <1	<1 <1
Batch 5 15/12/92			
1 (sample) (swab)	1 1	1 <1	<1 <1
5 (sample) (swab)	1 <1	1 <1	<1 <1
10 (sample) (swab)	<1 <1	<1 <1	<1 <1
19 (sample)	<1	<1	<1
20 (sample)	<1	<1	<1
21 (sample)	<1	<1	<1
Batch 6 16/12/92			
3 (swab) 3 (sample)	<1 Sp	<1 <1	<1 <1
6 (swab) (sample)	<1 <1	1 <1	<1 <1
12 (swab) (sample)	<1 <1	<1 <1	<1 <1
17 (sample)	<1	<1	<1
18 (sample)	<1	<1	<1
19 (sample)	3	Sp	1
20 (sample)	Sp	Sp	<1
Batch 7 18/12/92			
2 (swab) (sample)	<1 <1	<1 Sp	<1 <1
10 (swab) (sample)	<1 <1	<1 <1	<1 <1

Microbiological counts (CFU/g)			
Bag Codes	55°C (Aerobes)	30°C (Aerobes)	30°C (Anaerobes
14 (sample)	<1	<1	<1
15 (sample)	Sp	<1	<1
16 (sample)	1	<1	<1
17 (sample)	<1	<1	<1
20 (sample) (swab)	<1 <1	<1 <1	<1 <1

(Note: Sp = "spreader" colony)

Table 13 Aseptically packaged bolognaise (six weeks at 4°C)

Microbiological counts (CFU/g)				
Batch	**Bag No.**	**55°C (Aerobes)**	**30°C (Aerobes)**	**30°C (Anaerobes)**
Batch 1	**7**	<1	<1	<1
	8	<1	<1	<1
	9	<1	<1	<1
Batch 2	**7**	<1	<1	<1
	8	<1	<1	<1
	9	<1	<1	<1
Batch 3	**8**	<1	<1	<1
	9	<1	<1	<1
	11	<1	<1	<1
Batch 4	**7**	<1	2	<1
	8	<1	<1	<1
	9	<1	<1	<1
Batch 5	**6**	<1	<1	<1
	7	<1	1	<1
	8	<1	<1	<1
Batch 6	**8**	<1	1	<1
	9	<1	<1	<1
	10	<1	<1	<1
Batch 7	**7**	<1	<1	<1
	8	<1	<1	<1
	9	<1	<1	<1

Table 14 Bolognaise particle content and colour

Treatment	% Particles	Hunter colour		
		L	a	b
Rep 3				
Frozen	56.7	29.67	17.09	15.10
Canned	47.4	25.59	15.73	14.07
Aseptic	47.5	30.42	19.91	17.01
Rep 4				
Frozen	55.6	27.35	16.45	14.32
Canned	54.6	23.75	14.01	12.53
Aseptic	49.4	30.45	19.28	16.98
Rep 5				
Frozen	55.7	25.66	14.29	13.14
Canned	53.2	21.84	12.89	11.83
Aseptic	53.4	26.45	14.83	13.93
Rep 6				
Frozen	67.9	28.38	17.79	15.31
Canned	49.4	24.99	15.91	13.81
Aseptic	50.8	28.60	18.43	15.48
Rep 7				
Frozen	61.3	27.94	17.85	14.67
Canned	48.4	24.85	14.96	12.93
Aseptic	48.3	29.65	18.02	15.77
Mean				
Frozen	59.4	27.8	16.7	14.5
Canned	50.6	24.2	14.7	13.0
Aseptic	49.9	29.1	18.1	15.8

Sensory data are presented in Table 15.

Table 15 Aseptic bolognaise sensory data *

Parameter	Aseptic	Canned	Frozen
Bolognaise flavour (0 = none, 100 = high)	57.0 (a)	42.8 (b)	61.0 (a)
Saltiness (0 = none, 100 = high)	44.1 (a)	53.5 (b)	42.0 (a)
Other flavour (0 = none, 100 = high)	20.6 (a)	54.7 (b)	21.7 (a)
Consistency (0 = thin, 50 = ideal, 100 = thick)	31.8 (a)	46.3 (b)	44.6 (b)
Colour (0 = unacceptable, 100 = very acceptable)	59.4 (a)	38.9 (b)	60.4 (a)
Particle size (0 = small, 50 = ideal, 100 = big)	35.0 (a)	45.4 (b)	54.9 (c)
General appearance (0 = unacceptable, 100 = very acceptable)	55.6 (a)	40.2 (b)	61.2 (a)

* Means followed by the same letter are not significantly different ($p<0.01$).

These results show that the aseptically packaged bolognaise was rated above the canned product for flavour, colour, and appearance. The aseptic scores for these parameters, were only slightly less than for the frozen bolognaise. The aseptic bolognaise received lower scores for consistency and particle size, than the canned and frozen products.

Assessments of the bolognaise samples stored for six months at 25°C, had not been carried out at the time of termination of this project.

Chilled pasteurised bolognaise sauce

Microbiological data for pasteurised aseptically packaged, and hot-filled bolognaise sauce, stored at 4°C, are presented in Table 16. Mean data on colour, consistency, pH and odour are shown in Table 17.

Bolognaise was tested microbiologically for aerobic mesophiles and thermophiles, and for anaerobic mesophiles. Counts were low (less than 200/g aerobic mesophiles, no thermophiles or anaerobes) in both cases after two weeks at 4°C, and colour, odour and consistency were unchanged.

However, after three weeks, a "stale" odour was detected. Counts in the hot-filled cryovac bags had increased to 600 to 800/g aerobic mesophiles. Counts in the aseptically packed bags were 80 to 240/g, although one sample had a count of 16 000/g. After four weeks at 4°C, results were similar, although one of the Cryovac bags had a count of 24 000/g. The organisms present appeared to be *Bacillus* sp. It is concluded that this product has a shelf life of two weeks at 4°C.

