VOL. 46 No. 3 September 1986

CSIRO Food Research Quarterly

The shelf life of meat during retail display

By B.P. Cain and V.H. Powell

CSIRO Division of Food Research, Cannon Hill, Queensland, 4170

Introduction

Meat preservation is primarily concerned with the inhibition of microbial spoilage. To this end, the value of low temperature storage has long been recognized. Historically, appreciation of this fact led to the storage of meat in caves, then in cool cellars, and finally in mechanically refrigerated cabinets.

Industry is conscious of the need to produce meat with an acceptable colour, appearance, wholesomeness and presentation to the consumer. These are the main factors affecting the sale of meat from refrigerated display units.

The presentation depends to a large extent on the skill of the butcher in the preparation and display of the product, but retention of the attractive bright red colour of beef and the characteristic colour of lamb and pork for the greater part depends on the efficient operation and maintenance of the refrigerated display.

The principal factor affecting both the colour and the shelf life of meat on display is the maintenance of optimum temperatures.

Performance of meat on display

The effects of temperature on meat are best understood by first gaining a knowledge of some of the following properties of meat:

- Water loss
- Tissue respiration
- Microbiology
- Colour

Water loss

When meat is cut, the exposed surfaces exude liquid which detracts from the appearance of meat. Although efficient chilling of carcasses can reduce the quantity of exudate (Powell 1978), a certain amount will always be present when meat cuts are prepared for retail sale. In general, the lower the meat temperature, the less the exudate lost. Unfortunately, if meat temperatures are allowed to fluctuate, large amounts of exudative loss will result, and the higher the average temperature of the sliced or vacuum packed meat, the larger this loss (Powell, unpublished data).

If unwrapped, meat is almost certain to lose weight by evaporation. Its appearance will deteriorate by drying, resulting in a darkening of the meat surface.

Tissue respiration

Meat is a biological material containing respiratory enzyme systems which consume oxygen and produce carbon dioxide. The level of respiration varies between muscles, individual animals, species and time after slaughter.

Respiration is confined to the surface layer into which oxygen diffuses. The depth of penetration depends on a balance between the oxygen concentration at the surface driving oxygen inward, and tissue respiration which consumes the oxygen as it becomes available. At lower temperatures, depth of penetration is greater because oxygen consumption is less and solubility greater.

Microbiology

Microorganisms present on the surface of meat will cause spoilage when conditions permit. The nature and rate of spoilage is governed by the temperature, pH, water activity and gaseous environment of the meat.

After dressing, the surface of a carcass may carry between 100 and 10 000 bacteria/sq cm (Eustace 1979). After butchery, slices of meat may carry considerably higher numbers. Present among the bacteria are pseudomonads which can multiply in air and become the most dominant bacteria on chilled meat. Their proliferation eventually causes slime formation and the putrid odours commonly associated with spoiled meat.

Pseudomonads require oxygen for growth and, in air, will spoil meat in approximately 10 days at 0 °C, or 1 day at 20 °C, as

CSIRO Food Res. Q. 1986, **46**, 49-56

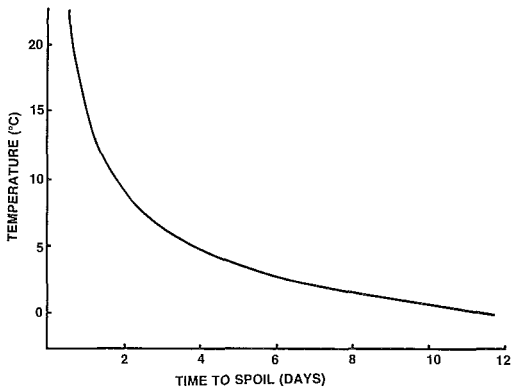


Fig. 1. Effect of temperature on the time for bacterial spoilage of moist meat.

illustrated in Fig. 1. The greater the bacterial load the greater their demand for oxygen which reduces that available for tissue respiration.

Recent work (Dainty *et al.* 1983) has shown that aerobic bacteria such as pseudomonads and *Achromobacter* cause metmyoglobin formation (browning) by a reduction of the available oxygen to the meat surface.

Temperature has the greatest effect on the rate of microbial activity on meat.

Colour

The colour of lean meat depends on the state of the iron-containing muscle pigment myoglobin. In air, myoglobin is oxygenated to oxymyoglobin, or oxidized to metmyoglobin. Oxymyoglobin, the bright-red ferrous form of the pigment, is favoured by high oxygen concentration, while low concentrations favour oxidation to the brown ferric form, metmyoglobin.

When a freshly cut piece of meat is exposed to air, both reactions take place. At the surface, where oxygen is freely available, oxymoglobin forms and extends inwards to near the limit of oxygen penetration where metmyoglobin predominates. Beyond this level where oxygen has not penetrated, the pigment remains as reduced myoglobin, with its characteristic purple colouration.

Oxygenation of myoglobin is rapid; the surface of beef in air will appear red within a short time. On the other hand, oxidation to metmyoglobin is slow, and appears first as a thin brown layer at the limit of oxygen penetration. With time this brown layer thickens and becomes apparent to the observer. The rate at which these changes occur is heavily influenced by storage temperature, muscle type, degree of conditioning and pH (MacDougall and Taylor 1975).

Low temperatures will slow the deoxygenation reaction of oxymyoglobin to myoglobin and thus keep the pigments in the red oxymyoglobin state for longer periods of time. In addition, low temperatures will inhibit bacterial growth and their subsequent discoloration activity. The concentration of oxygen must be high enough to oxygenate the meat surface to a depth of at least 5 mm. At higher temperatures, this depth is less because of the greater oxygen demand by muscle respiratory systems (Bendall 1972).

The intensity of meat colour is determined by antemortem factors such as species, sex, age of animal, stress and ultimate pH of the meat (Seideman *et al.* 1984).

The colour intensity differences between species are primarily caused by differing concentrations of myoglobin. Beef has the highest, lamb is intermediate and pork has the lowest concentration of myoglobin and is therefore the lightest in colour (Walters 1975).

The colour of fresh meat is the most important factor to the consumer in selecting meat from a retail display (Kropf 1980; Taylor 1982). Consumers equate the colour of meat to freshness, and rely on colour as a criterion of quality, even though there is little correlation between colour and eating quality.

Knowledge of meat colour is also of key importance to the retailer. Maintenance of fresh meat colour at the retail level will result in less trim loss, an increased shelf life and higher probability of sale. The importance of display unit temperature and hygiene during cutting and presentation cannot be overemphasized.

The display of meat

As mentioned previously, it is the colour, appearance and presentation that are the principal factors that affect the sale of meat from refrigerated display units. The appearance and the presentation depend on the butcher, but retention of the attractive bright red colour for beef and the characteristic colour of lamb and pork is dependent upon the efficient operation, lighting and location of the refrigerated display unit.

There are various types and styles of refrigerated display units available for retail

display of fresh meat, although currently there are only two basic methods of presentation. These are to:

(a) display sliced meat on trays from which it is sold, as is commonly practised by the traditional butcher.

(b) display and sell meat on polystyrene trays overwrapped with clear PVC film.

The traditional butcher almost exclusively relies upon conduction to refrigerate his displayed meats (cold plate displays). Improvements in the design of display units have seen the introduction of bunker type units which operate by convection. Various forced air units, which make use of recirculated air as the method of maintaining temperature, have now become common. In the latter case, air is circulated by fans through cooling coils, then ducted to flow over the meat on display. This type of unit, designed for the display of wrapped meat, is predominantly used by supermarkets. Such developments in unit design were motivated by the need to maintain meat in an attractive, saleable condition for as long a period as possible.

The display and sale of vacuum-packed primal cuts has now become accepted as another method of meat marketing. It must be understood that meat packaged in this manner is a fragile product which requires careful handling and a low temperature environment of 0° to 1°C for maximum shelf life.

In order to obtain the longest possible shelf life for meat, the storage temperature should be as close to 0°C as possible. This will keep microbial growth to a minimum and prolong the retention of attractive meat colour. As it is impossible to maintain a steady 0°C in open meat display cabinets, a realistic optimum temperature range is 0° to 3°C.

Survey of refrigerated retail meat display units

Procedure

A survey of temperatures in various types and styles of refrigerated retail meat display units was undertaken. Table 1 lists the types, styles and location within the shop of the display units surveyed.

The survey was conducted in various butcher shops and supermarkets throughout the Brisbane metropolitan and surrounding areas. The display units were monitored in their usual operational condition.

Some premises were air-conditioned and others were not. However, due to the time of the year during which the survey was carried out (May to August i.e. winter) there was little difference between shop ambient temperatures.

Temperatures in each display were monitored using up to 40 copper-constantan thermocouples (type T) in conjunction with a Doric Digitrend 235

TABLE 1

Meat display units surveyed

Type	Style	Location
Cold plate	Standard	Window
,,	,,	Within shop
,,	With counter top	,,
Bunker	Cabinet	Window
,,	,,	Within shop
,,	With counter top	,,
Forced air	Cabinet	Within shop
,,	Two tier	,,
,,	Three tier	,,

TABLE 2

Typical performance of a cold plate type retail display

2a: Standard style (window) — day use only	
Location	Temperature (°C)
On plate	−10 to −2
Air at mesh rack	+2 to +6
Meat 10 mm above mesh	+8 to +11
Meat 25 mm above mesh	+12 to +14
Meat 50 mm above mesh	+15 to +18
Shop ambient: 17° – 18°C.	
2b: Standard style (within shop) — day use only	
Location	Temperature (°C)
On plate	−11 to −6
Air at mesh rack	0 to +2
Meat 25 mm above mesh	+4 to +6
Meat 50 mm above mesh	+10 to +14
Meat 100 mm above mesh	+12 to +15
Meat 150 mm above mesh	+14 to +16
Shop ambient: 16° – 17°C.	
2c: Counter top style (within shop) — day use only	
Location	Temperature (°C)
On plate	−12 to −8
Air at mesh rack	0 to +3
Meat 25 mm above mesh	+4 to +6
Meat 50 mm above mesh	+6 to +8
Meat 100 mm above mesh	+10 to +14
Shop ambient: 17° – 18°C.	

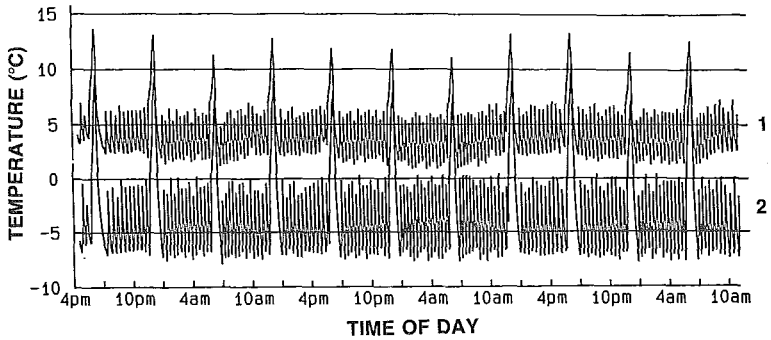


Fig. 2. Example of temperature history of thermocouple locations. 1. Supply air. 2. Return air.

datalogger and a Hewlett Packard HP-85 microcomputer. After positioning the thermocouples and setting the equipment in operation, temperatures were monitored at 5 minute intervals for periods of between 24 and 56 hours. In instances where the display units were operated only during shop trading hours, the monitoring equipment was run accordingly. If a thermocouple had to be moved the staff were asked to reposition it to its original position, or to a new position and note the time of movement.

