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Aseptic Processing of Meat Products

Summary

Aseptic processing involves sterilising the product (most meat products being low-acid foods containing particulates) 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. Particulate foods can be sterilised in scraped-surface heat exchangers. Other methods involve heating the particles separately, and combining them during filling. The effects of aseptic processing on meat product quality (colour, flavour, texture, and nutrition) are outlined in this paper.

Introduction

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. Pflug et al. (1990) have defined aseptic processing '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 sterilized, filled, and sealed in a sterile environment'.

For the purpose of this seminar, meat products will be considered to be low-acid (above pH 4.6) foods containing particulates. Some companies are producing aseptically processed low-acid foods containing particulates packaged in semi-rigid containers on a pilot-plant scale. As more experience is gained with the process, foods containing larger particulates such as beef stew, spaghetti, ravioli, chilli and chinese meat and vegetables will become available (Anon. 1988). 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 look to convenient and high-quality products in alternative (cheaper) forms of packaging (Murray 1985).

Aseptic processing of meat products presents special heat-transfer and quality-retention problems. This paper aims to review the advantages, problems and technology of aseptically processing foods containing particulates.

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 risk to public health from food poisoning. The time and temperature of heat processing to obtain sterility depends on the temperature history at the point in the product slowest to heat, on the chemical composition of the product, and on the types and numbers of micro-organisms 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. High 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 million million (Board 1989).

Different time temperature relationships are used to achieve the same sterilising effect. Conventional canning utilises temperatures of 116—121°C while aseptic processing technology is performed at temperatures ranging from 130-150°C. A shorter holding time at these higher temperatures will result in a similar sterilising effect as conventional methods.

Advantages of Aseptic Processing

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

- (i) Improved product quality (reduced loss of flavours, aromas, natural colours or volatiles);
- (ii) Energy savings;
- (iii) Consumer convenience;
- (iv) New marketing opportunities;
- (v) Bulk packaging

(Wernimont 1983; Anon. 1988)

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 in Table 1.

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

TABLE 1

	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)

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 \$US1.20/h. 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 \$UK5.91/h for aseptic processing.

Overall, aseptic packaging appears economically viable for high throughput, 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.

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 ($\text{pH} > 4.6$) 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 & 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 bio-indicator should be in the form of a particle, possessing at least the following necessary and/or desirable characteristics:

- (i) large size (about 2.5 cm), containing immobilised bacterial spores throughout the interior, and especially at the slowest heating zones;
- (ii) geometry, thermal properties and responses similar to real food particles;
- (iii) visual distinguishability from real particles, permitting easy recovery from processed product;
- (iv) retention of spores without leakage through all process steps;
- (v) shelf-stability, (this is more a desirable, rather than necessary characteristic);
- (vi) 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:

- (i) The different penetration rates for different particulates and for the carrier liquid phase. Therefore the liquid phase is often overprocessed;

- (ii) The possibility that although harmful micro-organisms are destroyed, enzymes will survive that can be detrimental to the product;
- (iii) The fragile nature of particulate products once heat treated and the difficulty in transporting such products without damage;
- (iv) The possible separation of particulate and liquid phases either during processing or in storage prior to packaging.

The difficulties outlined in (iv) 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 difficulties outlined in (i) could be overcome by processing the solid and liquid phases separately.

Process Technology

- (i) Scraped-surface heat exchangers (SSHE)

Scraped-surface heat exchangers will continuously process products that:

- (a) Are very heat sensitive;
- (b) Form film on the heat exchange surface;
- (c) Are highly viscous or become highly viscous during processing; or
- (d) Have a particle size or delicacy that can't be accommodated by other heat exchangers. Products containing up to 40% particulate content, and 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. Scraped-surface heat exchangers can effectively handle any products presently batch processed in kettles or tanks and 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, pate, meat and fish spreads, pet food and blood plasma (Day 1970; Volan & 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 143—149°C. Holding 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

(ii) 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.

(iii) Another system, still in the developmental stage, 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 particulate fees may be processed without shearing forces associated with some other types of heat exchangers.

(iv) Another system, the 'Stork Steripart' system (Anon. 1989), allows liquid and particulate fractions to receive different heat treatments. The liquid fractions can flow at a high velocity and are subjected to a heat treatment comparable to that of an 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.

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 and the food contact surface cannot be contaminated prior to filling. 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 micro-organisms per 100 cm². On paper based laminates loads ranged from 2 to 5 micro-organisms per 100 cm². Superheated or saturated steam could be used for sterilisation of packaging materials and has been applied for the sterilisation of polystyrene cups.

Quality Considerations

Colour

In canning, heat has to penetrate to the centre of the can (the 'cold spot') to sterilise the product. 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, de-amination 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 tryptophan 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, 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.

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