Table 16 Chilled pasteurised bolognaise (stored at 4°C)

Microbiological counts (CFU/g)							
Storage time (4°C)	Bag No.	55°C (Aerobes)		30°C (Aerobes)		30°C (Anaerobes)	
		Aseptic	Hot-filled	Aseptic	Hot-filled	Aseptic	Hot-filled
0 (unstored)	1	<1	<1	40	120	1	14
	11	<1	<1	30	130	3	13
	6	<1	<1	30	130	<1	1
1 week	12	7	<1	50	40	<1	<1
	7	-	<1	-	10	-	<1
	2	23	<1	40	40	1	1
2 weeks	3	<1	<1	10	10	2	<1
	8	<1	<1	5	6	<1	<1
	13	<1	<1	10	11	<1	<1
3 weeks	4	<1	5	80	650	64	40
	9	3	5	16 000	580	40	<1
	14	<1	<1	240	760	2	36
4 weeks	5	2	2	60	40	<1	3
	10	<1	<1	40	24 000	3	3
	15	1	<1	200	30	2	<1

Table 17 Chilled pasteurised bolognaise (stored at 4°C)

Storage time (4°C)	Processing method	Hunter colour			Consistency (cm/min)	pH	Odour
		L	a	b			
0	Aseptic	32.08	17.47	15.27	2.5	5.1	normal
	Hot-filled	33.64	14.77	15.51	2.5	5.1	normal
1 week	Aseptic	35.60	17.63	16.39	2.2	5.1	normal
	Hot-filled	34.25	16.63	16.28	2.5	5.1	normal
2 weeks	Aseptic	35.40	17.22	16.68	2.3	5.1	normal
	Hot-filled	34.92	17.28	16.83	3.0	5.1	stale
3 weeks	Aseptic	35.61	17.76	16.71	2.5	5.0	stale
	Hot-filled	34.73	16.32	17.05	2.5	4.9	stale
4 weeks	Aseptic	34.05	16.84	15.92	2.5	5.0	stale
	Hot-filled	34.44	16.51	16.50	2.5	5.0	stale

- Development of aseptically packaged stew
- Pumping characteristics of the stew (preliminary trial)

- Preliminary pumping trial

Table 18 summarises the particulate size and component distribution data. Cubed raw meat was generally larger in length and breadth than the specification but acceptable in depth. Cubed boiled meat generally met the specification except that shrinkage of the flank resulted in cubes being smaller in depth.

None of the samples pumped had the correct component distribution after pumping. 67% of samples had a low sauce content, and a high meat and vegetable content. This was probably related to the preferential pumping of the sauce mixture at the beginning of each run. The product did not flow into the pump and for most trial runs, had to be forced into the feed tank opening. Modifications to the particulate/sauce ratio feedtank mixing system were therefore needed.

Table 19 summarises the assessment of particulate integrity after pumping. Sauce temperature did not appear to influence particulate integrity and so not all treatments were assessed. Parameters such as particulate/sauce ratio and starch viscosity seemed to be more important considerations. The raw flank and raw rib were damaged extensively during the pumping process. However there was better retention of particle integrity when flank was used as boiled meat. The integrity of brisket was similar regardless of whether the particles had been precooked or remained raw. Although cooked clod was not assessed, it is assumed that this meat would have a similar integrity after pumping as the raw meat. Cooked rib was not assessed because of the extensive damage that occurred to the raw rib. Cooking of the meat would not increase the resistance to physical damage. Potato and carrot particulate integrity was variable.

It was concluded that cubed raw flank and rib meat strips were not suitable for pumping applications. However raw and cooked clod and brisket, and cooked flank maintained a high degree of integrity after pumping. Potato and carrot particulate integrity was variable, while onion integrity was consistently high. While the pump used in this study was suitable for this application, further experimental work was required on particulate/sauce ratio, starch base and feedtank mixing systems.

Table 18 Particulate size and component distribution data

Parameter	Units	Meat							
		Clod		Flank		Brisket		Rib	
		Raw	Boiled	Raw	Boiled	Raw	Boiled	Raw	Boiled
Measurement No. 1									
Mean	mm	19.3	12.5	20.6	12.6	17.4	N/A	30.7	28.4
Standard deviation	mm	3.91	2.41	4.00	4.71	3.58	N/A	17.1	10.6
Minimum	mm	12.0	8.0	12.0	4.0	10.0	N/A	12.0	11.0
Maximum	mm	27.0	17.0	27.0	21.0	25.0	N/A	80.0	52.0
Difference to specification	-	Yes	No	Yes	No	Yes	N/A	No	No
Measurement No. 2									
Mean	mm	20.8	17.3	22.6	20.0	20.7	N/A	103.0	72.6
Standard deviation	mm	4.61	3.23	4.79	6.50	2.33	N/A	48.95	25.27
Minimum	mm	11.0	7.0	16.0	10.0	18.0	N/A	45.0	32
Maximum	mm	28.0	20.0	30.0	31.0	27.0	N/A	207.0	130
Difference to specification	-	Yes	Yes	Yes	Yes	Yes	N/A	No	No
Measurement No. 3									
Mean	mm	17.6	13.2	14.3	14.3	17.8	N/A	31.6	28.8
Standard deviation	mm	3.93	3.49	5.98	5.98	3.49	N/A	12.22	8.42
Minimum	mm	9.0	9.0	6.0	6.0	11.0	N/A	14.0	13
Maximum	mm	23.0	23.0	30.0	30.0	27.0	N/A	70.0	43
Difference to specification	-	Yes	No	No	No	Yes	N/A	No	No
Measurement No. 4									
Mean	mm	13.4	10.1	12.7	8.6	12.6	N/A	2.6	3.8
Standard deviation	mm	2.89	4.15	2.66	2.60	2.97	N/A	1.25	3.1
Minimum	mm	10.0	3	9.0	5	8.0	N/A	1	1
Maximum	mm	20.0	18	17.0	15	18.0	N/A	6	11
Difference to specification	-	No	No	No	Yes	No	N/A	Yes	Yes

Parameter	Units	Meat							
		Clod		Flank		Brisket		Rib	
		Raw	Boiled	Raw	Boiled	Raw	Boiled	Raw	Boiled
Measurement No. 5									
Mean	mm	11.9	9.8	13.2	8.9	10.5	N/A	2.4	3.6
Standard deviation	mm	4.48	5.51	3.21	2.90	2.81	N/A	1.2	2.0
Minimum	mm	2	3	9.0	3.0	5	N/A	1	1
Maximum	mm	18	28	20.0	14.0	16	N/A	5	8
Difference to specification	-	No	No	No	Yes	No	N/A	Yes	Yes
Component Distribution									
Sauce	%	34.6	N/A	51.6	39.5	41	N/A	39	N/A
Meat	%	32.7	N/A	23.2	21	22	N/A	23	N/A
Vegetables	%	32.7	N/A	25.2	39.5	37	N/A	38	N/A

Table 19 Subjective assessment of particulate integrity after pumping

Product treatment	Comments
Raw Clod 50°C	Less than 5% of meat particulates damaged, onion integrity high, greater than 50% of potato and carrot particulates damaged.
Raw Clod 60°C	Less than 5% of meat particulates damaged, onion integrity high, approximately 25%-50% of potato and carrot particulates damaged.
Raw Flank 50°C	Greater than 75% of meat particulates damaged, damaged pieces contained fat which had separated from the lean or was connected tenuously, onion integrity high, maximum 25% of potato and carrot particulates damaged, potato had higher incidence of damage than carrot.
Raw Brisket 60°C	Approximately 20% of meat particulates damaged, damaged pieces contained fat which had separated from the lean or was connected tenuously, onion integrity high, maximum 25% of potato and carrot particulates damaged, potato had higher incidence of damage than carrot.
Cooked Flank 60°C	Approximately 20% of meat particulates damaged, damaged pieces tended to be those containing fat, onion and carrot integrity high, approximately 10% of potato particulates damaged.
Cooked Brisket 60°C	Approximately 25% of meat particulates damaged, onion and carrot integrity high, approximately 60%-70% of potato particulates damaged.
Raw Rib 60°C	Approximately 90%-95% of meat particulates damaged, meat pieces tore lengthwise resulting in a stringy appearance, onion, potato and carrot integrity high.
Cooked Clod 60°C	No data.

- Aseptically packaged stew

Test runs were carried out on a model "stew" of starch and potato cubes through the aseptic processing plant. These runs were delayed for four months, due to problems with the Intasept aseptic filler. The results were as follows.

Run 1 Effect of particle concentration

Formulations were (a) 40% 8mm potato cubes + 3% Fieldclear 714 + 3% Mazacca 3543 x and (b) 30% 8mm potato cubes + 3% Fieldclear 714 + 3% Mazacca 3543 x. Formula (a) became clogged in the feed pump inlet. Formulation (b) flowed freely through the system.

Run 2 Effect of starch concentration

Formulations were (a) 30% 8mm potato cubes + 2% Fieldclear 714 + 2% Mazacca 3543 x and (b) 30% 8mm potato cubes + 3% Fieldclear 714 + 3% Mazacca 3543 x.

Formulation (a) separated in the last stage of the Spiroflo heat exchanger (although no coolant was circulating). As a result, the potato cubes clogged up the Spiroflo tube. Formulation (b) flowed through without any separation. Thus, a high viscosity carrier is needed to prevent particle separation in this product. (Formulation (b) contained the maximum modified starch concentration permitted for thermally processed meat products.)

Run 3 Effect of changing from water to product

The formulation used was 30% 8mm potato cubes + 3% Fieldclear 714 + 3% Mazacca 3543 x. Particles were completely intact after the feed pump, scraped surface heat exchangers, and cooling tubes. However some breakup (approximately 10%) was evident after the back-pressure pump. The "stew" flowed through the aseptic filler without any clogging or blockage problems.

Run 4 Effect of changing from water to product

Water was first circulated through the system with a mono pump to simulate normal presterilisation. "Stew" was then pumped through with a lobe pump. Back pressure for the water was controlled with a pressure relief valve, but this clogged with particles before flow could be diverted to be controlled by the back-pressure pump. To overcome this problem, starch solution was introduced prior to the "stew". Once starch solution appeared at the end of the line (i.e. after the pressure relief value), flow was diverted to prevent any particles clogging the valve. The high viscosity of the starch was sufficient to prevent slippage occurring at the back pressure pump. This eliminated the need for particles to flow through the pressure relief value at the end of the line. However, pressure fluctuations were difficult to control, and further tests are needed.

Run 5 Effect of heating and cooling

This run was aimed at testing the effect of heating the "stew" to 130°C, holding, and cooling to ambient temperature. Coolant was circulated through the Spiroflo heat exchanger, before steam was admitted to the scraped surface heat exchangers. Blockage occurred in the cooling tubes, as the temperature of the "stew" fell to 8°C, and the starch

viscosity increased. This could be overcome by applying heat, before the coolant, thus preventing a big product temperature drop.

Further test runs are needed to refine processing conditions for the model "stew", before producing replicated batches of the actual product. This is because the flow properties of the stew are considerably different to the bolognaise (due to particle size and compositional differences).

Summary

A product containing small-sized particles, bolognaise sauce was sterilised (130°C/3.5 minutes) in a scraped surface heat exchanger, cooled in a tubular Spiroflo heat exchanger, and aseptically filled into sterile nylon-foil laminate Intasept bags. Quality was measured by microbiological plate counts, colour (Hunter L, a, b) particle content and sensory evaluation. The aseptically packaged product had better flavour, colour and appearance then the canned product, and was only slightly inferior to frozen bolognaise for these attributes. However, the aseptic product received lower scores for consistency and particle size than canned and frozen bolognaise. A chilled pasteurised bolognaise sauce was also processed by aseptic packaging, and by hot-filling into Cryovac bags. The storage life of the chilled product was 2 weeks at 4°C.

Experiments were carried out on a model "stew", containing potato cubes and a modified starch "sauce". A sauce of high viscosity was found to be necessary to suspend the particles, and prevent problems of separation and slippage. A maximum particle content of 30% was able to be pumped through the aseptic processing line. However, some pressure fluctuations were encountered.

5. SUCCESS IN ACHIEVING OBJECTIVES

The first three objectives (section 2) were largely achieved for the small-sized particulate product, bolognaise sauce but not for larger particulate meat and vegetable stews. This was mainly due to unforseen equipment problems, which caused considerable delays in the project. These problems largely were beyond the control of the research team. Such problems with new technologies are likely to occur but are difficult to anticipate. The lack of an engineer in the research team (except for a short period) and the loss of the specialist meat technologist, added to these problems.

The fourth objective (section 2) 2.4 was partially achieved by the commercial partner in the project, Kudos Meat Products Pty Ltd through visits to Japanese and domestic markets. However, progress was impeded by lack of samples of products. The remaining two objectives were not achieved as the project was terminated prematurely.

The project was evaluated by both a cost-benefit analysis and technical audit, early in 1993. Several of the criticisms in the technical audit were considered not to be warranted, and a response to these from the IFIQ research team is given in Appendix 3.

6. INTELLECTUAL PROPERTY

The intellectual property arising from this project to date is as follows:

- Development of a method to prepare alginate gel cubes included with spores of *Bacillus stearothermophilus*.

While there have been publications on small beads (Dallyn *et al.*, 1977 and Sastry *et al.*, 1988), the modification and application to larger cubes in this project is original, to the best of the research team's knowledge.

7. COMMERCIAL EXPLOITATION OF RESULTS

There has not been any commercial exploitation of the results obtained to date. Aseptically packaged bolognaise was found to have better quality than canned bolognaise for colour, appearance, and flavour, but not for textural parameters. It was not better than frozen bolognaise for any quality attributes. Therefore, there may not be a quality advantage in aseptically packaging this product, although there are economic (bulk packaging) and convenience benefits.

Preliminary data only were obtained on a larger particulate stew product, and more research and development is needed before any results can be commercialised.

It is the belief of the project team that it is technically feasible to produce a shelf-stable, larger particulate product with scraped surface heat exchanger technology coupled with aseptic packaging and that commercialisation of such a process can be expected in the next few years.

8. IMPACT ON MEAT AND LIVESTOCK INDUSTRY

This project has not had any impact on the industry at the time of writing this report. However, as indicated in Section 1, there is considerable potential for export of aseptically packaged, meat based particulate stews and curries to Japan, as well as a domestic market for bolognaise sauce.

The research team believes it is possible to produce these shelf-stable particulate products by the technology used in this project. Thus after further research and development, as well as market research, the work performed in this project could have substantial impact on the industry.

9. TOTAL FUNDING AND MRC CONTRIBUTION

- Total funding (October 1990 to June 1993) = $1 034 823

- MRC contribution

Capital equipment	=	$ 55 000
Salary	=	$107 356
Operating	=	$ 99 748
MRC Total	=	$226 104

- Estimated DPI contribution

Capital equipment	=	$150 000
Salaries & Overheads	=	$658 719
DPI Total	=	$808 719

* **Note:**

DPI "Salaries and overheads" were estimated by the following formula.

DPI salary and overheads contribution = (Total base salaries (DPI + MRC) x 3.5) - MRC salary and operating

= (247 378 x 3.5) - (107 356 + 99 748)

= 865 823 - 207 104

= 658 719

10. CONCLUSIONS

The project indicated that scraped surface heat exchanger/aseptic packaging technology was technically feasible for bolognaise sauce, a meat-based product with small-sized particles. This product sterilised at 130°C/3.5 minutes, has better flavour, colour, and appearance than canned bolognaise. However, textural parameters (consistency and particle size) were inferior to canned and frozen products. Although this indicates no overall quality advantage for the aseptically packaged product, any disadvantages may be offset by the economic advantages of bulk packaging and, reduced storage and transport costs.

Pasteurised (i.e. not sterilised) bolognaise had a shelf life of two weeks at 4°C. There was no quality advantage of aseptic packaging over hot-filling and tumble-cooling for this storage time.

This research shows that alginate gel cubes embedded with spores of *Bacillus stearothermophilus* could be used as indicators of heat sterilisation of particulate foods, in scraped surface heat exchangers. However, heat penetration into gel cubes was more rapid than into some food particles. More data are needed to ensure the gel cubes can be used to accurately establish a safe process for low-acid particulate foods.

An aseptically packaged "stew" containing larger particles required a sauce with high viscosity to suspend the particles and prevent problems of separation and slippage. The maximum particle content of product which could be pumped through the aseptic processing system was 30%. However some pressure fluctuations were encountered. Further research and development is required to complete the process development of an aseptically packaged beef and vegetable stew containing large particles.

Markets were identified for aseptically packaged beef-based stews/curry in Japan, and aseptically packaged bolognaise in Australia. Provided that product quality can be achieved an economically viable aseptic processing operation could be established. Further market research including assessment of products by potential customers will be necessary before these products can be produced commercially.

11. MEDIA COVERAGE

An article in "Foodweek" (26/5/92, page 12) included press coverage of this project, as part of the "Value-added processed meat seminars" held in Brisbane, Sydney and Melbourne during May 1992. This is attached as appendix 4.

12. PUBLICATIONS

Publications to date are as follows:

Isaacs, A.R. and Rogers, S. (1991) "Aseptic processing of foods containing particulates" Convention papers, 24th Annual Convention of the Australian Institute of Food Science and Technology, Hobart, July 1991, p 90-04.

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13. ACKNOWLEDGMENTS

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The project team also wishes to thank the following IFIQ staff: Hilton Deeth and Bill Dommett (for advice and general supervision at various stages of the project), Anne Ford (for sensory assessment), Ian Durward (for thiobarbituric acid analyses), and Stephen Nottingham (for statistical analyses).

We also thank Ray Byrnes and Jenny Shorter of Beef Industry Services, DPI Agricultural Production Group, for administrative advice and assistance.

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Appendix 1 REPORT BY KUDOS MEAT PRODUCTS PTY LTD ON A VISIT TO JAPANESE FOOD PROCESSORS

Progress report

DAQ.071 Assessment of scraped surface heat exchanger technology for the development of extended shelf-life meat products.

Details of milestones 4 and 6

Milestones 4 and 6 have been worked on together and the following potential clients have been visited by the Managing Director of Kudos Mr R.L. Beaver.

Export Nitto Food Products Co Ltd

This company is a leading Japanese Canner of meat products, with whom Kudos has been conducting business for the last four years. The project was discussed with Mr Harry Ono Director of the Company and Import Manager Mr Machida.

Nitto are interested in the concept of aseptic packaging and would be pleased to see samples of products at a later stage. Because of our good relationship there is a strong possibility of obtaining technical assistance from them in developing the proposed products.

Otsuka chemical company

This is the largest producer of retort curry packs and both the Senior Executive Director of Purchasing Dept Mr Otsuka and Supply General Manager Purchasing Dept, Mr Nadaguchi were aware of the technology when visited by Mr Beaver. The impression was gained that there would have to be very definite product improvements and or cost savings compared to their present flexible retort product before they would be interested. Kudos has been supplying this company for the last 2.5 years.

Housefoods

This is the second largest producer of retorted curry packs. During my visit in September 1991 they showed polite interest. This was an introductory visit and to date we have not conducted business with this company.

Ezaki Glico Co Ltd

Japan's fourth largest curry manufacture.

The technical manager Mr Matsuda has shown considerable interest in the project and

Kudos took him to IFIQ for a presentation. There is a positive interest from the Company and when samples can be produced and technical information produced we would expect to be able to work closely with them to develop specific products.

Bell Foods Co Ltd

The Chief Manager R&D Mr Tsujimoto has shown interest in aseptic packaged products and during his last visit to Kudos took the time to inspect the IFIQ establishment and discuss the project and expressed willingness to work with us when the project is more advanced.

Design Foods Co Ltd

The Principal of this company Mr Kato is a consultant to Supermarkets, Institutional Feeders and, Restaurants. Mr Kato is interested in the development of products for Institutional catering. Not being a manufacturer it gives the product an opportunity to promote an Australian Brand name into the Japanese Market.

Summary

Most of the major Japanese food processors are aware of aseptic packaging. However we will not be able to generate real interest until we can provide samples to show the quality benefits.

Domestic

Collins Foods International (Sizzler)

We have approached Collins Foods and acquainted them with the project and have shown interest particularly with their sauce type products, the volume of which is growing steadily. They have provided us with their confidential recipes for two of their sauces and these have been passed on to IFIQ for development.

Appendix 2 ECONOMIC EVALUATION OF ASEPTIC PACKAGING (LITERATURE REVIEW)

Introduction

Heat processed products (canned, retort-pouched, and aseptically) are stored at ambient temperature, and therefore storage costs are lower than for frozen foods. Aseptically packaged products have the additional economic advantage of virtually unrestricted package size. Aseptic bulk packaging is possible as the heat process is independent of pack size, unlike conventional canning.

According to Reuter (1989), the reasons for the rapid growth of aseptic processing technology are:

- Improved product quality due to low thermal damage;
- Low production and packaging material costs;
- Low transport and storage costs;
- Packaging formats designed to meet requirements enhance the attractiveness of Aseptically packaged products;
- The convenience aspect of the product.

Key areas for economic evaluation are energy usage, packaging cost, product throughput rate, and capital equipment costs. (Sczemplenski, 1988).

In this report, an economic comparison of aseptic processing and conventional processing, is made. Comparisons on the basis of product quality and technology have been made previously (Rogers and Isaacs, 1991).

ECONOMIC EVALUATION: ASEPTIC vs CONVENTIONAL PROCESSING

Energy consumption during processing, packaging, storage, and transport has been compared for aseptically packed, canned, and frozen foods. (Gadsden Rheem, 1991). Comparative data in KWh/tonne for the aseptic "Combibloc" pack and conventionally processed foods, are shown in table 1.

Table 1 Comparative energy consumption (KWh/tonne)

	Canned Foods		Frozen Foods		Aseptic
	Steel Cans	Glass Jars	Poly Bags	Cartons	Cartons
Processing	1,860	1,860	315	315	500 (approx)
Packaging Material	3,880	6,240	1,360	1,800	2,500 (approx)
Storage	120	120	1,740	1,740	120
Transport (500 Km)	230	230	160	160	160
Consumer storage	-	-	720	720	-
Total	6,090	8,450	4,295	4,735	3,280

(Source: Gadsden Rheem, 1991)

The data indicate that conventional canning incurs the highest processing and packaging energy use, but low storage consumption. Freezing has low processing and packaging energy use, but high energy consumption during storage. Energy consumption during aseptic packaging is lower than canning but greater than freezing for processing and packaging. Energy consumption during storage is lower than freezing, and similar to canning. Toledo and Chang (1991) compared steam and electricity consumption for a product throughput of 2,275 kg/hr. Steam consumption was 0.21 kg/kg of product for canning compared with 0.14 kg/kg of product for aseptic processing. This represented a saving of $US 1-20/hr. However, electricity costs for conventional canning were negligible compared with a power consumption of 0.0374 KWH/kg for aseptic processing. This represents a comparative loss of $US 5-91/hr for aseptic processing.

A comparison of packaging costs was also reported for three pack styles:- retail pack (226 g), institutional pack - acidic product (3 kg), and institutional pack - low acid product (3 kg). Comparative figures in $US are given in table 2.

Table 2 Comparative packaging costs ($US)

Pack Style	Canning	Aseptic packaging	Saving with aseptic processing
Retail (226 g)	0.085	0.065	324/hr
Institutional (acidic - 3 Kg)	0.45	0.20	540/hr
Institutional (low acid - 3 Kg)	3.05	1.65	347/hr

(Source: Toledo and Chang, 1990)

From this data, there are considerable cost savings with aseptic packaging, especially for institutional packs. The above authors also compared with installation and payback costs for the three types of aseptic packages (table 3).

Table 3 Installation and payback data

Aseptic system	Installation cost ($US)	Payback (yrs)
Retail	3,500,000	3.7
Institutional (acidic - 3 Kg)	750,000	2.0
Institutional (low acid - 3 Kg)	22,000,000	1.1

(Source: Toledo and Chang, 1990)

Institutional low acid packs had the highest installation costs. However, the added value in terms of convenience and better quality should allow these products to achieve higher prices and profit margins. Szemplenski (1988) compared the equipment installation costs for conventional canning and aseptic packaging of low acid foods. A conventional batch canning system utilizing four horizontal retorts, could be installed for well under one million dollars (US). A continuous system, utilizing a hydrostatic cooker, would cost about two million dollars (US). An aseptic filling system, of similar capacity would cost up to four million dollars (US). The capital cost of an aseptic low acid particle sterilisation system with a throughput of 1,000 kg/hr would cost about one million dollars (A), excluding the cost of product mixing tanks and the aseptic filler. (Heat and Control, 1990). Of course, aseptic packaging costs vary widely according to the type of filler, product throughput, and packaging material used.

Rose (1986) calculated comparative costs for aseptic and conventional heat processing lines, based on a throughput of 3,000 kg/hr (table 4). The figures indicate aseptic packaging had lower costs for energy, labour, labelling, and packaging, but higher charges on capital.

Table 4 Comparative heat processing costs

	Aseptic continuous £/1000 cartons	Batch retort £/100 cans	Continuous cooker/cooler £/1000 cans
Charges on capital	4.8	0.46	0.74
Energy	2.5	9.0	6.5
Labour	7.5	17.5	10.0
Label	0	6.0	6.0
Package	40	70.0	70.0
Chemicals	0.08	0	0
Total	54.88	102.96	93.24

Assumptions:
- Capacity 6,000 packages/h
- 0.5 kg/pack
- Same product
- Capital ROI = 15% pa
- 250 working days at 20 h

(Source: Rose, 1986)

A cost comparison of canned,bottled, and aseptically packaged fruit juice, found aseptic packaging to be the most economic alternative. (Anon, 1983). The figures, in $US per 4, 550L, are shown in Table 5.

Table 5 Costs in US$ for juice-packaging systems

Operation	Aseptic 1-litre flex. carton	Glass bottle (1,136 mL)	(2.27 L)	Steel can (1.31 Kg)
Processing	16.81	8.89	5.51	3.83
FILLING				
In-plant Costs	31.90	38.88	23.94	19.06
Package Costs	371.00	812.00	730.00	974.00
Total filling Costs	402.90	850.88	753.94	993.06
Casing	93.02	192.34	180.77	121.36
Case Handling	8.14	25.84	12.92	5.36
Plant Storage	7.15	18.04	9.93	4.87
Transport to Whse.	120.88	162.50	160.38	126.13
Warehouse Storage	4.19	4.44	4.76	4.15
Transport to Retail	12.09	16.25	16.04	12.61
Retail Storage	1.75	1.82	1.95	1.74
Retail Display	1.33	79.36	59.41	55.57
TOTAL	$668.26	$1360.36	$1205.61	$1328.68

Costs represent capital and operating expenses. Capital costs include equipment (3 yrs. @ 17%) and buildings (20-yr payout, no financing). Operating costs include leasing, labelling, individual containers, packing (shipping) materials, maintenance, labor, electricity, steam, water, and transportation.

(Source: Anon, 1983)

Aseptic packaging had the lowest costs for packaging, filling, transport to the warehouse and retail outlet, and retail display. However, processing costs were two to five times higher than for conventional methods.

A comparison of retort pouched products versus conventional canning, in terms of energy requirements and costs, has been reported by Steffe *et al* (1980). Retort pouches have an energy saving potential over conventional cans with regard to container manufacture, transport, and processing. In this study, figures, were based on spinach processed in steel cans and laminate retort pouches. The data are shown in Tables 6 and 7.

Table 6 Estimated processing energy use in each of three systems processing 43.3 metric tons of raw spinach per 8 hr shift

		Energy Usage	
System	**Operation**	**Electrical (kw-hr)**	**Thermal (steam) (GJ)**
Canning line (303 x 406 cans)	Filling	6.0	-
	Can closing	60.0	4.7
	Retorting	0.2	20.7
	Total	66.2 (0.7 GJ)	25.4
Retort pouch line (15.3 cm x 20.3 cm pouches)	Form/fill/seal	800.0	4.7
	Retorting	0.1	5.2
	Drying	223.5	-
	Cartoning	53.7	-
	Total	1077.3 (11.9 GJ)	9.9

(Source: Steffe *et al*, 1980)

From Table 6, electricity usage for processing in retort pouches was much higher than for conventional canning. However, thermal energy consumption (mainly steam) was lower than for canning.

Table 7 Estimated processing energy costs involved in processing 43.3 metric tons spinach per 8 hr shift (1985)

	Costs (in 1980 dollars)	
System	**Electrical energy**	**Thermal energy (steam)**
Canning line		
Filling	0.3	-
Can closing	2.9	18.0
Retorting	-	79.3
Total	3.1	97.3
Retort Pouch line		
Form/fill/seal	38.1	18.0
Retorting	-	19.9
Drying	10.6	-
Cartoning	2.6	-
Total	51.3	37.9

(Source: Steffe *et al*, 1980)

From table 7, electricity costs for retort pouches were higher than for a conventional canning line. Steam usage costs were in reverse order.

The interaction of packaging material and cost is shown graphically in figure 1 (Rose, 1986). Conventional packs (eg can, bottles) were more economic for small fill weights (less than 5 Kg). For large packs (greater than 20 Kg), aseptic "bag-in box" systems were more economic.

Smittcamp *et al* (1981) evaluated energy and packaging costs for aseptically processed beverage syrups, toping, pancake syrups, piefillings, preserves, and jellies. Packaging costs were greatly reduced in comparison with institutional size cans. Energy costs for heating and cooling the product were reduced by 30%.

Figure 1 Packaging material cost comparisons

(Source: Rose, 1986)

COMPARATIVE THERMAL PROCESSING COSTS IN AUSTRALIAN CURRENCY

Costs extracted from tables 2, 4 and 5 were first inflated to 1991 prices (at a rate of 10% p.a.) and then converted into Australian dollars at current conversion rates (A$1=US$0.80= UK£0.46).

Table 8 shows comparative heat processing costs for aseptically packed, and canned products processed by batch and continuous retort processes. Capital costs are highest for aseptic packaging and lowest for batch retorting. Energy and labour costs are lowest for aseptic packaging, and highest for batch retorting. Labelling and packaging costs are lowest for aseptic packaging. there is a slight cost for chemical with aseptic packaging. There is a slight cost for chemicals with aseptic packaging, but none for canning. Overall, aseptic processing costs are less than 60% of canning costs.

Table 9 shows comparative transport, storage, and retailing costs for aseptically packed, and conventionally packed cans and glass bottles. Carton handling and storage and transport costs are highest for glass jars and lowest for cans. Warehouse storage costs are lowest for cans and highest for aseptic cartons. Glass have the highest retail transport costs, and cans the lowest. Retail storage costs are highest for aseptic cartons and lowest for cans. Retail display costs are highest for glass containers, and lowest (by a great deal) for aseptic cartons. Overall, these costs are highest for glass containers, and lowest for aseptic cartons.

Table 10 shows comparative costs for package size. In all cases, aseptic packaging has lower costs than canning, and the differences are greater for institutional size than retail size packages.

Table 8 Comparative heat processing costs* (in 1991 $A)

Item	Aseptic	Batch Retort	Continuous Retort
Charges on capital	16.74	1.60	2.55
Energy	8.73	31.42	22.69
Labour	26.18	61.13	34.95
Labelling	0	20.94	20.94
Packaging	139.73	244.54	244.54
Chemicals	0.27	0	0
Total	191.65	359.63	325.67

(*3,000 kg/hr throughput, 500g packages)

Table 9 Comparative transport and storage costs (in 1991 $A)

Item	Aseptic Carton	Glass Bottle	Steel Can
Carton handling	21.79	60.93	10.95
Factory storage	19.15	42.53	9.93
Transport to warehouse	323.81	383.06	257.90
Warehouse storage	11.22	10.46	8.47
Transport to retail	32.37	38.31	25.76
Retail storage	4.68	4.28	3.56
Retail display	3.56	187.14	113.64
Total	416.58	726.71	430.21

(*per 4,550 L, 1 L packages)

Table 10 Comparative pack sizes (in 1991 $A)

Item	Aseptic	Canned
Retail (226 g)	0.08	0.12
Institutional - Acidic (3 kg)	0.27	0.62
Institutional - Low acid (3 kg)	2.26	4.19

CONCLUSION

Overall, aseptic packaging appears economically viable for high throughout, bulk (institutional) packs. Advantages of low steam consumption, low package cost, and high quality have to be balanced against the disadvantages of high capital cost, and high electricity usage.

The economic advantages would appear to favour exported bulk aseptic particulate products. However, for retail-pack, low volume products, conventional packs may be more economic. The final decision has to be made on a combination of economic, technical, quality considerations.

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Appendix 3 RESPONSE TO THE TECHNICAL AUDIT

Comments on Technical Audit Report for MRC Project DAQ.071 conducted by Professor P A Baumgartner and Mr P. Board, March 1993.

The technical audit report was prepared following an interview of the project team and perusal of all relevant documents including the report of the Benefit/cost study of the project in March 1993 by Gibson Associates. The Gibson Associates' report contained a copy of the Agreement between AMLRDC and QDPI for the project as well as the Research Agreement with Kudos Meat Products Pty Ltd.

The report was critical of the project and the parties involved, the QDPI project team, Kudos Meat Products Pty Ltd and the Corporation. While the project did have some difficulties as outlined earlier in this Final Report, it is the opinion of this project team that much of the criticism was ill-founded.

For example, in the Summary it is stated that neither the aim of the project nor a contract with Kudos Meat Products Pty Ltd for the marketing aspects of the project had been sighted by the audit team; these were contained in the Gibson Associates report of which the team had a copy.

The technical auditors' conclusion that the project set unrealistic goals is challenged. Admittedly the project was a difficult one but the goals were not unrealistic. As indicated previously, the project team firmly believes that reaching the technical goals of the project were, and still are, achievable. The research carried out by the project team and the experience gained with the scraped surface heat exchanger equipment and the aseptic packaging machine had put the project team in a position to be able to meet the technical aims of the project within months of the termination date.

The report appears to ignore the fact that the commercial partner, Kudos Meat Products Pty Ltd, had had considerable experience in exporting meat products to Japan and had identified the particulate products aimed at in this project as having high commercial potential in that country. Although further analysis of the Japanese market had been required during the project, the market orientation of the project from the beginning and the knowledge of the market by Kudos were not fully appreciated by the audit team.

Responses to some of the specific points raised in the report are given below.

1. SCIENTIFIC CALIBRE AND COMMITMENT OF THE RESEARCH TEAM

Auditor's comment

"We have serious concerns about the capacity of the project team to do the work required under this project. The most serious deficiencies were a lack of engineering expertise and of knowledge of thermobacteriology of low acid foods. We are also concerned that the food technologists, apart from Mrs Rogers, seem to have little experience in meat technology; Mrs Roger's involvement in the project ended on 3 May, 1991 a few months after the project started, and her expertise was not replaced. These deficiencies have

senior staff to spend much time acquiring appropriate expertise and this ntinuing. The involvement of Mr Jobin has strengthened the engineering the team but he started at a very late stage in the project".

Response by IFIQ research team

- The team has been highly committed to this project since its commencement. It was realised that engineering expertise was needed, and the appointment of an engineer was requested by Ms Sheryle Rogers in April 1992. The request was considered by Mr Bob Tedesco, the previous project manager, but was not approved.

- It was also realised that knowledge of the thermobacteriology of low-acid foods was needed, hence the appointment of an experienced microbiologist, Mr Neil Hollywood, to the project.

- Mr Hollywood has had considerable experience in the microbiology of meat products, including heat-treated microwaved foods. Furthermore, Mr Bob Isaacs has had previous experience with the aseptic processing of fruit purees (but not low-acid foods), utilising a scraped surface heat exchanger, tubular heat exchanger, and Intasept aseptic filler.

- Ms Sheryle Rogers resumed duty in February, 1992 and continued on the Project until her resignation in June, 1992. IFIQ sought to fill the meat technologist position after her resignation but had difficulties recruiting a suitable replacement. The position was eventually filled in July 1993.

2. SOUNDNESS OF APPROACH TO THE OBJECTIVES

Auditor's comment

"We were surprised that the project staff elected to design and build equipment for aseptic processing of low-acid particulate food especially as several large international organisations have expended large efforts in this area with varying success".

Response by IFIQ research team

- The project was based on adding to, and modifying existing equipment at IFIQ, which had been used to aseptically process and package acidic purees. This technology had been successfully applied to mango puree, passionfruit pulp, acidified ginger pulp, tomato pulp and tomato paste. It was intended to apply this technology directly to low-acid particulate products (both chilled and ambient stored); however the higher temperatures and pressures, and longer holding times required caused some unforseen difficulties.

  In retrospect, purchase of a complete, turn-key system would have obviated many of the difficulties encountered. This would have necessitated a much greater capital expenditure by MRC (or QDPI) which the project team believed was unlikely to be approved.

Auditor's comment

"We are also surprised that the project team have not had closer contact with the Food Research Institute, Werribee, where we understand a commercial aseptic unit is available".

Response by IFIQ research team

- Contacts had been made with the Food Research Institute at Werribee. Ms Sheryle Rogers and Mr Neil Hollywood visited that institute and discussed this project with the meat group. It was intended to carry out some commercial scale runs at Werribee at the end of the project. However up to late 1992, the Werribee plant had been tested on a pasteurised paté product but not on particulate products. Particulate products (fruits and vegetables) were put through the plant for the first time in 1993.

  This information had been provided to the audit team during the interview and hence the inclusion of the above statement in the report was unwarranted.

Auditor's comment

"In addition to the constraints referred to above the project has been delayed by equipment failures. The pilot plant was assembled without first carrying out basic engineering calculations or even referring to published information on the performance of pumps. The only engineering calculation shown in the Progress Reports dealt with a Reynold's Number which was not appropriate for the product under study. Mr Jobin has made some significant improvements to the equipment since his appointment a few months ago.

We understand that the continued involvement of Mr Jobin depends on additional funding from MRC, and other staff will continue until the end of the present project funding".

Response by IFIQ research team

- The feed pump used in the trial was capable of pumping at the pressure and flow rate required. However, its performance was weakened by a worn rotor and worn bearings. A replacement rotor was unavailable in Australia, and had to be obtained from the USA.

- The Reynolds number repeated in the Progress Report was calculated to give an approximate indication of the product flow properties. However, it was realised that the product was a non-newtonian fluid and also that the presence of particles would complicate rheological behaviour.

- As indicated above, the need for engineering input into the setting up of the system and establishing the required processing conditions was recognised in early 1992, but, despite being invited to make requests for assistance for identified deficiencies in resources, a request for a short-term engineering appointment was not approved by MRC.

Auditor's comment

"The project team have made very effort to meet the milestones in the original and amended schedules but we are concerned that many of the Progress Reports are incomplete or contain errors. For instance, essential information is missing from the graphs in Progress Report No. 12, the Fo values were not calculated, and in Progress Report No. 5, the can size was not stated and the L value versus time graph is wrong. Much of the microbiological work was unnecessary and some of the data in Progress Report No. 12 on 12D processes for C. Botulinum spores are wrong".

Response by IFIQ research team

- While the audit team identified some specific shortcomings in the Progress Reports (see explanations following), we believe that the reports, in general, provided sufficient information to meet the requirements of the Corporation.

- The minimum Fo value for the aseptically packaged bolognaise was 27; based on the liquid phase of the product. Canned products were packed in 307 x 309 cans. The temperature v time graphs in Progress Report No. 12 are computer print outs from a data logger. The difficulty of distinguishing the curves, reflects a limitation of the software.

- The graphs of L value versus time, are actually lethal rate versus time. There was a typographical error in progress report no. 12 on 12D processes for *Clostridium botulinum* spores. The error is that "10D process = 0.2 min at 130°C", should read "1D process = 0.2 min at 130°C".

- It is surprising that the audit team considered that much of the microbiological work was unnecessary. Achieving sterility during heating and ensuring sterility during packaging is the whole aim of the process and hence the microbiological work carried out to test this was considered essential and an integral part of the agreed methodology.

Auditor's comment

"We consider that the project cannot meet its objectives in the time available and with the present resources. We understand that additional time and resources have been requested and these may allow some of the technical objectives to be met".

Response by IFIQ research team

- It is the belief of the research team that the technical objectives of the project could have been met if equipment problems had not been encountered. For example, the aseptic packaging was delayed for 4 months by a problem with the flow meter on the aseptic filler which was beyond the control of the IFIQ research team. Several other equipment delays occurred which were beyond the control of the research team.

3. MEETING OBJECTIVES

Auditor's comment

"We recommend that the feasibility of using the Werribee facility for processing demonstration packs be investigated before further funding is allocated".

Response by IFIQ research team

- The feasibility of using the Werribee aseptic plant was investigated, as previously stated. It might still be an option for any future trials.

4. EFFECTIVENESS OF MRC SYSTEMS

Auditor's comment

"We do not know what inquiries MRC made in deciding to have this project carried out at IFIQ. However, it is clear the project lacked focus, for instance, its title refers to scraped surface heat exchangers but it concerns aseptic processing; the types of product and pack sizes were not defined, and there is only shaky evidence that aseptic processing is advantageous for meat products".

Response by IFIQ research team

- The project had a clear focus, as indicated by the objectives in the Contract with MRC, and the structured milestones. The project title, "Assessment of scraped surface heat exchanger technology for the development of extended shelf-life meat products" reflects the objective. The project was solely based on the application of scraped surface heat exchangers. Aseptic packaging was an essential adjunct as a 'tool' for packaging the sterile product produced by the SSHE.

- The types of product and pack sizes were not precisely defined although the commercial partner had identified these in the Japanese market. Final definition of these would have been an integral part of the project following demonstration of the technical feasibility and the production of demonstration products.

- We believe that considerable evidence exists for the advantages of aseptic processing of a range of foods, including meat-containing products. The project team adopted a more positive approach to production of this new product line than that cautioned by the auditors in this respect.

Auditor's comment

"There were also unrealistic expectations relating to the Japanese market research aspects of this project. The justification for working on bolognaise sauce for an Australian restaurant chain must be questioned in the light of the small potential market and the apparent commercial success and acceptability of similar established products."

Response by IFIQ research team

- Although the project was aimed at meat and vegetable particulate "stew" products, initial emphasis was given to a bolognaise sauce (containing meat) because the commercial partner had identified a domestic customer for aseptically packaged bolognaise. There is also an export market to Japan, for this product. The audit team apparently made their 'marketing' comments without any marketing data to support them.

- The decision to work on bolognaise sauce was very soundly based. The reasons for the decision were two-fold: 1. bolognaise sauce is a particulate meat and vegetable product which is the nearest product to a meat and vegetable stew that is almost homogeneous. It was therefore the ideal product to use to establish the heating conditions in the SSHE necessary to achieve sterility without the added problems of separation of particles from sauce in large-particulate products and 2. if an aseptic bolognaise product could be produced by this technology with a quality equal or superior to that of the current frozen product, there would be a ready market for it (if the price was right).

5. OTHER COMMENT

Concern was expressed by one reviewer, that the project should have utilised ohmic heating, rather than scraped surface technology. Ohmic heating is claimed to be advantageous for rapidly heating large particulate foods. However, capital and operating costs are higher. Also, there is no ohmic heating equipment in Australia. The cost of conducting a three day trial in the U.K. is very high (approximately $35 000).

The only remaining problems with the large particulate model system trialled in this project would not be overcome by ohmic heating. Also, ohmic heating would not affect the cooling and filling sections of the process which would still involve conventional technology.

It should also be noted that when this project was commenced in 1990, ohmic heating was not available commercially and is still not available in Australia. Hence it is unrealistic to suggest that this project should have considered ohmic heating rather than SSHE technology.

It is anticipated that ohmic heating will be further developed in the future and may become a viable technology for meat-containing particulate products. The meat industry should maintain a watching brief on this and similar technology.

FOODWEEK

LITTLE INNOVATION IN RED MEAT

Significant opportunities exist for processed red meat products in Australia and overseas, says Stefan Fabiansson, the Meat Research Corporation's off-farm program manager.

Dr Fabiansson, speaking at value-added meat product seminars held in Sydney, Melbourne and Brisbane this month, said the MRC had developed a program to exploit market opportunities for red meats.

It covered new product development for domestic and export markets and included sub-programs on market research, technology, management and packaging.

In the foodservice industry, opportunities included production of a basic curry mix, using lamb as the main ingredient, and providing ready-to-use meat in a plastic casing for the pie market.

The MRC was investigating the smallgoods market which traditionally did not have a good image for fat and salt content.

Dr Fabiansson said there was insufficient innovation in the convenience meal segment to increase market share of red meat products.

"There is a lack of restructured red meat products as is common in the chicken industry," he said.

And, except for hamburgers, there was no red meat convenience product for the lunchtime market – "perhaps some form of nugget" was needed.

"The corporation is currently funding a restructured red meat product which we believe will have significant impact in the marketplace," he said.

The red meat industry needed to tailor products to take advantage of microwave ovens.

"For example, for breakfast, develop a product in the form and size of a crumpet which is reheatable and toasted. Basically, it would be a restructured product and a high fibre replacement," he said.

Another example was to produce a small, flavoured mutton-based meat product by masking the taste or smell with a sugar coating.

REVERSE TREND: Marketing meat in pre-cooked, pre-browned and heat-and-eat forms could stem the consumer swing away from red meat, says Raymond Mawson, from the Food Research Institute in Victoria's Department of Food and Agriculture.

Dr Mawson told the seminar the idea was not new, but new processing opportunities were now available.

Pre-browned meat could be distributed chilled or frozen and the consumer simply heated the product.

The Australian Meat & Live-stock Corporation's Ausmeat program and development of new butchery methods were critical to encouraging a healthy image towards red meat.

There were opportunities to make whole roasts or sliced roast meats in gravy or sauce for reheating.

Dr Mawson said there was potential to use current technology to "roast" uncured meat in a cooking bag

This method is currently used in foodservice, but the product is aesthetically unattractive.

But Dr Mawson said it could be made more attractive by adding a dry, self-thickening gravy base which reconstituted during cooking.

"The key consumer concern seems to be that flavour, as opposed to eating texture, should be maintained," he said.

Dr Mawson said new processing techniques had the potential to give freshness-conscious customers products with a "fresher, less-processed appearance".

EXPENSIVE IDEAS: Future product development will involve upgrading and imitating existing products, Bob Hamilton, technical director of Brisbane-based food design and manufacture company, Earlee Products, told the seminar.

Mr Hamilton said there would be fewer new products because new ideas were expensive to develop and their acceptability was uncertain.

"Traditional raw materials will disappear, increase in price, be in short supply, or subject to new food regulations which may affect their use," he said.

"Technical and marketing people must write the product concept together and continue to communicate throughout the project."

Mr Hamilton said the final decision should not be left to the chief executive – "he is probably the least qualified to make a final decision on the taste acceptability of a product".

Earlee Products was founded by Mr Hamilton in 1989. It has done food design for companies including Woolworths, Collins Foods, Magic Menu Systems and Cordina Chicken Farms.

ASEPTIC BENEFITS: Improved product quality, energy savings and new marketing opportunities are some of the advantages of using aseptic processing for meat products, Bob Isaacs, a food technologist from Brisbane's International Food Institute of Queensland, told the seminar.

Mr Isaacs said aseptically packaged products had an economic advantage because the heat process, unlike conventional canning, was independent of pack size.

"Aseptic packaging appears economically viable for high through-put, bulk packs," he said.

But the advantages of low steam consumption and package costs and high quality had to be balanced against the disadvantages of high capital costs and electricity usage.

For retail-pack, low-volume products, conventional technology might be more economical.

Problems with aseptic packaging included ensuring adequate heat penetration to ensure sterility.

Colour and flavour changes were less severe in aseptically processed products, but toughening of meat was more likely. ✣