Survey results analysis

Graphs of the data collected were produced to give a temperature history for each thermocouple location for the entire monitoring period. An example of the type of graph produced is seen in Fig. 2.

These graphs were used to prepare typical temperature performance data for each type and style of display. The data for each is summarised in Tables 2 to 4. Because the refrigeration units cycle, the air temperature fluctuations within the display at any given location follow this cycle. These cycles are typically of 10-15 minutes duration. The air temperatures noted in Tables 2 to 4 are the mean upper and lower temperatures of the cycle.

Results and discussion

Survey results

Cold plate types (Table 2):— Fresh, unwrapped, sliced meat displayed in cold plate units was often stacked to 50 mm or more above the mesh on the plate. At this height above a cold plate not fitted with a counter top, the temperature of the meat is such that the maintenance of a bright red colour (bloom) is poor, and could be expected to be maintained for only half a day. During the same period, the bacteria on the meat would be growing more rapidly than is desirable. Of the cold plate systems,

TABLE 3

Typical performance of a bunker type display unit

3a: Cabinet style (window) — day use only

Location	Temperature (°C)
Air adjacent to coil	−12 to + 2
Air at mesh rack	0 to + 5
Meat 50 mm above mesh	+8 to +13
Meat 100 mm above mesh	+10 to +16
Meat 175 mm above mesh	+13 to +18

Shop ambient: 18° – 19°C.

3b:Cabinet style (within shop) — 24 h use

Location	Temp (°C) day	Temp (°C) night[A]
Air adjacent to coil	−10 to 0	−10 to 0
Air at mesh rack	−2 to +3	−4 to 0
Meat 50 mm above mesh	+2 to +7	0 to +3
Meat 100 mm above mesh	+7 to +12	+3 to +6
Meat 175 mm above mesh	+7 to +12	+4 to +7

Shop ambient: day: 18°C; night: 14°C.
During daytime defrosts air temps. rose to between 8° and 12°C.

3c: Counter top style — day use only

Location	Temperature (°C)
Air adjacent to coil	−12 to −2
Air at mesh rack	−2 to +2
Meat 50 mm above mesh	+2 to +5
Meat 100 mm above mesh	+3 to +7
Meat 175 mm above mesh	+7 to +11

Shop ambient: 18° – 19°C.

[A]Night cover fitted out of trading hours.

TABLE 4

Typical performance of a forced air type display unit

4a: Cabinet style (within shop) — 24 h use.

Location	Temp. (°C)	Defrost temp. (°C)
Supply air	−8 to −2	15
Return air	+2 to +8	15
Air beneath load limit lines	+2 to +7	13
Meat temp. (top slice)	+5 to +8	13

Shop ambient: day: 18 °C; night: 18 °C.

4b: 2 tier style (within shop) — 24 h use.

Location	Temp. (°C)	Defrost temp. (°C)
Supply air	−7 to +2	+7
Return air	+2 to +6	+9
Air beneath load limit lines	−2 to +3	+5
Meat temp. (top slice, both tiers)	+2 to +5	+6.5

Shop ambient: day: 19 °C; night: 15 °C.

4c: 3 tier style (within shop) — 24 h use.

Location	Temp. (°C)	Defrost temp. (°C)	
		day	night
Supply air	0 to +5	19	16
Return air	+5 to +8	20	16
Air beneath load limit lines (all tiers)	+2 to +6	15	15
50 mm above load limit lines (all tiers)	+5 to +10	—	—
Meat temp. (top slice on all tiers)	+4 to +8	9	9

Shop ambient (average): day: 20 °C; night: 16 °C.

only those with counter tops could be considered satisfactory. In these display units, acceptable meat colour and quality for the consumer is maintained for one to two days. Within the shop, standard cold plate units should have covers similar to counter tops fitted to assist in maintaining a low temperature in the meat displayed.

Because of incident radiation from both outside the shop and from display lighting, temperatures at 50 mm above the mesh in cold plate display units located inside street windows averaged 8 °C above comparable counter displays within the shop. We consider the temperatures in standard cold plate displays are unsatisfactory for the maintenance of good colour and microbial quality.

Bunker types (Table 3):— At 50 mm above the mesh in the bunker style display units within the shop there is only a marginal difference in the temperature of meat displayed in either a counter top style or an open cabinet style. At higher levels above the mesh (e.g. 100 mm), the counter top style maintains better meat temperature than the open cabinets. For the same reasons that the cold plate type inside a street window is unsatisfactory, the bunker cabinet inside a street window cannot maintain sliced or vacuum packaged meat at acceptable temperatures.

The operating principle of these cabinets is based upon cold air falling from the refrigeration coils, the cold air being contained within the bunker. The associated convective movement of air is sufficient to cause a slight drying of exposed meat surfaces. This drying effect is more pronounced at higher temperatures.

A bunker-type display fitted with a counter top or cover maintains better temperatures because the cold air is contained in the unit and the warmer ambient air kept out of the display. This also reduces the convection rate and hence the slight drying effect noted previously.

Forced air types (Table 4):— All of the forced air cabinets are capable of keeping meat at optimum display temperatures (i.e. 0° −3 °C). The majority surveyed maintained meat in the range of 4° to 8 °C. Incorrect setting of the refrigeration controls was the reason why most operated at higher than optimum temperatures.

Optimum meat temperatures are obtained by keeping the supply air temperature below zero, typically −5 °C, dependent on the display unit's construction and refrigeration system.

Only wrapped meats are displayed in this type of unit because of the drying effect caused by the air movement within the unit.

Several defrost cycles (typically three or four) each day allow air temperatures to rise

by up to 15 °C for several minutes. During each cycle the meat temperature will rise, typically 5 °C. This fluctuation in meat temperature not only causes colour deterioration and increased bacterial growth, but also increases exudate loss (Powell, unpublished data).

General discussion

The range of temperatures monitored in the displays varied widely from unit to unit.

Fortuitously, turnover of fresh sliced meat was usually such that most pieces of meat were not in display units for periods in excess of half a day. However, this was not universally true. Instances of meat (both fresh and vacuum packaged) being displayed for an entire day(s) at unacceptably high temperatures (viz. 8 °C and above) were not uncommon.

As noted earlier, this survey was undertaken during the Brisbane winter, when shop ambient temperatures rarely exceeded 20 °C. During summer, we would expect that in non-air-conditioned shops, temperatures of 30 °C or more would be reached, and therefore, we would anticipate higher meat temperatures in most display units, particularly those of the cold plate type.

Lighting associated with displays was found to cause the upper layer of meat to be 2 ° to 3 °C higher than meat in displays without lighting. This rise in meat temperature was associated with a light intensity of 1000 lux or more. Lower temperature rises were apparent at lower light intensities. Forced air displays generally tended to have higher light intensities than the other types of displays.

It is apparent that there is a basic lack of knowledge and understanding regarding the refrigeration performance of display units, as well as the effects of display lighting and other sources of radiant heat on the condition of meat.

Based on the temperatures monitored in the various display units, and from discussions with butchers on their perceptions of meat colour acceptable to their customers, we would expect the display life of meat in the various display units to be similar to that detailed in Table 5.

Other factors

Lighting

Lighting is an issue on which some retailers have very definite views. This is particularly true of those who sell their product on a self-service basis. Most displays with special lighting used "Plantlux", "Grolux" or similar tubes which have a high percentage of red in their spectral emission. This enhances the meat's appearance, adding to the consumer appeal. This red glow emanating from some meat displays, delicatessens and butcher shop windows was so intense that even white meats looked red.

It has been suggested (Kropf 1980) that lights with a red emission of around 25% give a better rendition of colour while meat is on display. Kropf recommended "natural" fluorescent tubes (having a red emission of approximately 25%) as being the most honest in terms of colour rendition.

Light intensity is also a factor which can affect meat colour and temperature. The less meat is exposed to light the better. It has been recommended (Kropf 1980) that light intensity be kept as low as reasonably possible, but never more than 1100 lux. One situation which we surveyed (part of a supermarket chain) used a light intensity of 600 lux. We felt that this was adequate illumination of the meat on display.

TABLE 5

Expected display life for fresh meat in various types of retail display units

Type	Style	Expected display life[A] (days)
Cold plate	Standard (window)	<0.5
Cold plate	Standard (in shop)	0.5
Cold plate	With counter top	1–2
Bunker	Cabinet (window)	0.5
Bunker	Cabinet (in shop)	1–2
Bunker	With counter top	2–3
Forced air	All styles	2–3

[A]At 50 mm above the mesh for cold plate and bunker types, and beneath the load limit line for forced air types. Reduced display life is expected at levels above 50 mm.

Fluorescent lights are regarded as being cool but even they emit significant amounts of radiant energy. In our trials, in which we used "Sylvannia" Natural fluorescent tubes located to give 1000 lux at the meat surface, a thermocouple mounted on a black 5 cm^2 fin consistently measured 2 °C hotter with the lights on than when they were off. The radiant energy passed through the cold air to impinge directly on the surface of the fin in the same way as it would affect the surface of meat in the display unit.

Energy

The major energy consumer in a meat display unit is the refrigeration compressor. Most refrigeration units are sized so as to handle the chilling requirement of the display. On a warm day, the unit is running most of the time. Retailers with forced air and bunker style displays often leave meat in the displays overnight. This practice is satisfactory provided the temperatures in the displays are adequate. However, the refrigeration system is then required to run most of the night as well.

One of the bunker type cabinets surveyed was run on a 24 h basis, with a night cover fitted outside of trading hours. The cover, a roller blind of aluminium insulation material, could be drawn across the cabinet and clipped in place. It was permanently mounted at the rear of the cabinet. From Table 3(b), it can be seen that with the cover in place, temperatures were reduced by approximately 4 °C at the 50 mm level. At higher levels this reduction was greater.

A forced air display unit installed at the Meat Research Laboratory was monitored to determine energy usage and running time. The display unit was a cabinet style 3650 mm in length, 830 mm wide and 170 mm deep (rack to load limit), coupled to a 2 kW refrigeration unit. The refrigeration compressor ran continuously day and night, consuming 40 kWh of electricity in a 24 h period while operating with no cover, and had a supply air temperature averaging -6 °C (meat temperature 0° -2 °C). When a cover of 25 mm thick polystyrene was placed in position, the compressor ran for only half the time. The system consumed 20 kWh of electricity in a 24 h period and provided a supply air temperature averaging -8 °C. In other words, the air temperature, and thus meat temperature, was lower and the refrigeration unit consumed only half the energy of the display without a cover.

If night covers are used in commercial operations for 14 h per day, an electrical energy saving of 30% is achievable because of a reduction in running time for the compressor.

It was also interesting to note that the condensate from the coil at defrost when the cover was fitted was reduced by 70%. As the night cover also reduces the requirement for frequent defrost cycles, the unit can be operated all night without a defrost period. Thus, the maintenance of low, unfluctuating temperatures will be achieved, which should give longer meat display life and less exudative loss.

Caution should be exercised if night covers are contemplated to ensure that the lower temperatures achieved do not freeze the meat. Separate controls for night and day operation may be necessary.

Conclusions

Conditions to ensure good display life and colour of meat include the maintenance of correct storage and display temperatures, hygienic preparation and low display illumination levels.

Cold rooms for the storage of carcasses and primal cuts prior to preparation for sale should be operated as close to 0 °C as possible, with a relative humidity of 85-90% and low air circulation. Beef carcasses which have a deep butt temperature of 15 °C or greater should not be accepted by the butcher, as these carcasses risk the development of bacterial growth, surface discoloration and excessive exudate loss.

Hygienic preparation procedures should be adhered to at all times.

Maintaining optimum meat temperatures of 0° -3 °C in display units is recommended. For each 2 °C rise in temperature there is a loss of 1 day in display life.

Street window display units are not recommended.

If cold plate display units are used they should be within the shop and have a counter top cover.

The performance of bunker type units is superior to the cold plate types, but they too should be located within the shop and have counter tops fitted.

For wrapped meat, forced air types offer the best temperature environment. Even so, they should be operated to give 0° -3 °C meat temperature for best results.

The use of night covers gives superior temperature control and savings in electrical energy.

Display illumination should not exceed 1000 lux, and should preferably be kept at lower intensities.

References

Bendall, J.R. (1972). Consumption of oxygen by muscles of beef animals and related species. *Journal of the Science of Food and Agriculture* **23**, 61.

Dainty, R.H., Shaw, B.G., and Roberts, T.A. (1983). Food Microbiology: Advances and Prospects. Society of Applied Bacteriology Symposium. Series No. 11, p151 (Roberts, T.A. and Skinner, F.A. (Eds)), Academic Press.

Eustace, I.J. (1979). Microbiological Considerations for Chiller Design and Operation. CSIRO Report, Refrigeration for Meat Industry Engineers and Consultants 1-1.
Kropf, D.H. (1980). Effects of Retail Display Conditions on Meat Colour. Proceedings of the Reciprocal Meats Conference, 33, 15.
MacDougall, D.B., and Taylor, A.A. (1975). Colour retention in fresh meat stored in oxygen — a commercial trial. *Journal of Food Technology* **10**, 339-47.
Powell, V.H. (1978). Weep in vacuum-packaged meat. Proceedings of the 24th European Meeting Meat Research Workers, Kulmbach, paper D1.
Seideman, S.C., Cross, H.R., Smith, G.C., and Durland, P.R. (1984). Factors Associated with Fresh Meat Colour: A Review. *Journal of Food Quality* **6**, 211-37.
Taylor, A.A. (1982). Retail packaging systems for fresh meat. Meat Science Technical International Symposium Proceedings. National Livestock & Meatboard, Illinois.
Walters, C.L. (1975). In 'Meat' (Cole, D.J.A. and Lawrie, R.A. (Eds)). AVI Publishing Co.

Development of the adsorption freeze-dryer

By G.A. Bell and J.D. Mellor

CSIRO Division of Food Research, North Ryde, New South Wales, 2113

A novel freeze-drying process, which exploits the properties of adsorbents under low temperature and high vacuum, was invented recently at the Food Research Laboratory at North Ryde (Mellor and Bell 1985). Two small-scale prototypes have been developed and a larger commercial-scale dryer is being assembled. We offer here some general information on this work, and invite further inquiries to be directed to the Division of Food Research. Full technical details and claims will be published at a later date.

In conventional methods of freeze-drying, materials are prepared in a vacuum chamber at temperatures above -40 °C, this being the lowest temperature to which it is practicable to cool refrigeration coils to ensure a vapour-pressure driving force. The coils are used to condense water vapour which leaves the subliming ice front in the material, often at -20 °C. If materials do not initially contain sufficient water to cause self-cooling under vacuum, the freeze-drying process must be supplemented by a second cooling system. This is necessary for some foods, plants and flowers, and other biological specimens. Hence a conventional freeze-dryer must include a vacuum chamber, a primary refrigerator, a secondary refrigerator, and a heater, in addition to pressure-controlling and temperature-sensing devices.

The development of the new process arose from the need to remove water from biological material with minimal disruption to the structure and chemistry of the specimen. Very rapid cooling can be used to freeze the sample so that the water content freezes into an amorphous ice state, without any damage caused by ice crystals. Freeze-drying offers a means of removing the amorphous ice, with very little change to the material, provided that ice crystals are not allowed to 'recrystallize' during the process.

Recrystallization usually occurs at temperatures warmer than -70 °C. Until now, freeze-drying was excluded as a means for removing water at 'ultra-low' temperatures because sublimation at temperatures below -40 °C is not practicable by conventional means. The authors set out to develop a process in which material can be dried at temperatures below -70 °C, and within reasonable drying times.

Novel process

The new devices consist of a single chamber in which a vacuum is drawn. The internal workings of the chamber achieve five conditions:

- Sublimation of ice to vapour and its removal, all at the same temperature,

which can be set to any desired level;

- Removal of water vapour by a cooled adsorbent, whose vapour pressure is lower than the conventional refrigerated condenser;
- Significant vapour-pressure driving force under all conditions of pressure and temperature;
- High vacuums at which higher rates of pressure-dependent freeze-drying occur (Mellor and Lovett 1968);
- Low temperatures which are maintained until the product is almost completely dry.

A rack inside the chamber holds the samples, and a perforated adsorbent container with baffle traps the water vapour. The device is inserted into a cold environment, e.g., a freezer store, domestic freezer, dry-ice container or container of liquid nitrogen. A relatively inexpensive heater, protected by a thin insulated barrier and a controller regulate the overall temperature of the device inside one of these cold environments. The device can be scaled up for commercial use, or down for laboratory and portable applications.

Prototypes

Two different prototypes of the invention (Fig. 1) have been tested on plant and animal material. One version (Fig. 1A) was designed for use in a home freezer, the other (Fig. 1B) for insertion into cryogenic chambers, such as a liquid nitrogen container.

In the cryogenic version, the vacuum line is attached some distance from the chamber by means of a stainless steel extension tube, thereby preventing heat transfer to the inside of the chamber and maintaining flexibility of the vacuum connections.

Miniature roses (Fig. 1) freeze-dried in dryer A have retained their shape and colour for two years after drying and retained their fragrance for many months after drying. Similar drying tests in a conventional freeze-dryer resulted in poorer specimens of flowers, with heavy wrinkling, brown colour and loss of fragrance (Mellor, unpublished).

Frozen brain, dried in model B at cryogenic temperatures, showed very good preservation when viewed under the light microscope (Fig. 2); however, freeze preparation prior to drying is also important to the state of final preservation (Bell and Mellor 1984). Work is continuing on methods of rapidly freezing specimens prior to freeze-drying.

In the laboratory-scale prototypes, adsorbent was regenerated after each drying run. The larger-scale prototype, under construction, will be used to study further the properties and processing requirements of the absorbent during the drying of commercial quantities of food and other products.

Economics

The detailed costs of freeze-drying can be calculated (Mellor 1978), and the economic advantages of the CSIRO freeze-dryer are:

- Equipment costs for the device will be about half that of a conventional system.
- Adsorption freeze-drying will require less general maintenance and 'down time' than conventional systems.

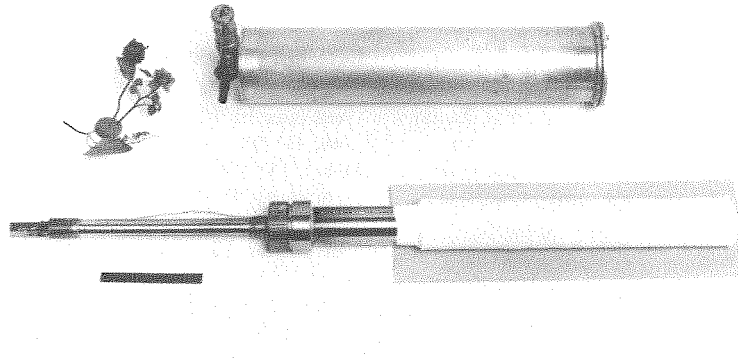


Fig. 1. Bench-scale prototypes of the new freeze-dryer. Scale bar = 10 cm.
A: Tested on biological tissue samples, leaves and flowers, some of which are shown.
B: Used to dry brain tissue samples, at cryogenic temperatures, as part of the Division's research into the sense of smell.

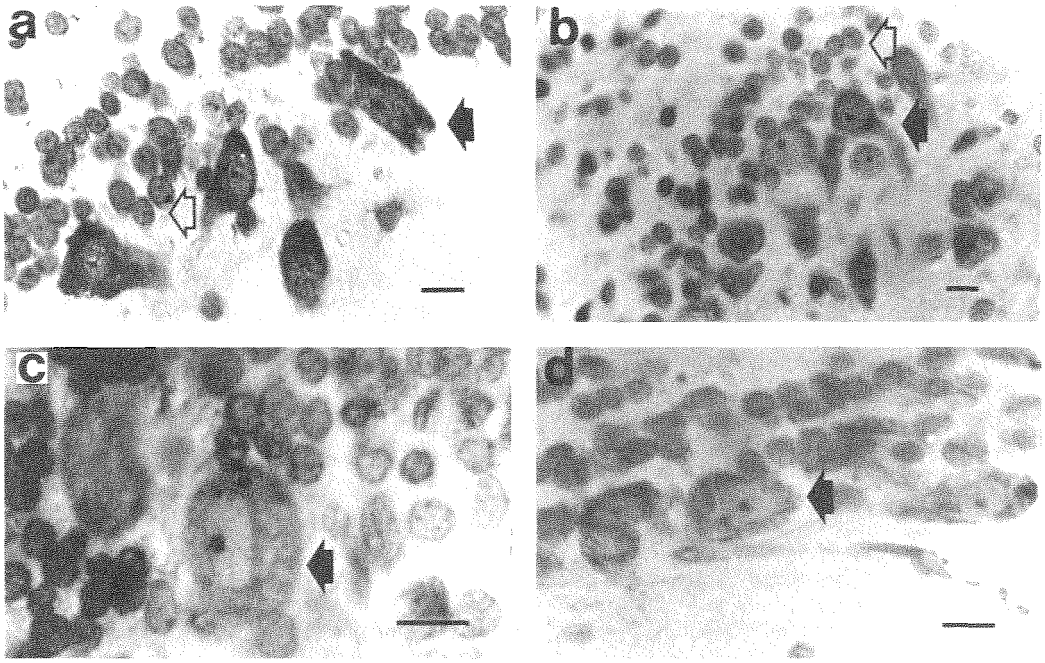


Fig. 2. Light photomicrographs of smell-responsive cells in rat brain.
Examples of mitral cells are shown with filled arrows and granule cells with unfilled arrows.
Scale Bar = 10 μm.
A: Cells from the mitral cell layer of the main olfactory bulb of the rat brain, frozen at -70°C and freeze-dried at -40°C.
B and C: Cells from the same region frozen at liquid nitrogen temperature and freeze-dried at -60°C.
D: Cells from the same region frozen at liquid nitrogen temperature and freeze-dried at -140°C.

- The energy required to maintain the cold environment into which the new devices would be inserted will be less than that required to drive the refrigerated condenser in a conventional freeze-dryer.
- Cost savings will be obtained in production of the vacuum. In a large conventional freeze-dryer the system usually requires two vacuum pumps: a large capacity unit for fast pump-down to avoid surface thawing of frozen samples and a small capacity holding pump. Since only the latter will be necessary for the new freeze-dryer, savings will result from reduced costs of purchase and maintenance of the vacuum equipment.
- Finally there will be no danger of the material thawing during the vacuum pump-down, and so costs due to spoilage will be minimized.

The new devices will cover a wide range of applications: industrial products including foods and pharmaceuticals, biological and medical specimens (including blood), flowers, museum specimens and many laboratory uses where removal of moisture from labile substances is required.

References

Bell, G.A., and Mellor, J.D. (1984). Olfactory mitral cell integrity after freeze-fixation. *Neuroscience Letters* **46**, 197-201.

Mellor, J.D. (1978). Fundamentals of Freeze-Drying. (Academic Press: London) pp.252-6.

Mellor, J.D., and Bell, G.A. (1985). Adsorption freeze-dryer. Australian Patent Application No. PH00941.

Mellor, J.D., and Lovett, D.A. (1968). Flow of gases through channels with reference to porous materials. *Vacuum* **18**, 625-7.

Off-flavours related to the use of sorbic acid as a food preservative

By J.D. Daley, G.T. Lloyd, E.H. Ramshaw and W. Stark

CSIRO Division of Food Research, Highett, Victoria, 3190

Introduction

Sorbic acid (*trans, trans*-2, 4-hexadienoic acid) and its more water-soluble potassium salt are additives permitted for use in a range of foodstuffs as fungistatic preservatives. They are used commonly to retard mould growth in dairy products, baked goods, beverages and fermented vegetables (for reviews see Lück 1976, Sofos and Busta 1981). The maximum level permitted in cheese or cheese spreads by the Model Food Regulations of the Australian National Health and Medical Research Council is 3 g/kg, i.e. 0.3%. At this level sorbic acid inhibits the growth of many moulds but some species of *Penicillium* grow, presumably metabolising the sorbic acid (Marth *et al.* 1966) and a range of moulds capable of growing in, and depleting, sorbate in a synthetic medium have been isolated from mouldy samples of sorbate-treated cheese varieties such as Cheddar and Mozzarella (Finol *et al.* 1982).

Treatment with sorbic acid has not been expected to cause problems since sorbic acid is non-toxic to humans (Deuel *et al.* 1954a) and is one of the most harmless preservatives known. It is relatively stable to oxidation and its metabolism is considered to proceed by the mechanism known to degrade fatty acids (Deuel *et al.* 1954b). However, off-flavour defects have been associated with the use of sorbic acid in Cheddar cheese (Marth *et al.* 1966), Feta cheese (Horwood *et al.* 1981), wine (Crowell and Guymon 1975) and a non-carbonated soft drink (Götz *et al.* 1978). Some studies have reported a decrease in sorbic acid concentration during storage of preserved comestibles (e.g. "Yamagobozuke", a pickled vegetable, by Takanami *et al.* 1976; prunes by Bolin *et al.* 1980) as a result, presumably, of its degradation. In addition, the concentration of sorbic acid on the outer layer of Gouda cheese dipped in the preservative decreased as the sorbic acid diffused into the centre of the cheese (de Ruig and van den Berg 1985) and an off-flavour described as "chemical, not familiar to the graders" was present in the surface layer of cheese. The defects in cheese (Horwood *et al.* 1981, Marth *et al.* 1966) and soft drink (Götz *et al.* 1978) were described as "hydrocarbon, kerosene, plastic, plastic paint" and were attributed originally to the plastic packaging materials. However, analysis showed that 1,3-pentadiene was present and in one of the studies (Horwood *et al.* 1981) its odour above cheese slurries was described by organoleptic assessors as "solvent, paint, or chemical". Liewen and Marth (1985a) demonstrated subsequently that 1,3-pentadiene could be produced by mould action on sorbate. Similarly, various explanations for the "geranium" defect in wine were offered before it was attributed to the formation of 2-ethoxyhexa-3,5-diene during the metabolism of sorbic acid by lactic acid bacteria (e.g. Radler 1978).

This paper describes a further occurrence of "kerosene" off-flavour in a cheese-based spread contaminated with mould. It illustrates the disadvantage of using sorbic acid as a preservative when mould growth occurs.

Techniques

Materials

Potassium sorbate was supplied by Ajax Chemicals, Sydney, Australia.

Trans-1,3-pentadiene (purum > 97%) was obtained from Fluka AG. Switzerland.

The cheese-based spread was a retail sample supplied by its manufacturer in plastic tubs. Samples were collected by inserting a syringe into the headspace of the plastic tub.

Headspace gas chromatography

The compounds in 5 ml samples of

CSIRO Food Res. Q. 1986, **46**, 59-63

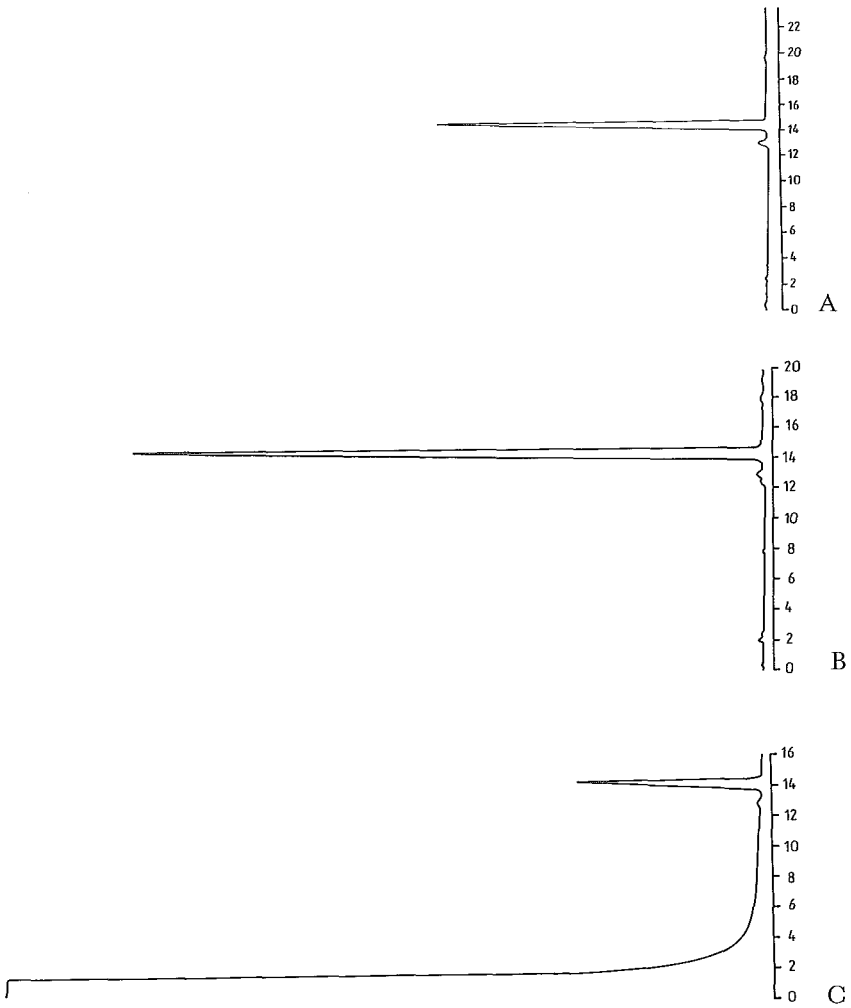


Fig. 1. Headspace chromatograms of cheese-based spread (A), fungus grown on medium containing sorbate, (B), authentic *trans*-1,3-pentadiene (C).

headspace were separated using a 1.22 m x 6 mm glass column packed with approximately 15 g of Graphpac-GC 80/100 coated with Carbowax 1500 (Alltech Associates, Inc., IL, USA). The column temperature was held at 40 °C for 4 min then programmed at 4 °C/min to 100 °C and the nitrogen carrier gas flow rate was 40 ml/min measured at 40 °C. Separated components were detected by a flame ionization detector.

Gas chromatography/mass spectrometry

The compounds in 5 ml samples of headspace were separated using a 1.82 m x 4 mm i.d. glass column packed with approximately 25 g of Graphpac-GC 80/100 coated with Carbowax 1500. This column was operated under the temperature conditions noted above with a helium carrier gas flow rate of 20 ml/min. The effluent from the gas chromatographic column was passed through the jet separator to direct approximately 2 ml/min to the quadrupole mass analyser of the Finnigan 1020 mass spectrometer (Finnigan Corp., Sunnyvale, Calif., USA). Ions were scanned from m/z 29 to m/z 250 during 4 s and the data displayed as a reconstructed ion chromatogram (RIC). Individual components were identified by comparison of their mass spectra with the spectra held in

the National Bureau of Standards (NBS) library using the Finnigan data system. Results were expressed as the degree of purity and fit.

Microbiology

The contaminant fungus was isolated from the surface of the cheese-based spread using YM agar (Difco Laboratories, Detroit, Michigan, USA) and transferred onto Czapek Dox agar (Oxoid Ltd., Basingstoke, Herts, England) for identification. Growth studies of the fungus were conducted at 5°, 20° and 25°C in YM broth (Difco) with 300 ppm added potassium sorbate. The dry weights of fungus grown in experimental and control media were compared.

Results

Identification of 1,3-pentadiene

The chromatograms obtained using the Graphpac/Carbowax column are shown in Fig. 1 for the headspace above the cheese-based spread (Fig. 1A), the headspace above the fungus grown on a medium containing potassium sorbate (Fig. 1B) and the authentic *trans*-1,3-pentadiene (Fig. 1C). Peaks at short retention time are characteristic of the headspace above cheese samples while the peaks about 13.5 min and 15 min are related to the off-flavour and have retention data identical to those for the authentic *trans*-1,3-pentadiene. Fig. 2 shows the RIC chromatogram from the headpsace of the cheese spread and Fig. 3 the mass spectrum of the major peak at scan 313. Authentic *trans*-1,3-pentadiene gave an identical retention time and mass spectrum under the same conditions and the mass spectrum of scan 313 gave a purity and fit greater than 99% when compared with the spectrum of 1,3-pentadiene in the NBS library. The minor peak at scan 278 had a mass spectrum very similar to that of scan 313 and may be the *cis*- or a branched chain isomer of 1,3-pentadiene. The retention times of the authentic pentadiene and the isolated compound were identical on two other columns of different polarity. This coincidence of retention together with the near identical mass spectra are strong evidence that the isolated compound is 1,3-pentadiene. The configuration is likely to be *trans* in accord with the configuration of sorbic acid as a *trans, trans*-2,4-hexadienoic acid and comparison with the authentic *trans*-isomer.

Identification of fungus

The isolated fungus was grown on Czapek Dox agar and found to be a *Penicillium* with irregular triple-staged branching and rough stalks. Colonies were blue-green, velvety and spread with irregular margins suggesting that the fungus was *P. roqueforti*. Its identification was confirmed (J. Pitt, personal communication) and the fungus appeared to be similar, if not identical, to that described by Marth *et al.* (1966) as capable of degrading potassium sorbate. The isolated

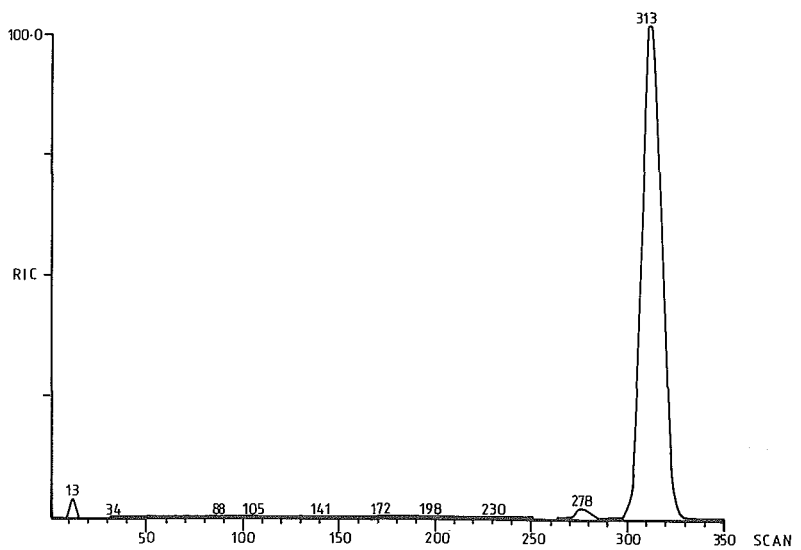


Fig. 2. Reconstructed ion chromatogram of cheese based spread.

fungus was found to be tolerant of acetic acid by inoculation onto malt extract agar plates with 0.5% glacial acetic acid added at pouring. No growth was evident at 25 °C after 4 weeks but at 20 °C colony size was 5 mm after 7 days and at 5 °C the first signs of growth appeared after 18 days.

Studies of the isolated fungus in YM media with 3000 ppm potassium sorbate showed that growth was inhibited and after 4 days the dry weight was reduced by 61% at 20 °C and 65% at 25 °C. At the normal temperature of storage of the spread, 5 °C, growth in the YM medium was inhibited even further. Nevertheless, the organism remained viable, some growth occurred over a period of 10 days and after 17 days the dry weight was 45% of that of the control. The growth at 5 °C corresponded closely to the experience of Liewen and Marth (1985a) who detected 1,3-pentadiene in cheese inoculated with the sorbate-resistant mould *P. roqueforti*-K1 after incubation for 2 weeks at 5 °C.

Discussion

The identification of 1,3-pentadiene in another occurrence of a "kerosene" off-flavour raises questions of toxicity as well as concern about the off-flavour. Comparison with standards of authentic 1,3-pentadiene suggests that the contaminated product contained at least 10μg/ml of headspace. This figure is well above the threshold concentration (2.5 ppm) for odour detection above brine solutions (Horwood *et al.* 1981) and suggests that it would be above the flavour threshold established by these workers for cheese slurries at about 4 ppm.

It has been suggested that growth of sorbate-resistant fungi could produce mycotoxins and that the 1,3-pentadiene produced may be mutagenic. However, while Liewen and Marth (1985b) found that some strains of sorbate-resistant fungi could produce toxins when grown in normal media, none of the fungi produced toxins when 3000 ppm sorbate was added to the medium. Similarly, although 1,3-butadiene and its metabolites have been reported to be mutagenic or carcinogenic (Malvoisin *et al.* 1979), Liewen (1985) has reported that the pentadiene was not mutagenic in any of three test systems.

There is ample evidence that some fungi will metabolize sorbic acid. If a sorbate-resistant fungus survives it may produce 1,3-pentadiene, 2-ethoxyhexa-3,5-diene, 2,4-hexadienol or 4-hexenoic acid. Furthermore, if the sorbic acid is applied to the wrapping or surface of the product its surface concentration may be depleted by migration into the interior (de Ruig and van den Berg 1985). The depletion of the sorbate either by diffusion or metabolism allows more fungal growth and more metabolism and it is possible that mycotoxins could be produced when the sorbate is exhausted. However, the strength of the off-odour produced by the 1,3-pentadiene is such that, even if fungal growth cannot be seen clearly, it is unlikely that the food would be consumed.

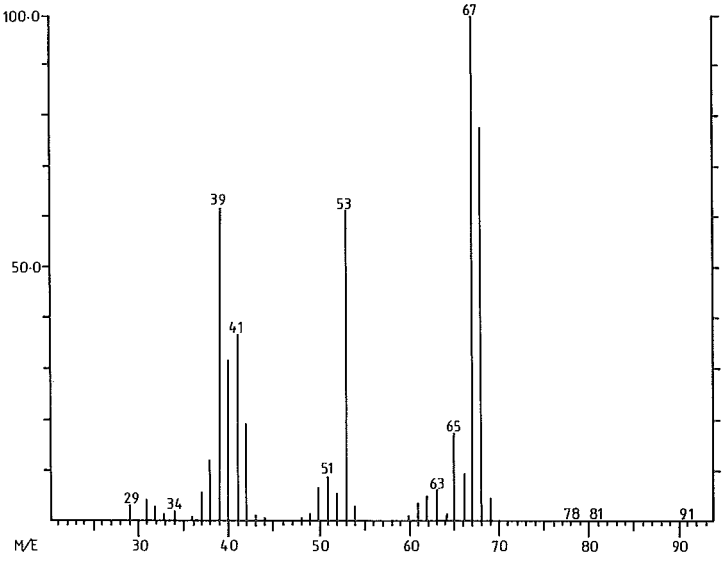


Fig. 3. Mass spectrum of major peak at scan 313.

Conclusion

Sorbic acid has been known as a safe food preservative for many years. However, the number of occurrences of off-flavour traced to metabolism of sorbic acid by sorbate-resistant organisms suggest that careful sanitation and sound storage conditions are still necessary. There may be advantages in the use of higher levels of sorbic acid or different approved preservatives such as natamycin that may be more lethal to the moulds or not as prone to depletion by diffusion.

The use of a biocide to control fungus growth is an efficient process in most cases. However, when a resistant fungus is encountered worse damage to the foodstuffs may occur from the fungal metabolites of the biocide than from the original fungal contamination. In the case of sorbates metabolized to pentadiene the off-flavour produced renders the product inedible and worthless.

References

Bolin, H.R., King, A.D., and Stafford, A.E. (1980). Sorbic acid loss from high moisture prunes. *Journal of Food Science* **45**, 1434-5.

Crowell, E.A., and Guymon, J.F. (1975). Wine constituents arising from sorbic acid addition, and identification of 2-ethoxyhexa-3,5-diene as source of geranium-like off-odor. *American Journal of Enology and Viticulture* **26**, 97-102.

Deuel, H.J., Alfin-Slater, R., Weil, C.S., and Smyth, H.F. (1954a). Sorbic acid as a fungistatic agent for foods. I. Harmlessness of sorbic acid as a dietary component. *Food Research* **19**, 1-12.

Deuel, H.J., Calbert, C.E., Anisfeld, L., McKeehan, H., and Blunden, H.D. (1954b). Sorbic acid as a fungistatic agent for foods. II. Metabolism of α, β-unsaturated fatty acids with emphasis on sorbic acid. *Food Research* **19**, 13-9.

Finol, M.L., Marth, E.H., and Lindsay, R.C. (1982). Depletion of sorbate from different media during growth of *Penicillium* species. *Journal of Food Protection* **45**, 398-404.

Götz, M., Heffter, A., Jaeger-Stephani, I., and Nonnweiler, W. (1978). Mikrobieller Abbau von Sorbinsaure in Erfrischungsgetränken zu Pentadien-(1,3). *Lebensmittelchemie und Gerichtliche Chemie* **32**, 77-8.

Horwood, J.F., Lloyd, G.T., Ramshaw, E.H., and Stark, W. (1981). An off-flavour associated with the use of sorbic acid during Feta cheese maturation. *Australian Journal of Dairy Technology* **36**, 38-40.

Liewen, M.B. (1985). Degradation of sorbic acid by molds. *Dissertation Abstracts International, B* **45**, 2444. *(Dairy Science Abstracts* **47**, 7835).

Liewen, M.B., and Marth, E.H. (1985a). Use of gas chromatography and mass spectroscopy to identify and determine 1,3-pentadiene in cheese or mold cultures. *Zeitschrift fur Lebensmittel-Untersuchung und Forschung* **180**, 45-7.

Liewen, M.B., and Marth, E.H. (1985b). Production of mycotoxins by sorbate-resistant molds. *Journal of Food Protection* **48**, 156-7.

Lück, E. (1976). Sorbic acid as a food preservative. *International Flavours and Food Additives* **7**, 122-7.

Malvoisin, E., Lhoest, G., Poncelet, F., Roberfroid, M., and Mercier, M. (1979). Identification and quantitation of 1,2-epoxybutene-3 as the primary metabolite of 1,3-butadiene. *Journal of Chromatography* **178**, 419-25.

Marth, E.H., Capp, C.M., Hasenzahl, L., Jackson, H.W., and Hussong, R.V. (1966). Degradation of potassium sorbate by *Penicillium* species. *Journal of Dairy Science* **49**, 1197-205.

Radler, F. (1976). The formation of off-flavour from sorbic acid by lactic acid bacteria. *Abstracts of Papers, 5th International Fermentation Symposium, Berlin,* 366.

Ruig, W.G. de, and Berg, G. van den (1985). Influence of the fungicides sorbate and natamycin in cheese coatings on the quality of the cheese. *Netherlands Milk and Dairy Journal* **39**, 165-72.

Sofos, J.N., and Busta, F.F. (1981). Antimicrobial activity of sorbate. *Journal of Food Protection* **44**, 614-22.

Takanami, S., Shinha, Y., Yoshida, T., and Nakajima, T. (1978). Composition of organic acids in pickles and behaviour of volatile fatty acids in "Yamagobozuke" added with sorbic acid during storage. *Nippon Shokuhin Kogyo Gakkai-shi,* **25**, 9-13.

Dietary cheeses — low fat, low salt*

By G.W. Jameson

CSIRO Division of Food Research, Highett, Victoria, 3190

Introduction

Medical and public opinions are increasingly inclining to the view that a general reduction of dietary fat and salt intakes is desirable as a health maintenance measure and for treatment of specific conditions such as hypertension. In the USA there is a possibility of regulatory control of sodium levels in cheese being introduced (Zehren 1982). Reports from the USA and the EEC indicate that numbers of specialty cheeses with compositions modified for the dietary market are already being produced, but little of this cheese is reaching Australia. Limited manufacture of low salt, low fat and reduced fat cheeses is also taking place within Australia, but there appear to be opportunities to improve product quality and expand the product range.

No estimates of the likely size of the dietary cheese market are available. However, it is of interest that one supermarket chain reported at a previous Specialty Cheese Seminar that some dietary grocery items (e.g. low-salt peanut butter) are now selling in similar volumes to their conventional counterparts. It is also of interest that unsalted butter sales grew by 27% in July–October 1984 *v.* July–October 1983, while salted butter sales grew by only 3.6% in the same period. Unsalted butter retail sales are now estimated to be about 7–8% of total butter retail sales. These data are not surprising in view of National Heart Foundation estimates that 1.1 million Australians have been diagnosed as having some degree of hypertension, and 0.75 million are on medication for high blood pressure.

Dietary cheeses will provide economic benefits to manufacturers in at least three ways:

- High returns — sales of this type of product may be less sensitive to price than normal.
- If low-fat cheeses are made, the fat saved can be sold in other products.
- New markets may be generated. It is likely that some customers with health problems or an unusual degree of interest in preventative measures have either ceased consuming cheese or are eating greatly reduced quantities. Offering these consumers an acceptable product would, in effect, open up new markets and would not detract from existing sales.

A very rudimentary calculation suggests that each 1% increase in Australian domestic cheese consumption, which might be generated by manufacture and sale of dietary specialty cheeses, could generate $1–2 million additional revenue for the industry.

Reduction of salt levels in cheese

No regulatory impediment exists to the reduction of salt levels in cheese, provided that the cheese remains safe for human consumption. However, it is well known that there are major technical impediments to this reduction. Salt is an essential ingredient in cheese, where it performs several functions:

Restricting non-starter microorganisms

Salt restricts the growth of non-starter microorganisms. Uncontrolled growth of non-starter lactic acid bacteria (NSLAB) can be a serious problem in dry-salted cheeses. These contain considerable residual lactose at salting, metabolism of which by NSLAB can lead to defective flavour in Cheddar cheese (Fryer 1982; Lawrence *et al.* 1983). In unsalted Cheddar cheeses, proteolysis and lipolysis were accelerated, and cheese flavour was always abnormal and unacceptable (Thakur *et al.* 1975; Lindsay *et al.* 1982).

Favours cheese-ripening organisms

The growth of organisms required for

*This paper was presented at a Seminar on Specialty Cheeses for Australia II, November, 1985. The Seminar was organized by the Australian Society of Dairy Technology, Victorian Division.

CSIRO Food Res. Q. 1986, **46**, 64-68

cheese ripening may be favoured by the use of salt, usually by restriction of growth of other organisms. For example, the moulds and bacteria used in surface-ripened cheeses are relatively salt-tolerant.

Cheese moisture control

Salt plays a role in cheese moisture control through its ability to expel moisture from curd. Salt uptake and moisture expulsion operate by a process of *mutual,* impeded diffusion (Geurts *et al.* 1974).

Influence on cheese characteristics

Salt has direct influences on body, texture and flavour characteristics of cheese. The mechanisms for these include the direct contribution of salt to flavour, and indirectly via the effect of salt on casein proteolysis (Grappin *et al.* 1985). Minor direct effects of salt on the cheese structural matrix may also occur. For example, Olson (1982) reports that high salt (1.8–2.0%) Mozzarella was somewhat less meltable and less stringy on pizza than low salt (1.1%) Mozzarella, and also differed in some body characteristics. After maturation for 3–4 weeks however, the differences between the two groups of cheeses were much greater. The high salt cheeses had lost some of their excessive brittleness and they melted better, but the low salt cheeses showed much greater changes (e.g. weak body), presumably due to more extensive proteolysis. For Cheddar cheese, the effects of salt content on quality of commercial cheese have been reported by Lelievre and Gilles (1982).

Salt elimination

In view of the functions served by salt in cheese its elimination is probably impossible, and the intending manufacturer of reduced-sodium cheeses has only two options:

- partial replacement of sodium chloride by potassium chloride
- reduction of salt to the (limited) extent permitted by the ripening chemistry of a particular cheese variety.

Using potassium chloride

The extent to which potassium substitution is feasible is limited by the astringent, bitter taste of potassium chloride. Mixtures of NaCl/KCl (1:1 on molar basis) are acceptable and are available for table use through retail outlets. Such mixtures have been used to replace NaCl in the salting of cheese, usually with some success. For example, Lindsay *et al.* (1982) salted Cheddar cheese at various levels (1.25–1.75%) with the KCl/NaCl mixture and with NaCl alone. All the cheeses were acceptable, but there was some consumer preference for cheese salted with NaCl at the higher levels. Cheddar cheese salted with the KCl/NaCl mixture was later used in the manufacture of consumer-acceptable processed cheeses which contained up to 75% less sodium than usual (Karahadian and Lindsay 1984). This large reduction in what is normally a high-sodium cheese product was achieved by using citrate-phosphate emulsifiers (1.85%), largely consisting of potassium salts. Preliminary work at CSIRO using the 1:1 KCl/NaCl mixture for salting of Swiss cheese was also quite successful. It was considered, however, that the relatively high cost of KCl would deter manufacturers from using it for brine-salted cheeses (J.J. Mayes, personal communication).

More limited success has been obtained with the alternative approach to reducing cheese sodium content — by simply reducing the salting rate. The difficulties encountered with Cheddar cheese have already been outlined, but one novel approach which was apparently successful was the supplementation of cheese milk with whole milk retentates to concentrations of 1.5:1–1.9:1 (Kosikowski 1983). Low salt cheeses (1% NaCl) made from the supplemented milk were of good quality and lacked the pasty body and acid, bitter flavour of the low-salt controls. This was attributed to the increase in curd buffering capacity, which prevented excessive acid development after salting, thereby preventing excessive depletion of calcium from the curd.

Starting with low salt varieties

Another approach to salt reduction is to select a cheese variety which is normally salted lightly and then seek to further reduce salt levels. Swiss cheese matures satisfactorily with low salt levels due to a combination of the inhibitory action of the high cooking temperature on microbial populations and the propionic fermentation of lactate which might otherwise serve as a substrate for growth of adventitious flora (Mocquot 1979). Published manufacturing methods usually recommend salting Swiss cheese at a rate of about 1% ± 0.2% (e.g. Reinbold 1972). Swiss cheese sold in the USA has been reported as having a mean NaCl content of 0.67% (Zehren 1982), while samples of Australian-made rindless Swiss cheese were

found to have salt contents of 0.5–0.8%. Preliminary work at CSIRO has shown that it is possible to reduce the salt content of Swiss cheese to 0.44% without impairing quality, and further reductions may be possible (J.J. Mayes, personal communication).

Reduction of fat levels in cheese

The way in which fat influences cheese body by filling interstitial spaces in the protein/mineral structural mesh (thereby influencing the degree of cross-linking possible) has been described by Jameson (1985).

The role of fat breakdown in contributing to cheese flavour, is also well known (Adda *et al.* 982). With this background, the hard, tough, dry body and low flavour level which characterize cheese made with lower fat content than normal are readily understood.

The most common approach to remedying the body defects in low fat cheeses is raising the moisture content — replacing fat with water. While this does weaken the excessively strong cheese structure, it also raises the level of moisture in fat-free substance (MFFS), and reduces salt in moisture (S/M) content. Both of these have critical effects on cheese maturation processes (Lelievre and Gilles 1982), and for some cheeses there are regulatory limitations on the extent to which MFFS can be increased. High MFFS is associated with rapid degradation of cheese protein, with a risk of unbalanced flavour and excessively weak body, while low S/M may allow growth of undesirable microflora.

An alternative approach to the manufacture of low fat cheeses has recently been explored by Dutch workers (de Boer and Nooy 1980). Semi-hard cheese with 20% fat in dry matter (FDM) was made by a combination of ultrafiltration and evaporation (Fig. 1). Milk was separated and the skim component concentration 7-fold with extensive diafiltration, followed by evaporation at 50° -60°C in a scraped-surface evaporator. High fat (80%) cream was blended with the skim concentrate, followed by a relatively small amount of calcium chloride (0.01%), giving a pre-cheese with about 59% moisture content. Sodium nitrate and/or spices could also be added at this point. The mixture was cooled with a scraped-surface heat exchanger, rennet (20% of normal amount) and starter concentrate added, and mixed in a second scraped-surface heat exchanger. After coagulation in moulds, the cheeses were subjected to normal finishing processes. A yield increase of about 25% was obtained. The cheeses were said to be of satisfactory quality, but the most striking observation was that they had much more acceptable body characteristics than the corresponding low-fat conventionally-made cheese: the consistency was smoother, creamier, and less rubbery. The microstructure of the experimental cheese was found to be more open than that of controls, and it was inferred that the whey proteins were acting as an inert filler, replacing to some degree the fat in conventional cheeses. A later study showed that the whey proteins (18.5% of total cheese protein) were completely resistant to

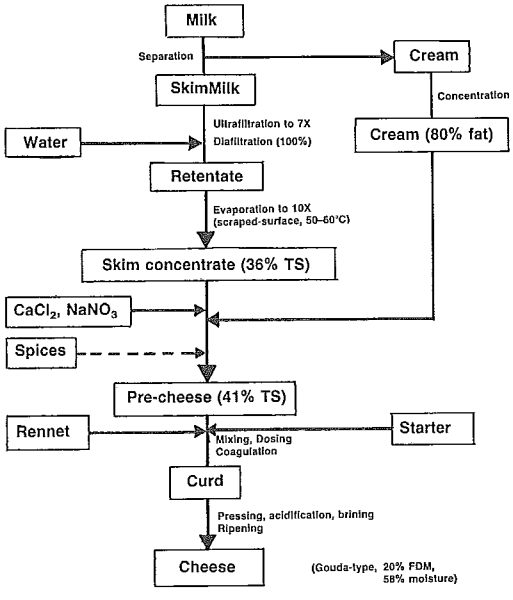


Fig. 1. Manufacture of semi-hard cheese made by a combination of ultrafiltration and evaporation.

proteolysis during maturation (de Koning *et al.* 1981). As the whey proteins have no flavour, they therefore do not contribute to cheese flavour in any way, but their water-binding properties do affect cheese body when they are present in large amounts. These properties can be turned to good account in cheeses with fat contents so low that the cheeses would normally be unacceptable. It is not known whether this process is in commercial use, but it would appear to have considerable potential.

Changes in Australian food regulations

The National Health and Medical Research Council (NH&MRC) adopted a Model Food Standards Regulation for cheese in June 1984. While imposing some limitations, this Regulation allows considerably more scope for the innovative cheese manufacturer than previous State food legislation. New State food legislation based on the NH&MRC Regulation has been drafted in all States, and proclaimed in all States except NSW. As if often the case, total national uniformity in legislation has proved elusive. Manufacturers may thus be denied the opportunity of marketing their products nation-wide in the same package — a significant disadvantage in what is a relatively small national market.

The NH&MRC regulation begins with a new definition of cheese (Table 1) in which the principal definition is very broad, and is supplemented by an "alternate make" provision. The list of allowed additives (Table 2) is not unduly restrictive. There is no provision for raw milk cheese, but a minimum heat treatment of 62 °C/15 s is permissible if the cheese is matured in a specified manner. Salt content of cheese varieties is not specified, and terminology for categories of cheese with lower salt content than normal has been discussed but is not yet in force.

In the new regulation, the Schedule of named cheeses has been substantially reduced, and cheese not named therein is no longer automatically treated as Cheddar. Compositional limits for the 21 named varieties are provided as maximum moisture content and minimum FDM (Table 3) MFFS values slightly higher than those normally encountered for the respective cheese varieties are also listed.

TABLE 1

Definition of cheese

(1) (a) Cheese is the solid or semi-sold product obtained —

(i) by coagulating milk, skim milk, partly skim milk, cream, whey or buttermilk or a mixture of these materials, through the action of protein coagulating enzymes, heat or acid; or; . . .

(ii) by processing techniques involving coagulation of milk or materials obtained from milk that give an end-product that has the same essential physical, chemical and organoleptic characteristics as the product defined by subparagraph (i) of this paragraph.

(National Health and Medical Research Council Model Food Standards Regulation H9).

TABLE 2

Allowed additives

Salt
Calcium chloride
Acid calcium phosphate
Modifying agents
Phosphoric acid
Glucono-delta-lactone
Herbs, spices, edible seeds or other seasonings
Flavourings
Natural colourings
Starter cultures or enzymes

TABLE 3

Schedule of named cheeses

Variety	Moisture (max., g/kg)	FDM (min., g/kg)	MFFS (g/kg)
Blue	470	500	600
Brie	500	500	690
Camembert	600	400	740
Cheddar	380	500	570
Cheedam	460	430	620
Cheshire	440	480	620
Colby	400	500	590
Edam	470	400	620
Emmenthal	410	430	570
Feta	550	420	700
Gouda	450	480	630
Gruyere	390	450	560
Havarti	500	450	670
Monterey	440	500	630
Mozzarella	500	400	650
Parmesan	320	320	430
Provolone	450	450	620
Ricotta	800	—	—
Romano	350	380	490
Swiss	410	430	570
Tilsit	500	450	670

Within the present context, the most relevant aspect of the NH&MRC regulation is the way it treats reduction of fat content in cheese. For the named (Schedule) cheeses, a *"reduced fat"* category is provided, for which the cheese FDM must fall in the range 75–85% of that specified in the Schedule, and the MFFS must not exceed the listed value in the Schedule. "Reduced fat" processed products are also defined (e.g. processed cheese — 20–25% FDM, 55% moisture maximum; Cheese spread — 20–25% FDM unless specified on label). Manufacturers should note that the limiting MFFS values provided for reduced fat Schedule cheeses are not necessarily based on practical experience. They provide for slight elevation of MFFS which may compensate for the effect of reduced fat content on cheese body, but restrict this elevation in order to preserve the varietal characteristics of the cheese in accordance with understanding of the influence of MFFS on the cheese maturation process (Lawrence *et al.* 1983). For example, Cheddar MFFS is specified as 57%, while the preferred range for normal-fat Cheddar is 52–56% (Lelievre and Gilles 1982).

Another category provided for the Schedule-named cheeses is *"low fat"*. The requirement for entering this classification is very stringent: a maximum fat content of 15% FDM. It is likely that palatable cheeses qualifying for this appellation will only be produced by major innovations in technology — for example, the UF-based procedure described previously.

Outside the list of named cheeses in the Schedule, the new regulation provides the manufacturer with virtually unlimited opportunities. All that is required is that the cheese package be labelled with an appropriate description, and with the *maximum moisture content* and *minimum fat content* on a *wet weight* basis. Labelling format (e.g. size of lettering) is specified, but may differ slightly from State to State. Indicating that a non-Schedule cheese has a moderate fat content may present some problems in terminology — "reduced fat" appears to be reserved for Schedule-named cheeses, and "low fat" is permissible only if FDM does not exceed 15%. A useful theme was used by Dairy Crest (UK) for their "Tendale", which is advertised as "Cheddar with Half the Fat" (for one sample: moisture 46.1%, FDM 27.2%, MFFS 54.0%).

References

Adda, J., Gripon, J.C., and Vassal, L. (1982). The chemistry of flavour and texture generation in cheese. *Food Chemistry,* **9,** 115-29.

Boer, R. de, and Nooy, P.F.C. (1980). Low-fat semi-hard cheese from ultrafiltrated milk. *Nordeuropaeisk Mejeri-Tidsskrift,* **46,** 52-61.

Fryer, T.F. (1982). The controlled ripening of Cheddar cheese. *Brief Communications, XXI International Dairy Congress Moscow,* **1,** (bk. 1), 485.

Geurts, T.J., Walstra, P., and Mulder, H. (1974). Transport of salt and water during salting of cheese. 1. Analysis of the processes involved. *Netherlands Milk and Dairy Journal,* **28,** 102-29.

Grappin, R., Rank, T.C., and Olson, N.F. (1985). Primary proteolysis of cheese proteins during ripening. A review. *Journal of Dairy Science,* **68,** 531-40.

Karahadian, C., and Lindsay, R.C. (1984). Flavour and textural properties of reduced sodium process American cheeses. *Journal of Dairy Science,* **67,** 1892-1904.

Koning, P.J. de, Boer, R. de, Both, P., and Nooy, P.F.C. (1981). Comparison of proteolysis in low-fat semi-hard type of cheese manufactured by standard and by ultrafiltration techniques. *Netherlands Milk and Dairy Journal,* **35,** 35-46.

Kosikowski, F.V. (1983). Low sodium Cheddar cheeses through whole milk retentate supplementation. *Journal of Dairy Science,* **66,** 2494-2500.

Lawrence, R.C., Gilles, J., and Creamer, L.K. (1983). Review: The relationship between cheese texture and flavour. *New Zealand Journal of Dairy Science and Technology,* **18,** 175-90.

Lelievre, J., and Gilles, J. (1982). The relationship between the grade (product value) and composition of young commercial Cheddar cheese. *New Zealand Journal of Dairy Science and Technology,* **17,** 69-75.

Lindsay, R.C., Hargett, S.M., and Bush, C.S. (1982). Effect of sodium/potassium (1:1) chloride and low sodium chloride concentrations on quality of Cheddar cheese. *Journal of Dairy Science,* **65,** 360-70.

Mocquot, G. (1979). Reviews of the progress of dairy science: Swiss-type cheese. *Journal of Dairy Research,* **46,** 133-60.

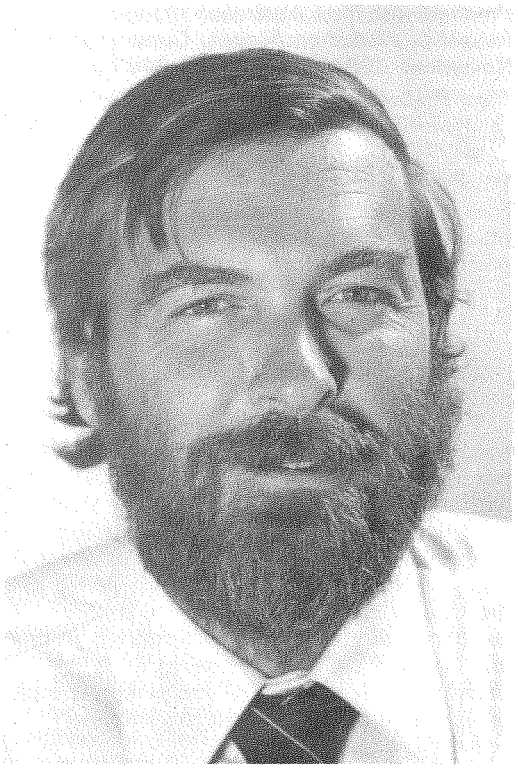
Olson, N.F. (1982). Salt affects cheese characteristics. *Dairy Field* **165,** 72-4.

Reinbold, G.W. (1972). Swiss Cheese Varieties. Pfizer Cheese Monographs, **5,** 120.

Thakur, M.K., Kirk, J.R., and Hedrick, T.I. (1975). Changes during ripening of Cheddar cheese. *Journal of Dairy Science,* **58,** 175-80.

Zehren, V.L. (1982). Sodium labelling of cheese. *Proceedings 19th Annual Marschall Invitational Italian Cheese Seminar, Madison, Wis.,* 20-26.

News from the Division



New appointment

On 19 June 1986, Dr J.H.B. Christian, Chief, CSIRO Division of Food Research, announced that the CSIRO Executive had appointed Dr J.G. Zadow as Officer-in-Charge of the Dairy Research Laboratory. He will succeed Mr L.L. Muller who retires on 8 August, 1986.

Dr Zadow joined the, then, Division of Dairy Research, CSIRO, as an Experimental officer in 1967 after experience in the paint and paper pulp industries. Since joining CSIRO, his research interests have included aspects of the ultra-heat treatment of milk, and whey and whey by-product utilization. The latter has covered protein recovery, whey protein functionality, membrane processing by ultrafiltration and reverse osmosis, demineralization, and lactose hydrolysis.

In 1979, Dr Zadow took charge of the Whey Group. He altered and expanded its activities and it became the Unit Processes Group, with a strong emphasis on commercial application. The results of the Group's research into the control of age gelation in ultra-high-temperature (UHT) milk, the incorporation of whey products into ice-cream, and on lactose hydrolysis in whey products and milk are now being used industrially. Studies on the application of reverse osmosis to reduce milk transport costs are undergoing semi-commercial proving trials in an industrial environment. All these projects have required the development of close links with top-level Australian and overseas dairy industry management personnel, from the formative stages to commercialization, being funded in part by commercial R & D agreements largely initiated by Dr Zadow.

The Division now has, in Dr Zadow's Group, a world-recognized centre of expertise in the application of ultrafiltration and reverse osmosis for the manufacture of whey-based products.

Dr Zadow has been awarded the Silver Medal of the Australian Society of Dairy Technology for publications in the field of dairy science and technology, and the degrees of Master of Science and Doctor of Applied Science for research on UHT processing and milk proteins. He is a member of the four Expert Committees of the International Dairy Federation that study Functional Properties of Milk Proteins, Heat Resistant Proteases in Milk, Whey Processing, and Membrane Operations. Early this year he served as an FAO and UNDP consultant at the National Dairy Institute of India.

Dr Zadow's R & D achievements have been outstanding and his appointment to lead the Dairy Research Laboratory is most appropriate. He will undoubtedly maintain the high level of industrial R & D and technology transfer that he has helped the Laboratory to achieve.

Award

FRL's 'E.W. Hicks Memorial Prize' for 1985 has been awarded to Mr Peter Britt, Apprentice Carpenter, for his outstanding performance during the entire three-year Carpentry and Joinery Trades Course, completed late last year at St George Technical College. He becomes the fifth tradesman to win the prize.

Peter is currently studying for the Building Certificate Course in his own time.

An article on the Hicks Prize appears elsewhere in this issue.

Proceedings: First Australian Mango Research Workshop (Cairns, Queensland, November, 1984) ISBN 0 643 040331

Plant Production Committee, Standing Committee on Agriculture

Ten major topics were discussed at the Workshop, these being the industry situation, crop physiology, genetic improvement, crop management, insect pests, diseases, postharvest physiology, packaging and handling, fruit quality and market acceptance, mango processing, and economics and marketing. A total of 40 papers, including reviews, were presented and now appear in these Proceedings.

Those sections of the Proceedings concerning the crop postharvest will be of particular interest in such countries as Mexico, Israel, South Africa, Brazil and Peru which already have or are building considerable export markets in mangoes and mango products, while anyone interested in the rapidly expanding Australian mango industry will glean much information from this book — the first to present a comprehensive account of the prospects and problems of this important tropical and subtropical crop.

Available from CSIRO Publications Sales Office, PO Box 89, East Melbourne, Victoria 3002. Recommended retail price is $A15.00.

CSIRO course — gas transmission rate measurements

A simple new method for measuring oxygen and water vapour transmission rates for packaging films has been developed by the CSIRO Division of Food Research. To promote the use of this method, which fills a gap in existing technology by using a pocket-sized measuring cell and other technical and cost advantages over alternative procedures, we are offering two half-day seminar/demonstration sessions.

Both sessions will be held on Tuesday, 21 October 1986, the first starting at 9.30 am, the second at 1.30 pm. Four lecturers/demonstrators will be involved in explaining the techniques. A registration fee of $50.00 per head will be charged, and registration should be received no later than one week before the demonstration. Cheques should be made payable to CSIRO Division of Food Research. Please address all enquiries to Dr R.V. Holland, CSIRO Division of Food Research, PO Box 52, North Ryde, NSW, 2113. Ph. (02) 887 8371.

The Hicks prize

For a quarter of a century readers of this journal will have seen the names of recipients of the 'E.W. Hicks Memorial Prize' in the News from the Division column. The prize was established in 1961 and a brief historical note may therefore be of interest.

The late E.W. (Bob) Hicks was Head of the Physics Group and Deputy to J.R. Vickery from the war years until his death in 1959. He was, to quote Dr Vickery, "an outstanding research worker in food science and he had a world reputation in the application of physics and mathematics to the problems of the preservation of food by heat and cold. Mr Hicks was a charming and most helpful colleague who gave a great deal of his time to helping others, often to the detriment of his own interests".

The staff of the Division of Food Preservation commissioned a bronze bas-relief plaque of Hicks to be made and this is now mounted on a wall of the lecture theatre, generally called the "Hicks Room". Contributions for the plaque came from industry, sister institutions and many individual friends and colleagues.

Because the cost of the plaque was less than the money subscribed to the fund, it was decided to present a prize (of 10 pounds) to the Technical Assistant of the Division of Food Preservation securing the most outstanding results on completion of a university degree or technical college diploma course.

The Prize was awarded for the first time in 1961 (on the basis of academic results for 1960). Nine graduates/graduands received the award between 1961 and 1969. When, in 1966, the subscribed funds were exhausted, the then Food Preservation Staff Club accepted responsibility for the Prize. To be eligible, a Technical Assistant had to show "the most meritorious academic record for his/her course", and it goes without saying that such courses were always in science.

The Selection Committee comprised the Chief of Division, President of the Staff Club, and Technical Secretary.

In 1971 the Division was reorganized and renamed the Division of Food Research. Another 70 staff were added (from the former Division of Dairy Research), making the assessment of academic results rather more difficult. Also, tertiary courses of a great variety, in three States, needed to be considered. As a result, the conditions for award of the Hicks Prize were altered in 1973. The Prize is now restricted to staff responsible to the Food Research Laboratory (FRL), the FRL Staff Club subscribes the prizemoney which is roughly 'indexed' and each of the four staff unions is represented on the Selection Panel, now chaired by the Officer-in-Charge of FRL. To be eligible for nomination:

> ". . . members of staff must have completed, during the previous academic year, a part-time course of study leading to a first degree, diploma, certificate, trade apprenticeship or graduate membership of a professional body (e.g. librarianship, accountancy). The greater portion of the course must have been undertaken whilst the staff member was employed at FRL, and the course must be relevant to the work of the Laboratory".

The winner of the award is expected to buy a book or books, for which a special 'ex-libris' is provided.

The following have received the Hicks Prize since its inception:

1960 J. Hayhurst and D.E. Plate
1961 J. Barr
1963 R.B.H. Wills
1965 P.F. Everson and R.W. Sleigh
1966 D. Aitken
1967 R.L. Hood
1968 J. Reid
1974 B. Jackson
1976 R.S. Nott
1978 J. Betts and F. Watters
1980 B.J. Mann
1981 B. Le Breton and P.E. Walton
1982 D. Medlin
1984 G. Hodson
1985 P. Britt

A special reason for writing this article now is to trace the progress of some of the early winners.

Of the first winners, Joan Hayhurst of the then Physics Section later obtained an MSc and DIC from Imperial College, London University, returning to Australia in 1965 to work in CSIRO's computing section. She is now "networking" in the Computer Communications Group at CSIRONET, Canberra. Dieter Plate, her co-winner in 1960, after graduating BSc from the University of Queensland, took a PhD in Textile Engineering at Leeds University in England and went on to become a senior research worker with the CSIRO Division of Textile Industry, Geelong, Victoria, where he leads the Wool Processing Group.

Jeanette Barr obtained a very good degree in bacteriology from the University of New South Wales in 1961 to secure her prize. She subsequently married a Methodist Minister and had three children; she lives at Springwood in the Blue Mountains of New South Wales.

One of the best known names in Australian food science circles must be that of Ron Wills (1963). On leaving the Division in 1972, he accepted a lectureship at the University of Otago in New Zealand, completed a PhD at Macquarie University, and is now Associate Professor in the School of Food Technology at the University of New South Wales. His (and his colleagues') work on the composition of Australian Foods, published in 'Food Technology in Australia', continues apace.

In 1965 Paul Everson (Cannon Hill) and Robert Sleigh (North Ryde) were joint winners. Everson obtained the Diploma in Industrial Chemistry from Brisbane Technical College and subsequently became a brewer — first at Casino in Northern New South Wales.

Rob Sleigh obtained his PhD from the University of New South Wales in 1982 and is a member of FRL's Food Structure Group. His current sojourn at the University of Uppsala in Sweden was mentioned in some detail in the Quarterly, Vol. 46, No. 2 (June, 1986).

David Aitken (1966), a one-time member of the Microbiology Section, received the Prize for results gained in his undergraduate course in biochemistry at the University of New South Wales. He subsequently went to Canada, where he obtained a PhD.

Another Prize winner still at FRL is Ross Hood (1967). Not long after his graduation (BSc, University of New South Wales) he went to the USA and obtained the PhD from the University of Minnesota. He is a member of the Food Safety and Nutritional Quality Group, specializing in the biochemistry of lipids in relation to the deposition of fat in meat animals and birds.

Apart from Paul Everson, the only one of the 'early' prize winners to have gone into

industry is Jim Reid (1968). He is currently Manager of the Quigley Division of Pfizer Pty Ltd in Sydney. The Division is a supplier of monolithic refractory to the Australian and New Zealand steel industries — in other words: he keeps the blast furnaces going!

The Hicks Prize was not awarded between 1968 and 1974, during which time the Division was re-organized and the Prize reconstituted as detailed earlier. The first of the new breed of winners was Brenda Jackson (1974) whose award was based on results leading to a degree from the NSW Institute of Technology. Brenda belonged to the CSIRO Division of Mathematics and Statistics, whose members are attached to other divisions throughout the Organization and whose contribution is vital to the scientific endeavour. Promoted to Experimental Officer, Brenda returned to her own Division, then worked as a programmer for the Water Board in Sydney, and when last heard of was a programmer in private practice.

The award for 1976 went to Robyn Nott, on completion of the Chemistry Certificate at Sydney Technical College. Robyn is now a Senior Technical Officer in the Plant Physiology Group, working on chilling sensitivity in plants. Her skills have extended to computing and electronics.

Joint winners for 1978 were John Betts and Frances Watters (Separovic). Although Frances' award was in recognition of her performance in studies leading to the Biological Technicians Certificate (Sydney Technical College), she went on to gain a BA degree from Macquarie University in 1985, with Honours in Physics. Frances is now an Experimental Scientist and a member of FRI's n.m.r. team. John Betts obtained the BAppSc. degree in Applied Biology from the NSW Institute of Technology and is now a Technical Officer at the Agricultural Research Centre at Tamworth in Northern New South Wales, working in the area of soil conservation and management. He is currently studying for his Master's degree.

Of the six prizes awarded since 1980, no fewer than five have gone to trades apprentices. The exception was Paul Walton, joint winner for 1981, who, having been admitted to the degree of BAppSc (Applied Biology) by the NSW Institute of Technology, accepted a Research Assistantship at Pennsylvania State University in the U.S.A. His subsequent M.S. thesis dealt with the regulation of swine adipose tissue metabolism by insulin and growth hormone. At the time of writing, Paul is well on the way to completing his PhD.

The first of the trades apprentices at FRL to win the Hicks Prize was Brian Mann (1980), for the excellent results gained in his Fitting and Machining Trades course. Whilst undertaking this course, Brian also studied towards the Mechanical Engineering Certificate. He is in England at present, working in the drawing office of a mining company.

In 1981 the Prize was shared by Brian Le Breton and Paul Walton. Brian came top of his class several times and topped his year in 1980, in the Carpentry and Joinery Trades Course. He is currently working as a landscape gardener whilst studying horticulture at Ryde Technical College.

David Medlin's performance in the Fitting and Machining Trades Course secured him the award for 1982. He is still with CSIRO, working as a Laboratory Craftsman (Fitter and Turner) at the Division of Radiophysics.

No award was made for 1983, consistent with the condition that "where no nominee is judged to have a sufficiently meritorious academic record, the prize shall not be awarded".

The two most recent winners, Glenn Hodson (1984) and Peter Britt (1985) won the Hicks Prize whilst working at FRL as Apprentice Carpenters. Both did exceptionally well in their Carpentry and Joinery Trades Courses; both studied for the Building Certificate Course in their own time. There is even a suggestion that they may set up a joint business as building contractors. Glenn is currently in Yorkshire, playing cricket 'semi-professionally' as well as working.

The last 25 years have brought many changes to the Division of Food Research, no less than to CSIRO as a whole, but there is no doubt that the establishment of the E.W. Hicks Memorial Prize has paid handsome dividends. With its undiminished insistence on excellence, it should continue to do so in the years to come.

The good memories of several members of staff, past and present, are gratefully acknowledged in the compilation of this paper.

George Fisher

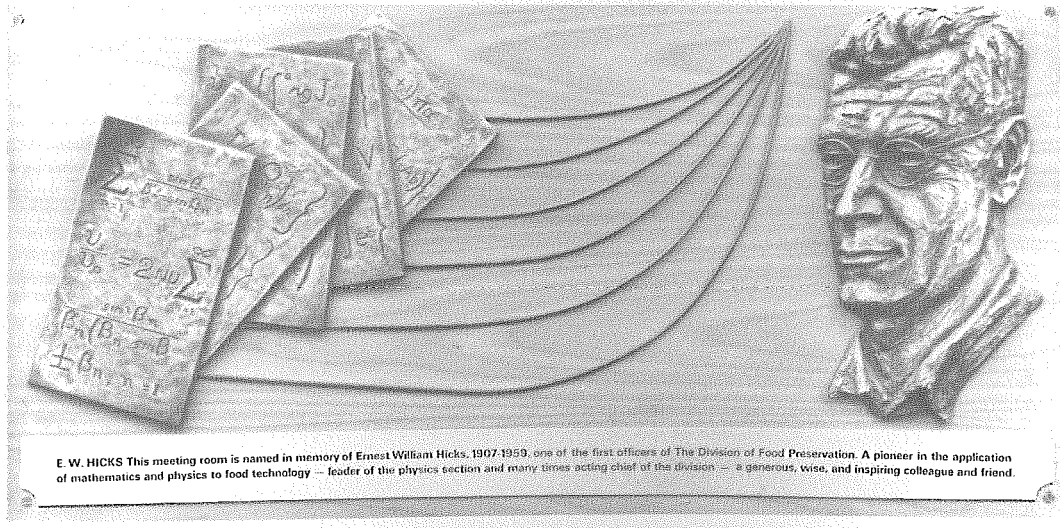
CSIRO Division of Food Research

Technical enquiries may be directed to

Food Research Laboratory
P.O. Box 52, North Ryde, N.S.W. 2113
(Delhi Road, North Ryde)
Telephone: 887 8333 (STD code 02)
Telegrams: Foodresearch Sydney

Dairy Research Laboratory
P.O. Box 20, Highett, Vic. 3190
(Graham Road, Highett)
Telephone: 555 0333 (STD code 03)
Telegrams: Foodresearch Melbourne

Meat Research Laboratory
P.O. Box 12, Cannon Hill, