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Dr. Parker

Handling food in the home

By K. C. Richardson

CSIRO Division of Food Research, North Ryde, N.S.W.

A consumers' guide to the use of the refrigerator and the care of many common items of food

Editorial note

It has been decided to broaden the scope and widen the distribution of the *Food Research Quarterly*. In this issue the leading article is directed primarily to consumers rather than food processors and it is intended that in most future issues articles of immediate interest to consumers will be included. Such articles have, of course, appeared in the past but they will now become a fairly regular feature. It is also hoped that by offering *Food Research Quarterly* to municipal libraries throughout Australia, it will reach a wider audience in future.

Since its inception nearly 50 years ago, the Division has done all it can to assist growers, processors and distributors of food in Australia to apply sound and safe methods of processing and packaging so that the quality of the product is protected from the farm gate to the table—often a long journey. This policy will go on and the journal will continue to publish articles giving the results of experimental work done in the Division or reviewing knowledge in areas of interest to technical and managerial staff in the food industry.

Although no issue will contain more than one article written specifically for the general reader, much of the subject matter will be of interest to him. Consumers may wish to glance through the rest of the contents and in doing so they may increase their knowledge of a subject that concerns all of us: how to secure high quality in the food we eat.

How to shop

Every homemaker wants to be sure that the food the family eats is safe and wholesome. It is therefore necessary to shop wisely in order to bring home the best quality foods available, at a reasonable price. Since most items of food are now bought at supermarkets where you, as customer, select your own purchases, a little extra time spent looking at a package and reading the label is well worthwhile. If you are pressed for time, or conditions in the store do not permit this, it should certainly be done when you return home.

Each item should be examined to detect possible spoilage: a torn package, an imperfect seal or a swollen or leaking can. Swollen cans are rare on supermarket shelves but their presence should always be brought to the attention of the store manager. Many chilled foods packed in flexible containers may also be spoiled as a result of microbial action which will produce gas and swell the container. This type of spoilage is sometimes seen in the chilled-food section of the supermarket. Foods which may be involved are fruit juices, unprocessed cheeses, made-up pastry and fruit yoghurt. Such items as these are not sterile and when spoilage occurs it usually means that they have been stored for some time above refrigeration temperatures. Cheeses packed in transparent films should always be inspected closely for evidence of mould growth.

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All perishable foods in stock, such as dairy products and delicatessen items, should be kept in a refrigerated display cabinet. They should be cold at the time of purchase and should not be bought from a store which allows the temperature of these products to approach room temperature.

Frozen foods should be selected from a display cabinet designed for them and items stored above the load line should not be purchased. The 'load line' is a line placed on a frozen-food cabinet by the manufacturer to indicate the level to which foods may be stored and still remain frozen. Unfortunately the load line is not always clearly visible, but it is usually about 5 cm below the rim of the cabinet.

If there are ice crystals inside a pack of frozen food or clumping of ice between packets of food in a frozen-food cabinet, it usually means that the product has partly thawed and then refrozen, and hence has lost some of its quality. The ice present in the pack is water which has been withdrawn from the foodstuff, and this loss of moisture cannot occur without undesirable changes in the flavour and texture of the food also taking place.

A careful examination of labels in the store or at home should be informative. Favour those brands which suggest storage temperatures or describe any special precautions necessary for storage. With basic items such as frozen and canned vegetables, directions for preparation should be carefully followed. Treat cautiously any advertising claims for health-giving properties in a particular foodstuff. These claims can be misleading. Sensible planning of meals with a variety of foods is the best method to ensure that your

Fig. 1. Some of the types of food dealt with in this article.

family is being properly nourished. Advice on this aspect of family care is freely available from State Departments of Health and the Nutrition Section of the Australian Department of Health (Fig. 2).

Buying large quantities of food which cannot be used within a reasonable time should be avoided. This is particularly so with perishable foods but applies also to so-called 'long life foods' such as canned and dehydrated commodities. The convenience and economy of buying in quantity is lost if some of the food deteriorates or spoils and has to be discarded. Be particularly wary of weekly 'specials' in food lines. Many specials are slow-moving lines nearing the end of their acceptable storage life. Several weeks' storage in the home may still be possible with stable items such as canned goods, but storage for many months without inspection should be avoided.

Bringing your purchases home

Reputable food processors and retailers take the necessary steps to ensure that food they have handled is in good condition when purchased. It then becomes the responsibility of the purchaser to maintain this care up to the time the food is consumed.

Proper transport of food from the store to the home is important. This primarily entails keeping temperature changes to a minimum. Chilled and frozen packaged foods should be wrapped in paper to reduce heat gain on the journey home; newspaper is adequate for this purpose although butcher's paper should be provided. If the staff at the store are unwilling to do this for you, take the time to do it yourself or shop around for a store which will wrap perishables for you. If staff aren't instructed to look after food as it is leaving the store it is probable that they don't look after foodstuff properly when it is delivered either. Many wise shoppers take along an insulated container when they know they will be buying items that must be kept cold till they return home.

When the food shopping has been completed it is a sound rule to return home as promptly as possible. For this reason the food

Fig. 2. Excellent booklets on many aspects of health and nutrition are available from government departments concerned with health and agriculture.

market should be the last stop on shopping day. If this is not possible it is advisable to leave food shopping for another day. When you arrive home, perishables should be placed in the appropriate section of the refrigerator or freezer immediately you are satisfied with the quality of your purchase and have read the storage instructions on the label.

How to store foods

Perishable non-frozen foods

By lowering the temperature at which foods are stored their rate of deterioration can be substantially reduced. Foods spoil because of chemical changes in their constituents and because of the growth of microorganisms naturally present on them. Both these processes are slowed down, but not stopped, at low temperatures.

The domestic refrigerator is extremely important to the homemaker who is trying to maintain the highest possible quality in the food served to the family. It is therefore advisable to follow certain practices when using the refrigerator.

- Food that is not in good condition should be disposed of. It should not be refrigerated. Food that is 'going off' will continue to deteriorate and may taint other food.
- Food that is to be used last should be kept in the coldest part of the refrigerator, as should items like seafoods. It is best to obtain information about your particular refrigerator from the manufacturer, but in most domestic refrigerators the upper shelves are colder than the lower shelves. Fig. 3 gives a guide to the temperatures likely to be found in a normal domestic refrigerator which is set at the middle of the temperature range. Thermometers made especially for refrigerator and freezer use are available from some department stores and are a worthwhile investment.
- Cooked foods that are not likely to be reheated before serving should be placed above uncooked foods or should be covered. This minimizes the risk of bacteria, including potential food-poisoning organisms, being inadvertently transferred from uncooked to cooked food in droplets of contaminated liquid.
- Foods with strong odours, e.g. seafood and some cheeses, should be well wrapped and, if possible, they should not be stored for long near foods that taint easily such as milk and cream. Flexible films coated externally with polyvinylidene chloride (PVDC) are the most effective barriers to the transmission of odours but are not readily available to most homemakers. The common cling-wrap polyethylene films are not very effective barriers but are of some benefit for short-term storage and should be used if other films are not obtainable.
- How to keep meat and other flesh foods deserves special mention. These foods form an important part of the diet of most Australians. Uncooked flesh foods always carry a population of microorganisms and some of these may be food-poisoning types. Careful supervision of their storage in the refrigerator is essential.

Table 1. Recommended storage temperatures for some foods

Food	Storage temperature °C	°F	Shelf life in the home
Poultry	0–2	32–35	2 days
Shellfish	0–2	32–35	2 days
Fish	0–2	32–35	2–3 days
Minced meat and offal	0–2	32–35	2–3 days
Meat	0–2	32–35	3–5 days
Cream	1–3	34–38	5 days
Milk	1–3	34–38	5–7 days
Fresh fruit juices	0–4	32–35	7–14 days
Cured meat	0–2	32–35	2–3 weeks
Butter	0–4	32–40	8 weeks
Margarine	2–7	35–45	Variable (8 weeks)
Cheese	3–7	37–45	Variable (1–3 months)
Oil and fat	2–7	35–45	Variable (6 months)
Dehydrated foods	21–24	70–75	Variable (6 months)
Canned foods	21–24	70–75	Variable (12 months)

The maximum recommended storage life for unfrozen fish and poultry is about 3 days. These two products deteriorate very rapidly because they normally carry a high initial population of microorganisms capable of growing at refrigeration temperatures. The same applies to minced red meat and to offal such as liver and kidneys.

Other cuts of red meat and cured meats like corned beef and mutton may be kept for longer, but care must be exercised. If the original high water content of the meat is maintained by wrapping in plastic film, surface growth of microorganisms will be encouraged and the meat will soon begin to get slimy and develop an off odour. If the meat is left unwrapped, the drying out which normally occurs slows down any growth of microorganisms but can lead to undesirable colour changes and loss of flavour. This, however, is the lesser of the two evils.

Hence wrapping is recommended for short-term storage—up to 3 days for fresh meat and a week for cured meats. If the meat has to be kept for longer (refer to Table 1 for acceptable limit) it should be left unwrapped. These foods should always be stored in the coldest part of the refrigerator, as close as possible to 0°C (32°F).

Frozen foods

Freezing food and keeping it at a very low temperature, around −18°C (0°F), almost completely arrests both chemical and micro-

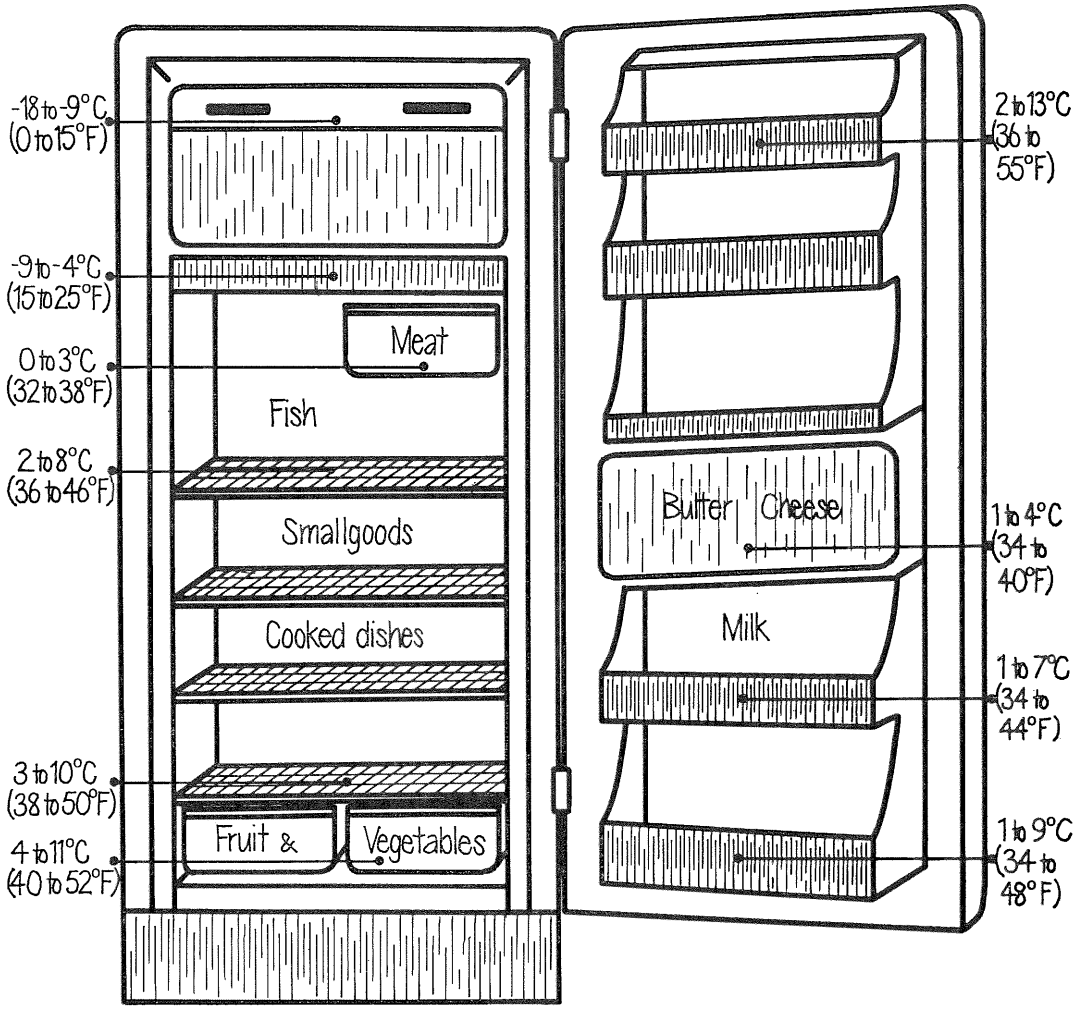


Fig. 3. Knowing the temperature of the different sections in your refrigerator will help you to place food where it will keep freshest.

biological deterioration. But thawing or even rises in temperature not great enough to initiate thawing enable the processes that were almost stopped by freezing to speed up and spoilage again becomes a problem.

Frozen foods should be placed in a freezer, or in the freezer section of the refrigerator, immediately the shopper returns home. It is difficult to justify the practice of placing commercially frozen foods in long-term storage at home. It is preferable to buy-in frozen foods as required, particularly as some home freezers do not hold food at a sufficiently low temperature to maintain high quality over an extended period. However, small quantities of food may be held frozen for a few weeks at −15° to −12°C (5–10°F) without any serious loss of quality.

People who freeze their own garden produce are in a somewhat different position as they have full knowledge of the history of the product from garden to freezer. Processing details and storage recommendations for home freezing are available in booklets from most State Departments of Agriculture.

Some frozen foods are best if cooked direct from the freezer; this applies particularly to frozen vegetables. If you are in doubt about the correct cooking procedure, refer to the instructions on the back of the packet. Frozen vegetables have usually been blanched before freezing and need only to be reheated or cooked lightly for serving. Smaller cuts of meat like steak and chops may be fried or grilled from the frozen state if desired; sausages may be blanched first for more even cooking. Other frozen foods, and in particular large cuts of meat and poultry, need to be thawed before use so that cooking may be properly controlled.

When a food needs to be thawed before cooking, thawing should be carried out at refrigeration temperatures, i.e. below 4°C (40°F). It is important not to let the temperature of the thawing food rise higher, for then any food-poisoning bacteria present will begin to multiply. Medium-sized portions of food such as a whole chicken or a rolled roast will usually thaw satisfactorily if taken from the freezer the night before they are to be used, and placed on a bottom shelf of the refrigerator.

When one has to prepare a meal from frozen meat at short notice, and thawing in the refrigerator is not possible, it is still desirable to thaw the meat before cooking. This can best be done by unwrapping the meat or poultry and thawing in cool *running* water. A sink with an overflow plug is particularly useful for this purpose but a number of other methods can easily be devised. One to two hours should be sufficient time to complete thawing.

In general, food which has been thawed and not used should not be refrozen. Provided it has been thawed under controlled conditions in a refrigerator operating below 4°C (40°F), the food may be refrozen with safety but may well have inferior texture and flavour when it is eaten. A better course is to store it in the chilling section of the refrigerator to be used within 48 hours. Food which has been thawed without temperature control may have developed a large population of food-poisoning organisms and should be discarded.

Dehydrated or dried foods

Another method of inhibiting microbial growth in foodstuffs is to remove the water they contain. Neither freezing nor dehydration is in any way a sterilizing process, and dried foods commonly carry a fairly heavy load of contaminating micro-organisms. When dried foods have been rehydrated they are once again highly perishable and must be treated as such. This means that if the food is to be held for some time in its rehydrated form before use, and this in most cases is difficult to justify, it should be refrigerated. The use of dried soup mix as a base for savoury dips at parties is now a common practice and particular care should be taken with them. When the soup mix is combined with other moist ingredients, conditions suitable for the growth of bacteria are restored and the product should therefore be refrigerated below 4°C (40°F) until it is served (Fig. 4). Similarly, stocks and gravies made from dehydrated ingredients are just as liable to spoil as preparations from fresh foods; they should be refrigerated until wanted for serving.

Because so much water has been removed from dried and dehydrated foods they are very stable against microbiological attack. Chemical breakdown will continue slowly, however, particularly once the pack has been opened and the food is exposed to air and the moisture in the air. It is therefore desirable to store these foods in as cool a place as possible away from obvious sources of heat such as a stove or direct sunlight. A storage life of about 6 months can be expected if the

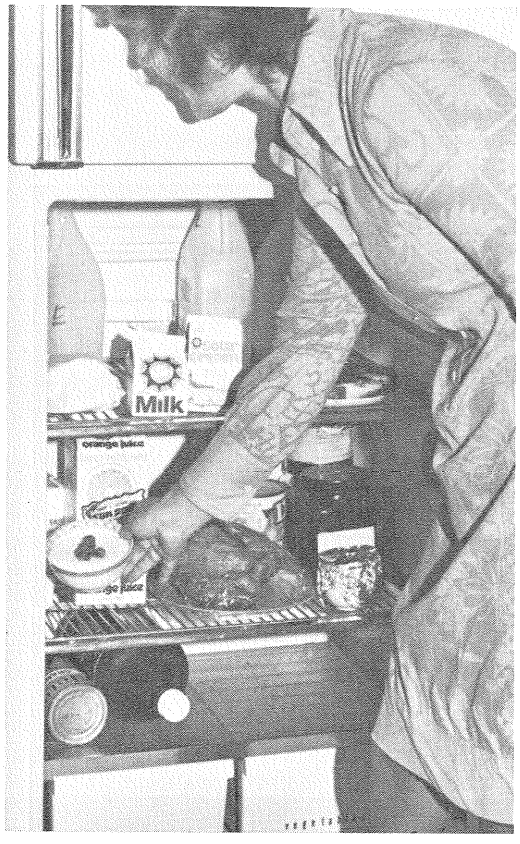


Fig. 4. Store dips in the refrigerator until serving time. Keep cold foods cold.

products are stored at 21–24°C (70–75°F) in the unopened container. Insect infestation is a constant problem with dried foods and regular inspection is recommended.

A special case in this range of products is the so-called 'high moisture pack' of prunes. These are marketed with a higher-than-normal water content to make them more suitable for dessert purposes. The higher moisture content makes them more liable to microbial spoilage and so the pack is marked 'Refrigerate after opening'. As with all instructions on packages this should be followed strictly. Other dried fruits will also retain their quality for longer periods at refrigeration temperatures, and if space is available they should be stored in the refrigerator after opening. However, it is important to remember that an overloaded refrigerator will not function efficiently and utilization of refrigeration space should always be carefully planned.

Canned foods

Canned foods differ from other processed foods in that the processing treatment is designed to sterilize them. This means that any contaminating microorganisms present on the food when it was placed in the can should have been destroyed by the subsequent cooking process. An exception to this statement is the canned ham product which has marked across the can 'Store below 4°C (40°F)'. This product does not receive a full sterilizing treatment because the texture of the meat is adversely affected by prolonged heating. Some imported canned meat and fish products are also in this category and the label of a canned food should always be read carefully before the can is stored.

A swollen or leaking can indicates some failure in processing and the contents of such cans should never be eaten (Fig. 5*a*,*b*). The contents should *not* be tasted before disposal. When the homemaker finds a doubtful can in the store cupboard it is wise to report the lot number to the manufacturer to alert him to the possibility that other cans may be in a similar condition.

If a can appears intact and is flat at the ends, we may assume that the processor has done his job properly and the food will remain safe from microbial spoilage until the can is opened. However, any unusual smell from the contents of a can which appeared sound before opening is sufficient grounds to discard the contents.

Once a can is opened the contents should be treated in the same way as fresh food of the same kind. Contamination of the contents becomes possible as soon as the can is opened and some of the contents removed. Because of this, partly used food in cans should be covered with plastic and refrigerated for storage.

Whether one leaves the food in the original can or transfers it to a plastic or glass container is a matter of convenience or preference. Some foods, when opened to the air, do attack tinplate rather rapidly and this results in the food taking on a metallic taste and possibly becoming discolored. Items which behave in this way are usually highly acid or highly salted: fruit juices and tomato products are perhaps the best examples. It is preferable to transfer these foods to another container before refrigerating.

If properly processed, unopened canned foods are very stable when stored under cool conditions away from obvious sources of heat.

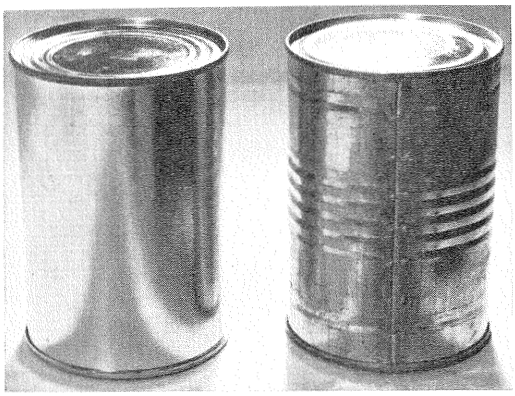


Fig. 5*a* and *b*. A spoilt can may bulge, giving it a rounded end (*a*) or it may leak at the seam (*b*).

A storage life in the home of 12 months can reasonably be expected for most products at storage temperatures of 21–24°C (70–75°F). Many canned foods will remain in good condition for much longer at cool temperatures, but since the true age of the foodstuff and range of storage temperatures to which it may have been subjected will be uncertain, a maximum of 12 months' home storage should be set. Exceptions to this are canned rhubarb, fruit juices, carbonated beverages and some baby foods; a maximum home storage life of 6 months is suggested for these foods.

Precautions during food preparation

Most cases of food poisoning result from mishandling food in the kitchen. 'Mishandling' in this context means leaving food to stand, cooked or uncooked, at temperatures which permit bacteria to grow, especially bacteria that can cause food poisoning. One must assume that these bacteria will be present naturally in or on a great many foodstuffs, particularly those used as a source of protein, e.g. meat, fish and poultry. In addition, everyone carries at least a few potentially harmful bacteria on the face, arms, hands and other parts of the body. If these organisms are carelessly transferred to a food which will support their growth (a dairy food, for instance, and milk or cream in particular) and the food is then kept at a temperature warm enough to allow the contaminants to grow, we have a potentially dangerous situation.

It is just as important not to transfer bacteria from one food to another by careless handling. Cooked and uncooked meats, in particular, should never be handled together and, when they are being cut up, the same utensils and boards should not be used unless these are thoroughly washed before a new portion of meat is handled (Fig. 6). Cooked meats consumed cold with salad dishes are a common cause of food poisoning. Although

Fig. 6. Use separate chopping boards for raw meat and cooked meat, especially if you feed raw meat to your pet.

the bacteria naturally present on the raw meat would have been destroyed by cooking, food-poisoning organisms are often transferred back to the cooked product via knives, cutting boards and hands contaminated by fresh meat. Storage at too high a temperature permits these new contaminants to grow to a level where they cause illness.

Equally stringent precautions apply to fried and barbecued meats, particularly chicken, bought from take-away food stores. If this food is to be consumed cold it should be stored below 4°C (40°F), as recontamination of the cooked meat must always be considered a possibility.

Fortunately we know the temperatures at which food-poisoning organisms can grow and it is a relatively simple matter to minimize the time any food spends in this temperature range (Table 2). The message should be clear: the shorter the time that foods, including cooked foods, are kept between 4° and 60°C (40–140°F), the less the chance of food poisoning. If food is to be served hot after cooking it should be held above 60°C (140°F). If the food is not to be used immediately after cooking, it should be cooled quickly and stored in the refrigerator below 4°C (40°F). This applies equally if the food is to be subsequently frozen. From the point of view of microbiological safety large bulky portions of meat should be avoided as they heat up and cool down slowly.

Many people are reluctant to put hot food straight into the refrigerator to cool. However, most modern appliances can cope with the added load and the practice may be followed with safety. If you are not happy with this procedure, preliminary cooling may be carried out by placing the hot food in a suitable container in cold water in the sink or some other vessel. The water may be changed a number of times and if the hot dish is a stew or a sauce it should be stirred from time to time. After a maximum period of 1 hour in cold water the food may be transferred to the refrigerator to complete the cooling.

If a food is to be eaten cold it should be served cold—this means it should remain refrigerated until it is required on the table. This applies particularly to such things as seafoods, salads with meat, vegetables or rice, and dessert items and cakes containing cream or imitation cream. The same care in keeping foods at a safe temperature should be taken when the items are brought from take-away food outlets to be eaten after some time has elapsed.

Table 2. Growth of food-poisoning organisms related to temperature of the food

°C	°F	
100	212	Cooking at boiling point
74	165	Acceptable for warm holding. No growth of food-poisoning bacteria but many bacteria can survive
4–60	40–140	DANGER ZONE Rapid growth of bacteria including food-poisoning bacteria
4	40	Acceptable refrigeration temperature. No growth of food-poisoning bacteria. Slow growth of spoilage bacteria
0	32	Freezing temperature. Very slow growth of spoilage bacteria

Because bacteria are always present on our bodies, excessive handling of foods must be avoided. Tongs or other implements should be used to handle food wherever possible. Scrupulous personal cleanliness must be practised by any member of the family preparing food. However, even the utmost care will not completely eliminate contamination. This is why the refrigerator, properly used, is your greatest ally in any plan to avoid food poisoning. Remember that it takes large numbers of certain bacteria to cause food poisoning and these bacteria cannot grow in foods stored below 4°C (40°F) or above 60°C (140°F).

Note to readers

A leaflet based on this material is available from the Consumer Liaison Section, Division of Food Research, CSIRO, P.O. Box 52, North Ryde, N.S.W. 2113. Please send a stamped addressed envelope 24 cm × 16 cm.

Flame sterilization

By D. J. Casimir

CSIRO Division of Food Research, North Ryde, N.S.W.

Canned foods may be sterilized economically and efficiently in the flame spin sterilizer. This article (based on a talk given at the National Chemical Engineering Conference, Surfers Paradise, 1974) is the first in a series and gives an overview of the process. Subsequent articles will deal with specific aspects of flame sterilization

The 1975 Food Industry Innovation Award of the Australian Institute of Food Science and Technology was made to Tarax Pty Ltd and Mr P. S. Lewis for the development and commercial operation of the flame spin sterilizer, in association with Mr F. M. Lohning of Lohning Bros Pty Ltd and Dr D. J. Casimir of this Division.

Whenever a food is subjected to heat sterilization its nutritive value, flavour, colour and texture, all of which contribute to its acceptability, may be affected to varying degrees depending on

- the speed of heating,
- the length of time the food is held at the highest temperature reached, and
- the speed of cooling.

Thus when selecting a thermal process the food processor must always bear in mind the necessity to produce a microbiologically stable product while altering as little as possible the food's nutritional and sensory qualities.

For many years the Division has been working on improved methods of thermal processing of canned foods, and in particular, on techniques of heating and cooling the food inside the cans more rapidly and uniformly. Increased rates of heating may be obtained by increasing the rates of heat transfer from the heating medium to the wall of the can and from the inside surface of the can wall to the product. The aim of our work was to obtain maximum rates of heat transfer without overheating the product in contact with the can or causing it to 'burn on'.

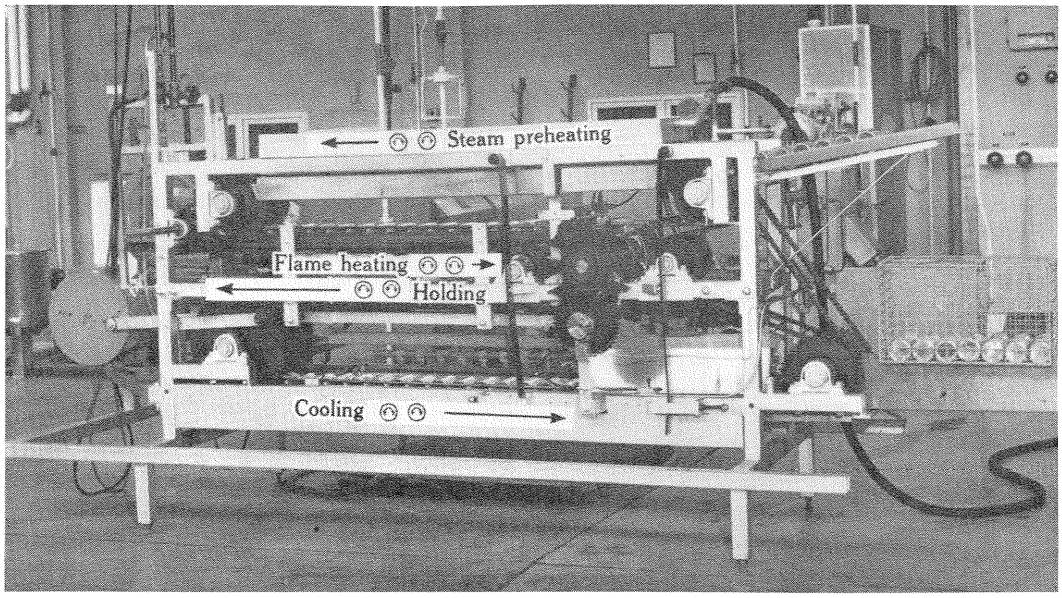
One successful approach, pioneered by French workers, involves heating cans of food directly by flames as the cans are slowly turning. We have refined the technique so that the contents of the cans are vigorously agitated during heating; with this modification flame sterilization may now be used for many highly viscous foods such as milk custards, and spaghetti and beans in tomato sauce.

This article gives design parameters and describes the operating characteristics of a flame sterilizer that was designed and built at FRL. The economics of the process, requirements for containers and some formulations for products are also discussed.

The prototype CSIRO flame sterilizer

Parameters for optimum heating conditions and product quality were elucidated after preliminary studies on a single-can flame sterilizer. A prototype of a continuous unit was then designed and built; in this machine the spinning cans are subjected to frequent changes in the direction of rotation.

As the unit was to be used for research as well as for demonstrating the procedure to the food industry, the design was such that conditions could be varied to suit a wide range of products. Hence the rate of progression of cans through the unit and the rate of movement of the shuttle bar, which imparts the reversing motion to the cans, are continuously variable; the length of stroke of the shuttle bar may also be varied in order to increase or decrease the number of times a can spins before the direction of the spin is reversed. In the preheating section the cans may be preheated in steam where necessary



The prototype CSIRO flame sterilizer.

so that they enter the flame heating section at a defined temperature. The burner is constructed in sections so that the number of burner stations can be changed to permit variation in the ratio between the time of heating in the flame and the holding time.

Cans are conveyed at four different levels. The cans enter the top level, where they are subjected to the reversing spin motion and are preheated with steam so that the product is well stirred and the temperature is uniform within the can. Preheating also ensures that all cans are at the same temperature when they enter the next level down for heating in the flames. Waste heat from this heating section is partly used for the production of steam in the preheating level above. The cans are also subjected to the reversing spin while being flame heated. In the holding section, which occupies the later part of the second level and the third level, the cans are not subjected to the reversing spin but move forward with a slow intermittent rolling motion. The fourth and lowest level is the cooling section where the cans are again given a reversing spin as they progress, immersed to about one-third of their diameter in a counter-current flow of cooling water.

A Geneva movement is used to impart an intermittent motion to the drag chain which moves the cans through the four processing stages—preheating, flame heating, holding and cooling—in order to obtain optimum location of each can with respect to the flame at each burner station. The intermittent motion permits cans to be readily removed for a stab temperature measurement, and also provides time for equilibration so that the surface temperature of the can may be taken with a probe during the non-progression period of the drag chain.

Because of the wide range of temperatures encountered within the machine and between start-up and operating temperatures, all the chains, guide bars and shuttle bars must be operated under tension so that distortion does not occur as a result of expansion.

Further details of the mechanical construction of the unit are given by Huntington and Casimir (1972).

Comparative costs of thermal processing

The quantity of steam expended when cans are processed in a stationary retort at 121·1°C for 2 h using standard procedures was reported by Sampson (1953). Of the total steam expended (150 kg), only 25 kg was used in heating the cans and contents. The remainder of the steam was lost as follows:
54·5 kg passed out of the vents,
24·5 kg was used to heat the retort and crates,
17·0 kg was used to heat the condensate in

Table 1. Comparative costs of heat required for the thermal processing of canned foods by different procedures

Processing equipment	Comparative costs of heat		
	F.M.C.*	Casimir (1972*a*)	Thorne (1972)
Static retort	100	100	100
Continuous rotary retort	50	—	91
Hydrostatic cooker	37	20	56
Fluidized-bed cooker	—	—	38
Microwave cooker	—	1230	—
Flame sterilizer	—	56	—

*Food Machinery Corporation (1971) personal communication.

the bottom of the retort, and 29·0 kg was used to replace the heat lost through radiation. Hence only 17% of the steam supplied to the retort was used for sterilization.

Comparative costs of heating in batch retorts, continuous retorts and flame sterilizers are given by Casimir (1970, 1972*a*). For the pilot-scale flame sterilizer developed at CSIRO the thermal efficiency of the flame sterilization process is 31%.

Some comparative costs of heating cans of food by several different methods are given in Table 1, based on a heat cost of 100 for thermal processing in stationary retorts.

Rate of heat transfer and burn-on

Owing to the high temperature differences used in flame sterilization (1770°C), the rate of heat transfer is determined largely by flame temperature. The extent of agitation and the viscosity of the contents of the can influence the occurrence of burn-on, but do not influence heat transfer provided that no burn-on occurs. With materials that are not susceptible to burn-on, e.g. water and glycerol solutions, rates of heat transfer from flames to can contents are virtually independent of the motion of the can, whereas in steam heating and water cooling the influence of agitation upon the film heat transfer coefficient at the inner surface of the wall of the can will be the factor controlling the heating or cooling rate.

Hence in flame heating we may assume that the external film coefficient is the limiting factor in heat transfer, whereas with steam heating the internal film coefficient is the limiting factor.

Morgan and Carlson (1961) in a study on fouling or burn-on at heat transfer surfaces in evaporators, found temperature to be the most important parameter of the heat transfer surface. In flame heating of foods in cans, the

Table 2. Heat transfer potential of various heating media

Hot side	Cold side	Clean surface forced convection coefficient* ($W/m^2°C$)	Temperature difference practical in commercial operation (°C)	Maximum heat flow potential (kW/m^2)
		Heating operation		
Steam	Water	1700–3000	0–90	270
Steam	Corn syrup	400–500	0–90	45
High temp. hot water	Water	1000–1400	0–110	154
Organic solvents	Water	300–850	0–85	72
Gases	Water	17–300	0–110	33
Flame	Water	931†	1700	1583
Fluidized bed	Water	17–300	0–110	33
		Cooling operation		
Water	Water	1100–1400	0–95	133
Water	Air or gas	30–55	0–95	5

*From Platecoil Catalogue No. 5-63 (1963).

†Calculated value based on the area of flame impingement on the wall of the can and the amount of heat transferred to the can in the CSIRO flame sterilizer.

temperature of the wall of the can just before burn-on occurred was dependent upon a number of variables such as the shear forces between the contents and the can wall, the residence time of the particular elements of the can wall in the flame, and the flame temperature. In a study which involved single-strength milk as the test food, Wu (1971) found that burn-on depended on the temperature of the can wall, the maximum metal temperature acceptable being *c.* 180°C.

Heating media

Saturated steam at various temperatures is the most commonly used medium for the heat processing of canned foods. But water, organic vapours, air, fluidized beds of hot particles and flames have also been used commercially or experimentally. Some indication of the heating properties of various media may be obtained by considering their heat transfer coefficients and the temperature differences that may be used in commercial practice (Table 2). Values for maximum heat flow show that for rapid heat transfer steam, hot water and flame should be considered as media for the heating cycle while water should be used as the cooling medium.

The high value for the maximum heat flow potential for flame heating was calculated as given below, but it must be emphasized that it applies only to the area of the wall of the can where the flame impinges, which in the CSIRO flame sterilizer is about 10% of the total area. With flame heating the temperature difference is large for the whole of the heating cycle, and hence a high rate of heat transfer is always maintained. That part of the wall of the can not subject to direct flame impingement is heated by the hot combustion gas at about 450°C and hence heat flow across this surface is about 40 kW/m^2.

From experiment it was found that a can 66 × 101·5 mm (305–320 ml lidded capacity), having a mass of 0·068 kg and containing 0·29 kg water (i.e. requiring the addition of 1253 J to raise the temperature 1°C), could be heated at 2·39°C/sec. This indicates a heat transfer rate to the can of 2995 W when the burner has a flame area of 14·12 cm^2 and a flame temperature of *c.* 1770°C. The average temperature difference between flame and can wall in the impingement area may be taken as *c.* 1700°C.

If we assume the overall heat transfer coefficient at the surface not subject to flame impingement to be 100 W/ (m^2°C) and a temperature difference of 400°C, the heat transferred across this surface may be calculated to be 760 W. If we subtract this heat flow from the total heat flow to the can, we find that 2235 W (2995 — 760) are transferred across the area of flame impingement, and hence the overall heat transfer coefficient for the flame impingement area may be expressed as

$$\frac{2235}{1{\cdot}412 \times 10^{-3} \times 1700} = 931 \text{ W/(m}^2\text{°C)}.$$

Evaluation of thermal processes

The thermal destruction of microorganisms at a constant temperature, T, may be expressed as a sterilizing value, F, as follows:

$$F = t \times 10^{(T-121{\cdot}1)/z},$$

where F is the sterilizing value or the time (min) at 121·1°C which gives the same amount of sterilization as the process being evaluated, T is the holding temperature (°C), t is the time (min) at temperature T, and z is the slope of the thermal death-time curve of bacterial spores of significance in canned foods. Therefore z represents the increase in temperature required to give a decimal reduction in the time required for inactivation of spores by heat. A z value of 10°C is generally used for most low-acid foods.

When the heating and cooling cycles are rapid, as is the case in flame sterilization, the contributions of these cycles to the total sterilizing value of the process are small and may often be neglected; the main contribution comes from the time at the holding temperature, T.

Hence, providing the cans do not cool in the high temperature holding section of the flame sterilizer, the sterilizing value of the process may be calculated from the above equation. To maintain a constant temperature in the holding section it may be necessary to have small burners there.

However, when there is a temperature change in the high temperature holding section and this change is a linear function of time, the sterilizing value in this section may be calculated from the equation of Cheftel and Thomas (1963):

$$F = z\left[\frac{\theta}{T_B - T_A}\right] \times 0{\cdot}4343\,[10^{(T_B-121{\cdot}1)/z} - 10^{(T_A-121{\cdot}1)/z}],$$

where T_B is the highest temperature (°C)

in the holding section, T_A is the lowest temperature (°C) in the holding section, and θ is the time (min) in the holding section.

The calculation of sterilization values for canned foods is discussed by Board (1972) who gives some values for specific foods.

Requirements for containers

Since the pressures developed during the thermal processing of canned foods in a flame sterilizer are not counterbalanced, the cans must be capable of withstanding the internal pressures without undergoing permanent distortion. With low-acid foods, where product temperatures up to 130°C are used, the internal pressures developed during the process may reach 275 kPa. The temperatures reached in canned acid foods (pH $<4\cdot2$) during sterilization are in the range 80–100°C and hence the pressures in these cans are lower. Because of the high pressures reached, flame sterilization of low-acid foods at high temperatures is restricted to smaller cans (<90 mm diam.), whereas acid foods may be flame sterilized in larger containers, even in drums.

Certain changes may be necessary in design and construction if cans are to withstand high unbalanced internal pressures. At the same time, the cans must be produced at a price comparable to that of cans for retorting, or else at a price which may be offset by savings in production costs associated with the flame sterilization process. Alternatively, the flame-sterilized product should be of such a quality that it will command a price offsetting the cost of the container. A further consideration is that any increase in thickness or temper of the tinplate should be such that the cans may still be readily opened by the consumer with an ordinary can opener.

The weakest areas of a can are the ends and the side seam. The ends of aluminium beverage cans, with or without small pear-shaped pull tabs, will withstand the high internal pressures, but the full tear-out ends of both aluminium and steel cans rupture at the score line when the temperature of the product reaches *c.* 120°C. For product temperatures up to 130°C, cans up to 90 mm diam. will be satisfactory provided that numerous indents are used to strengthen the standard side seams used commercially (Casimir 1972*b*). For flame sterilization, the ends of the cans require a single high-expansion ridge with as large a diameter as possible and several shallow expansion rings permitting end distortion to an extent that does not exceed the elastic limit of the metal (Casimir 1972*b*).

Externally lithographed and internally lacquered cans may be flame sterilized as the wall of the can does not reach temperatures at which the lithography or the lacquers deteriorate. Moreover, because thermal degradation is minimized during flame sterilization, sulphur staining is greatly reduced and thus the use of sulphur-resistant internal lacquers is unnecessary for products such as sweet corn.

Potential

The reversing spin flame sterilization equipment offers a thermal process comparable to that of aseptic processing, and the products are of exceptionally high quality. The sterilizer gives faster rates than any other process for heating foods in cans. For example, 66 × 101·5-mm cans of milk may be heated at 2·2°C/sec, while same-sized cans of vacuum-pack corn may be heated at rates as high as 3·5°C/sec. Heating rates in the French 'Steriflamme' are reported by Beauvais *et al.* (1961) and Cheftel and Thomas (1961) as *c.* 0·6°C/sec. Some rates for particular products in the 'Steriflamme' are: mushrooms in brine, 0·12°C/sec (Lawler 1967); canned peas, 0·16°C/sec (Cheftel and Thomas 1963); 78 × 111-mm cans of whole-kernel sweet corn in brine, 0·24–0·51°C/sec (Joseph and Gould, personal communication).

A new approach to the formulation of products is needed to obtain maximum advantage from the new technique. For a product to be suitable for flame sterilization, the main requirement is that the viscosity during the time the can is in the flame should permit sufficient agitation of the contents to get even heating within the can and enough turbulence at the inside of the can wall to prevent surface fouling or burn-on at the high rates of heat transfer. Casimir and Lewis (1972) describe a number of successful approaches to product formulation that give packs suitable for flame sterilization. Most formulas rely on achieving a microbiologically adequate process before thickening or rehydration is completed. In this way, packs such as spaghetti in tomato sauce, and macaroni and ravioli in cheese sauce have been successfully flame sterilized.

The process has also been successfully applied to vegetables in vacuum packs where the small quantity of liquid, as compared

with that in fully brined packs, reduces the amount of heat needed to achieve the required temperature rise in the contents and also the amount of heat that has to be removed during cooling. Dairy products that have been successfully flame sterilized include plain and flavoured milk, milk concentrates, cream (29% fat), milk custards and rice milk puddings.

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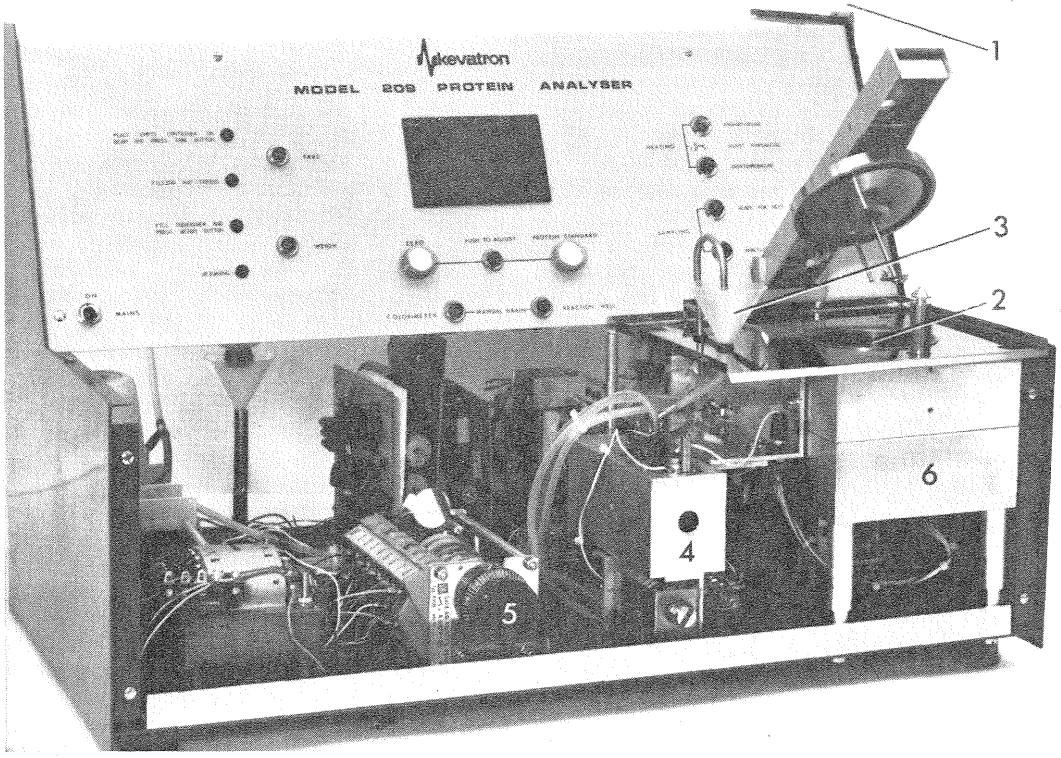
New patents

Protein analyser

An instrument capable of carrying out rapid determination of protein in cereals and other crops has been developed by a group in the Wheat Research Unit. The group includes Dr D. H. Simmonds, Mr J. Ronalds and Dr D. Graham during his period of secondment from the Division of Food Research. The Wheat Research Unit has applied for a patent.

Protein content is a particularly important quality factor in the marketing of wheat, barley and other small grains. Cargoes of Australian, Canadian and American wheat are now sold on the basis of a guaranteed protein figure. To facilitate this practice, it is desirable to segregate the crop according to protein content at as early a stage as possible. The efficiency of the segregating operation will largely depend on the accuracy and speed of the analytical method used.

The procedure developed by the Unit is based on the biuret colorimetric method for protein determination, but offers advantages in speed, convenience and output per operator. Using the commercial form of the equipment (see figure), an operator can perform an estimation every 4 min and present the results directly in digital form as percentage protein. The equipment automatically carries out the operations associated with the conduct of the biuret reaction, i.e. weighing the sample, adding the reagent, heating and mixing for a prescribed period of time, filtering, and performing a colorimetric analysis of the



Protein analyser with front panel removed and lid of reaction chamber raised. 1, Plastic sample cup; 2, reaction chamber; 3, filter funnel; 4, colorimeter; 5, sequence timer; 6, heating block. This prototype was built by Kevatron Instruments Pty Ltd for CSIRO.

filtrate. The apparatus is portable and works from a single power supply outlet. It requires no other services.

Operation of the equipment is extremely simple. The operator places an empty plastic cup in the holder of the ratio balance (extreme right). When the button marked 'Tare' is pressed, reagent flows into a small container suspended from the balance beam. The operator removes the cup, fills it to a prescribed mark with sample and places it back in the beam holder. On pressing the button marked 'Weigh', a weight of reagent proportional to the weight of sample is dispensed into an intermediate holding vessel. The operator then tips the tared sample into the reaction vessel, and moves the dispenser arm across to deliver the measured quantity of reagent into the vessel and to start the timing sequence. After a reaction period of *c.* 3 min the coloured suspension is automatically transferred to the filter funnel and the absorbance of the filtrate is measured, converted to percentage protein, and the result displayed on the digital panel meter. Provision is made for the operator to proceed with the taring of the next sample while the previous one is reacting with reagent. In this way a maximum output of 15 samples per h per operator can be achieved. Both accuracy and reproducibility of the method are good, and training of the operator and his involvement with the analytical technique itself are minimal.

The equipment costs about $2000. Its greatest value is expected to be at country receival points, for segregating wheat, barley and similar products, and in flour mills for checking the protein content of incoming wheat and following the composition of the flour streams as they pass through the roller milling process.

Ultra-heat treatment of dairy products

By J. G. Zadow

CSIRO Division of Food Research, Highett, Vic.

The purpose of sterilizing milk by heating (or indeed by any other method) is to inactivate the microorganisms and destroy the enzymes present in it. If the milk is to be stored for a lengthy period inactivation must be virtually complete. Unfortunately, heating also leads to changes in the components of the milk, which generally have an unfavourable effect on its properties, detracting from either its physical stability or its organoleptic quality. Such changes lead to the development of off-flavours, loss of nutritive value, changes in colour and formation of sediment.

As the temperature is raised, the rate of destruction of microorganisms increases faster than the rate of reactions leading to undesirable chemical changes. For example, the rate of destruction of spores of a particular strain of *Bacillus stearothermophilus*, a comparatively heat-resistant organism, increases by a factor of about 11 for each 10°C rise in the temperature used for sterilization. The rate of destruction of spores of a particular strain of *Bacillus subtilis*, a more heat-sensitive organism, increases by a factor of about 30 for each 10° rise in temperature of sterilization. On the other hand, browning reactions and reactions leading to the formation of undesirable flavour components increase in rate by a factor of about 3 for each 10° rise in temperature.

Hence it follows that the use of higher sterilization temperatures applied over shorter periods can sharply reduce the extent of undesirable chemical changes in the product while still permitting an equivalent destruction of microorganisms. This principle of sterilization by rapid heating of the product to a very high temperature for a very short period is the basis of the process known as Ultra-Heat Treatment (UHT). Whereas conventional retort sterilizers use temperatures of *c.* 120°C for about 15–20 min to sterilize milk, the UHT process heats the milk to more than 135°C, but generally for only 2–5 sec.

In practical terms, UHT processing may be defined as a continuous flow method of sterilizing liquids by heating them rapidly to a temperature exceeding 135°C, maintaining this temperature for a period sufficient to ensure sterility, and then cooling as quickly as practicable. The liquid product is now sterile and its organoleptic quality is considerably superior to that produced by retort sterilization. UHT processing is usually followed by an aseptic filling operation.

The International Dairy Federation (IDF) (1970) agreed on a definition of UHT milk: 'UHT milk is a milk which has been subjected to a continuous flow heating process at a high temperature for a short time and which afterwards has been aseptically packaged. The heat treatment must be such that UHT milk shall:

(i) pass the keeping quality tests described in IDF Standard 48 (1969)
(ii) give turbidity when subjected to the turbidity test as specified in Appendix I of paper B-Doc 2/1970'.

In the definition above, the keeping tests ensure the sterility of the product while the turbidity test ensures that the product was not inadvertently subjected to more severe sterilization processes. Undenatured whey protein is present in only very small amounts in retort-sterilized milk and such milk does not give turbidity in the specified test. UHT milk, on the other hand, contains a much higher level of undenatured whey protein and so develops turbidity on testing as specified.

UHT processing has been the subject of intensive investigation over the past 20 years, but earlier in the century considerable pioneer work was carried out on the process by Nielsen (Orla-Jensen 1913) and Lobeck (Knoch 1930). Difficulties in early operations focused on filling systems—the technology of the day was not capable of manufacturing the sophisticated aseptic filling units required to suit the UHT process. It was not until the advent of the Dole aseptic canning line and

the aseptic Tetra Pak* machine in the 1950s that UHT processing became commercially viable.

'Direct' and 'indirect' UHT processing

The rapid heating and cooling required in the UHT process may be achieved by either of two methods.

The 'direct' UHT process relies on heating by injecting steam into the product or injecting the product into steam; either step causes virtually instantaneous heating. After sterilization, the product is flash-cooled in a vessel which is operated at a vacuum designed to remove an amount of water from it equivalent to the amount of steam condensed during heating. There is thus essentially no net change in the volume of the product. It is obvious that particular attention must be paid to the quality of steam in plants employing direct UHT processing.

The 'indirect' UHT process relies on heat transfer to and from the product through stainless steel interfaces as used in a pressurized plate or tubular heat exchanger. The periods required for heating the product to sterilization temperature and for cooling it after sterilizing are therefore considerably longer than those required in direct UHT processing.

Fig. 1 is a flow diagram of the Alfa Laval VTIS/VTS pilot-scale UHT plant at the CSIRO Dairy Research Laboratory, Highett. This unit may be used for either direct or indirect (plate heat exchanger) UHT processing. The time–temperature relationships for these processes are shown in Figs 2 and 3 respectively. The longer heating and cooling periods associated with indirect processing are evident from these diagrams. Fig. 4 shows an Alfa Laval VTIS (steam injection) UHT plant in operation at Launceston, Tas.

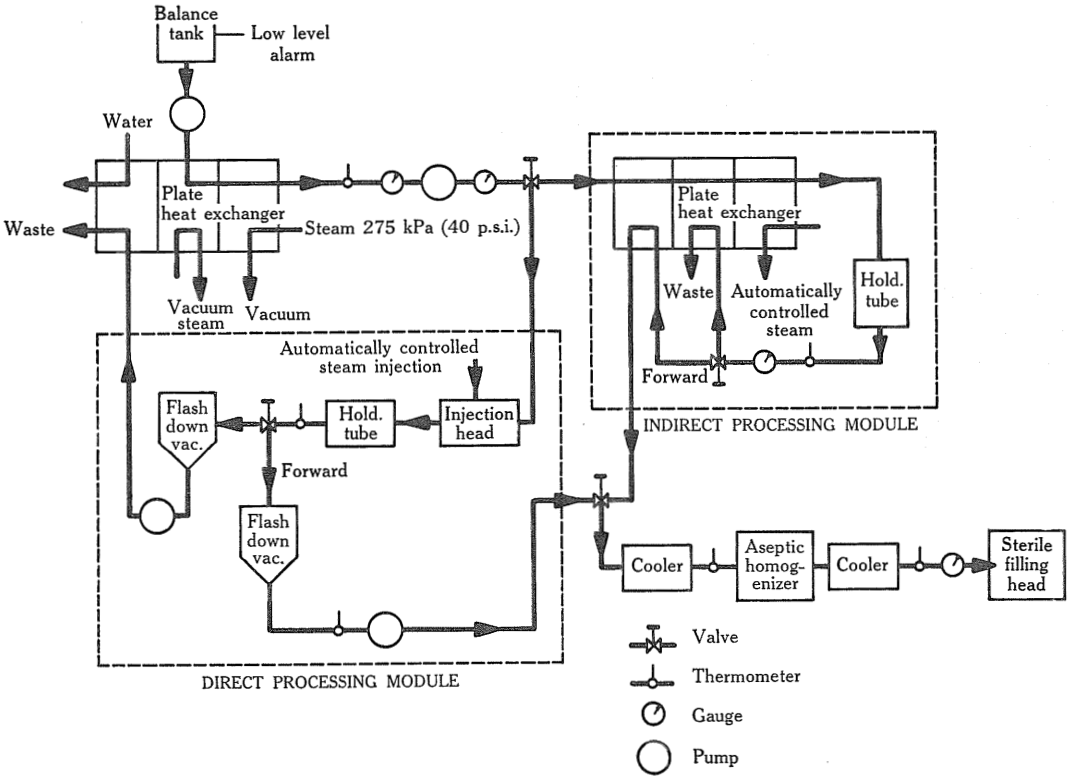


Fig. 1. Flow diagram for the Alfa Laval VTIS/VTS UHT pilot plant at the Dairy Research Laboratory, CSIRO, Highett, Vic.

*Registered trade name.

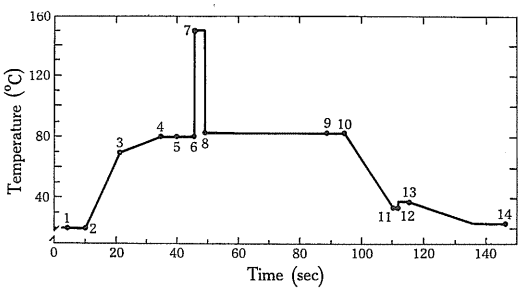


Fig. 2. Temperature of product during passage through the direct system of the Alfa Laval VTIS/VTS UHT pilot plant. 1, Pump to preheater; 2, preheating commences by vacuum flash-down vapours; 3, preheating by vacuum steam; 4, preheating ceases; 5, by-pass to indirect system; 6, steam injection section; 7, holding tube; 8, vacuum flash-down section; 9, re-entry from indirect heating section; 10, precooling; 11, entry to homogenizer; 12, exit from homogenizer; 13, cooling; 14, filling.

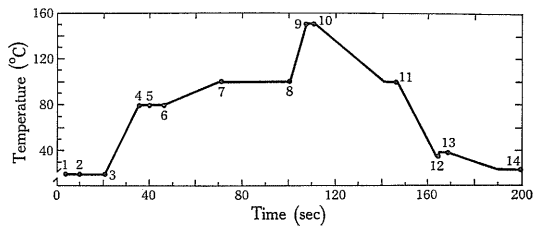


Fig. 3. Temperature of product during passage through the indirect system of the Alfa Laval VTIS/VTS UHT pilot plant. 1, Pump to preheater; 2, entry to non-active preheating section; 3, preheating by vacuum steam; 4, preheating ceases; 5, by-pass to direct heating system; 6, entry to sterilizing plate heat exchanger; 7, passage through non-active heat exchanger section; 8, sterilizing section of plate heat exchanger; 9, holding tube; 10, entry to cooling section of plate heat exchanger; 11, precooling; 12, homogenization; 13, cooling; 14, filling.

Dairy products containing fat must be homogenized to prevent fat separation during long-term storage: a homogenizer is thus an integral part of most commercial UHT plants. If homogenization is carried out downstream from the sterilizing section of the plant it has been shown to reduce sediment formation and fat separation in the product. However, all equipment located downstream from the sterilizing section must be sterilized before operations are commenced and must remain sterile during operation. This necessitates extensive modifications to the homogenizer to prevent bacterial contamination of the product, but the gain in quality offsets the additional expense (Jordan 1968).

It is difficult to assess the comparative merits, in terms of effect on milk quality, of direct and indirect UHT systems. Theoretically, the direct system with its minimal preheating and cooling periods should result in less heat damage to the product. In practice, however, the relative advantages of each process are not clear cut.

Recent studies (Zadow 1969) compared the extent of heat damage to milk caused by direct and indirect UHT when both systems were operated at equal sterilizing temperatures for equal holding times. This basis of comparison must of course yield results biased towards the direct system with its very short preheating and cooling periods. The degree of denaturation of the heat labile protein β-lactoglobulin found in these trials is shown in Table 1; lower denaturation occurred in direct processing.

Franklin *et al.* (1970) have compared direct and indirect UHT processes on the basis of operation at 'equal sporicidal efficiency'. The operating parameters of each process were set so that equal lethal effects were obtained on a particular strain of *B. stearothermophilis*. The conditions necessary to yield equal sporicidal efficiencies were 144°C for 3 sec for direct processing and 141°C for 3·6 sec for indirect processing. Table 1 gives the extent of heat denaturation of β-lactoglobulin as reported by Burton (1972), when these times and temperatures were used.

The effect of different methods of sterilization on the denaturation of whey protein is shown in Table 2 with Kieseker's (1972) data. The denaturation occurring as a result of UHT processing, either direct or indirect, is much less than that occurring with retort sterilization. The less damaging effect is also

Table 1. Comparison of effects of direct and indirect UHT on denaturation of β-lactoglobulin in milk

Direct processing		Indirect processing		
Conditions	β-lactoglobulin denatured (%)	Conditions	β-lactoglobulin denatured (%)	Source
135°C/3 sec	34·4	135°C/3 sec	91·1	Zadow (1969)
144°C/3 sec	68·4	141°C/3·6 sec	82·9	Burton (1972)

indicated by the changes in ferricyanide reducing values (Table 2); these values indicate the extent of heat-induced lactose–protein interaction brought about by each of the three processes.

Formation of deposits in UHT plants

The formation of deposits in the sterilizing section of the plants is a problem common to all UHT systems. Such deposits limit the period of operation possible before the plant has to be cleaned and they may also lead to sediment in the product. With the direct system, deposit formation or 'burn-on' may occur in the steam injection head or in the holding tube. Nevertheless, periods in excess of 8 h are not uncommon in the manufacture of direct-processed UHT milk. With indirect processing the problems are more severe, as burn-on can rapidly reduce the rate of heat transfer and the clearance between the heat exchanger plates, and a point is soon reached where increasing back pressure necessitates shutting down the complete system for cleaning. To avoid this problem, it is common practice to operate the cleaning-in-place (CIP) cycle of indirect UHT plants after 3–4 h of manufacture. During the CIP operation the sterility of the plant is maintained, and manufacture of the product can be recommenced immediately after completion of the CIP cycle.

It is recognized that the extent of deposit formation and resultant sediment in the product can be reduced by preheating the milk at *c.* 85°C for an extended period (4–6 min) before UHT processing. Such a technique will result, however, in an increase in the level of undesirable flavour compounds in the product, together with considerable denaturation of β-lactoglobulin. The particular factors affecting the formation of sediment in UHT milk have been studied in detail by Samuelsson *et al.* (1962).

Aseptic packaging

Aseptic packaging is an integral part of modern UHT processing. Many aseptic packaging systems have been devised, three of which are used by UHT plants in Australia. They are the Tetra Pak and Tetra Brik* aseptic machines and the Dole aseptic canning line. The Tetra Pak and Tetra Brik aseptic systems use a multilayer laminate, made up of paper, aluminium and plastic, to form the carton, the laminate being previously sterilized by hydrogen peroxide and heat. These laminates are non-permeable to gases and vapours and are intended for use with products having an extended shelf life. In the Dole aseptic canning line the cans are sterilized at *c.* 250°C with superheated steam, precooled by steam condensate, aseptically filled and seamed. Dole units are available for aseptic filling of cans ranging in size from < 100 ml to > 20 l. Aseptically packed products are always given a period for incubation before they are distributed to point of sale.

Characteristics of UHT milk

Nutritive value

Any discussion of the nutritive value of UHT milk should take account of two factors —the effect of the UHT process itself and the influence of long-term storage. The nutritive value of the major components of milk (proteins, lipids, carbohydrates and minerals) has been shown to be virtually unaffected by UHT processing. Similarly, the UHT process has little effect on the more heat-stable vitamins of the B group, such as riboflavin, thiamine, pantothenic acid, biotin, nicotinic acid, vitamin B6 and vitamin B12. UHT processing does not appear to affect the level of ascorbic acid, but a small loss in folic acid and dehydro ascorbic acid content may occur. A comparison of vitamin losses occurring as a result of pasteurization, in-bottle sterilization and UHT treatment, based on the

Table 2. Comparison of effects of different heat treatments on the denaturation of whey proteins in milk (Kieseker 1972)

Sample	Whey protein denatured (%)	Ferricyanide reducing value
Direct UHT 135°C/2 sec	12·3	5·4
Indirect UHT 135°C/2 sec	40·3	14·4
Rotary retort-sterilized 120°C/12 min (250-ml can)	58·0	48

*Registered trade name.

Table 3. Typical values for percentage loss of vitamins from milk during pasteurization and sterilization (Porter and Thompson 1972)

Vitamin*	Pasteurization		In-bottle sterilization		UHT sterilization
	HTST	Holder	115°C/30 min	110°C/15 min	(direct or indirect)
Thiamine	< 10	10	35	20	10
Vitamin C	10	20	50	40	10
Folic acid	0	0	50	40	15
Vitamin B12	0	10	90	60	< 10

*Vitamins not listed are unaffected.

data of Porter and Thompson (1972), is shown in Table 3. The losses in the UHT-treated milk are much lower than those in milk that is retort-sterilized.

There appears to be little change in the nutritive value of the major components of milk during storage. However, significant losses in vitamin B6, vitamin B12, ascorbic acid and folic acid may occur during extended storage of UHT milk in Tetra Pak containers (Table 4). Losses of folic acid and ascorbic acid during storage are related to the availability of oxygen in the system. Significant losses of these components could therefore be expected in UHT milk produced by systems without vacuum cooling (Ford *et al.* 1969).

Storage life

The major problem limiting the storage life of UHT milk is gel formation. 'Age gelation', as it is called, occurs after a period depending on storage conditions and seasonal changes in the raw milk, amongst other factors. Typically, this period may vary from 15 weeks for storage at 30°C to 18 months or more for storage at 2°C. The problem of age gelation has been a significant factor in slowing commercial acceptance of the UHT process, particularly as retort-sterilized milk does not suffer from this defect. Overseas workers (Corradini and Bottazzi 1966) have reported that gelation occurred in milk processed by direct UHT treatment, but it was not found in UHT milk processed by the indirect method. These authors considered that the degree of denaturation of β-lacto-globulin was an important factor in age gelation. However, Samuelsson and Holm (1966) expressed the view that reactivation of proteolytic enzymes that survive the sterilization process was responsible for age gelation. It is generally conceded that the onset of this defect can be controlled by increasing either sterilization temperature or holding time above those normally employed. Of course, such a step leads to greater heat damage with a corresponding increase in undesirable flavour compounds in the product.

Flavour

'Cooked' flavour is negligible in pasteurized milk, noticeable in fresh UHT milk and may

Table 4. Typical values for percentage losses of vitamins from UHT milk after storage in Tetra Pak cartons (Porter and Thompson 1972)

Vitamin*	Period of storage (days)	Oxygen level after processing (ppm)	Loss during storage at 15–19°C (%)
Vitamin B6	60	0·1	40
	60	1–2	40
	60	8	40
Vitamin B12	60	0·1	60
	60	1–2	60
	60	8	60
Ascorbic acid	60	0·1	20
	14	1–2	90
	7	8	100
Folic acid	60	0·1	0
	60	1–2	5
	14	8	100

*Vitamins not listed are unaffected.

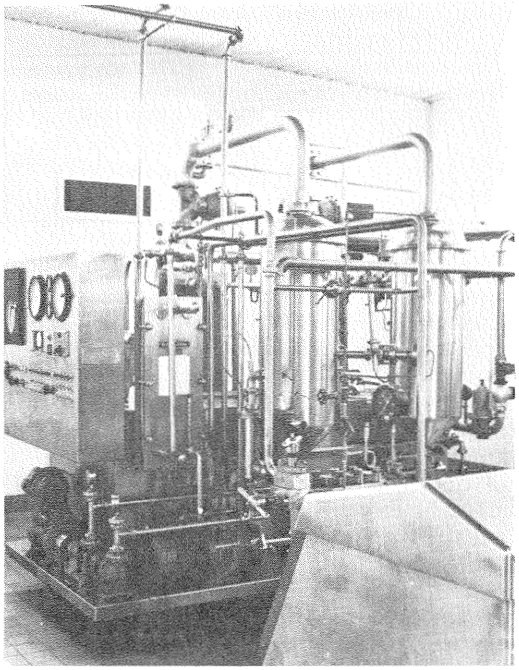


Fig. 4. Alfa Laval VTIS steam injection UHT plant. Photograph by courtesy of Baker's Milk Pty Ltd, Tas.

be very strong in retort-sterilized milk. The development of this flavour is probably produced by sulphydryl groups unmasked in the denaturation of β-lactoglobulin (Lyster 1964). The changes in flavour occurring in UHT milk during storage are related to both storage temperature and oxygen content (Ashton 1969). In general, samples stored at lower temperatures maintain an acceptable flavour for longer periods than those stored at higher temperatures. In the short term, UHT milk with a high oxygen content is generally preferred, but over a long period it may develop a strong oxidized flavour. Hence, for consumption after long-term storage, UHT milk with an initially low oxygen content is preferred. By manipulating the oxygen content of the product, the manufacturer of UHT milk can ensure that his product has maximum palatability during the most likely period of consumption.

UHT whipping cream

As noted earlier, homogenization is generally used to prevent the separation of fat in dairy products. It is well known, however, that even mild homogenization can reduce or totally destroy the whipping properties of cream. Hence the major problem in the manufacture of UHT whipping cream is to select processing conditions which will balance the opposing requirements for satisfactory whipping and for physical stability during storage.

Recent studies (Kieseker and Zadow 1973) have shown that the whippability of UHT cream correlates with the extent of fat globule clustering. Clustering of fat globules could be increased by decreasing the pH of the cream, increasing the ionic calcium content of the cream or by careful selection of homogenizing conditions. Although increased clustering did lead to improved whippability, it also resulted in greater separation of fat during storage. This defect was overcome by adding to the cream low levels of organic stabilizers such as lecithin or carageenan. It is probable that such organic stabilizers reduce separation of fat by forming a thixotropic structure, with a resultant increase in effective viscosity of the cream. The method of manufacture of UHT cream recommended by these authors relies, therefore, on production of a cream with a large degree of fat clustering to enhance whippability, while excessive fat separation is prevented by the addition of organic stabilizers. UHT cream containing such stabilizers has a shelf life of more than 90 days, compared with 15–20 days when stabilizers are not used.

Outlook

In Europe and the USA, demand for UHT products has continued to rise strongly over the last few years. For example, in the Federal Republic of Germany the sale of UHT milk rose from 0·13% of the total milk market in 1965 to 1·96% in 1969, with sales of up to 5% of the market being achieved in particular areas. In one area in France, consumption of UHT milk increased from 4% to 8% of total milk production between 1971 and 1973. In general, there has been a considerable *per capita* increase in the consumption of UHT milk in Europe, whereas the consumption of other types of milk has been going down slightly.

The manufacture of UHT milk has aroused considerable interest in countries with warm climates. For instance in Zambia the production of recombined UHT milk is about 95 000 litres per day and at this level is unable to satisfy demand. With the success of this operation, the introduction of UHT processing of recombined products in other

countries with warm climates seems a probable future development.

In Australia, four firms are manufacturing UHT products and a significant market for Australian UHT milk has been developed in the more remote areas and also overseas.

The UHT process may be used to manufacture a wide range of specialty products such as puddings, ice cream, thick-shake mix and custards, each of which has excellent storage characteristics and good organoleptic quality. It is likely that demand for such products will increase.

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News from the Division

Appointments

Mr A. J. Hillier, B.Sc. (Hons), has joined DRL as an Experimental Officer to study the biological mechanisms of formation of flavour compounds in dairy products by lactic acid bacteria. He is working with Dr G. R. Jago at the Russell Grimwade School of Biochemistry, University of Melbourne.

The Division was fortunate in being allocated six positions for technical assistants under the Australian Government's NEAT Scheme (National Employment and Training Scheme). The positions are tenable during 1975 and are for persons studying at the technical certificate level. FRL and DRL have each appointed two assistants and MRL and TFRU one each.

Transfer

Mr I. J. Eustace, Experimental Officer at DRL, has transferred to the Industry Section of MRL at Cannon Hill. He will investigate microbiological and chemical problems relating to meat and meat products and participate in extension activities.

Visiting worker

Associate Professor A. V. Robertson of the University of Sydney spent eight weeks in FRL's Flavour Chemistry Section early in 1975. Professor Robertson directs the Mass Spectrometry Unit of the University.

Colombo Plan Fellow Miss Boonyasee Sa-Ngapong from Thailand was given an insight into CSIRO non-research administration and management during a three weeks' attachment to FRL late in 1974.

Work overseas

Dr J. H. B. Christian, Associate Chief, visited Switzerland in April to take part in a Joint FAO/WHO Consultation on Microbiological Specifications for Foods.

Mr K. J. Scott, Senior Research Scientist with the N.S.W. Department of Agriculture, who is located at FRL, North Ryde, was a guest worker with the N.Z. Apple and Pear Marketing Board for the first three months of this year. With Dr R. B. H. Wills, formerly of FRL, he carried out a program of work aimed at reducing the incidence of bitter pit,

an important physiological disease of apples.

Dr D. Graham of PPU, was in Japan from 6 January to 2 April as Visiting Professor for the Japan Society for Promotion of Science. He worked in Professor Takashi Akazawa's Department at Nagoya University.

Mr D. G. James of TFRU is on three years' leave from the Division, having accepted a term appointment with the Food and Agriculture Organization of the United Nations. *En route* to Rome he took part in a symposium on the Indian fish-processing industry at Mysore.

Mr J. D. Mellor, of the Physics Section at FRL, has returned to the Division after two years' absence; most of this time was spent in France where Mr Mellor was engaged in writing a textbook on freeze-drying of foods.

General

At the request of the Australian Department of Science, FRL organized a three-day seminar in April on 'Food—Postharvest and Processing Technology' for the Association for Science Cooperation in Asia (ASCA). This meeting of ASCA was attended by representatives from nine countries and resulted in a recommendation for three collaborative projects between several of the participants.

As part of the Division's growing involvement in scientific and technological aid programs for countries in South-east Asia, Dr W. B. McGlasson of PPU spent most of March in Pakistan's Nuclear Institute for Agriculture and Biology as an 'Aid Expert', at the request of the Australian Development Aid Agency.

At the same time, Mr P. W. Board of FRL attended a meeting of the Codex Committee on Processed Meat Products in Copenhagen, Denmark, at the request of the Department of Foreign Affairs.

Several members of FRL staff lectured at a Meat Canning Technology course at Hawkesbury Agricultural College in February. The course, to be repeated soon, was for Australian Department of Agriculture meat inspectors and veterinarians.

Awards

The University of Queensland has awarded the Bachelor of Economics degree to Dr D. J. Horgan and the Bachelor of Science degree to Mr F. D. Shaw, both of MRL.

FRL's E. W. Hicks Memorial Prize, which has not been awarded for several years, was won this year by Miss Brenda Jackson of the Division of Mathematics and Statistics, attached to FRL. The prize is donated by the FRL Staff Club for the most meritorious results in a course of study leading to a first degree, diploma, certificate or other professional qualification. The prize is named after the late E. W. Hicks, the Division's senior physicist at the former Homebush laboratories, who died in 1959.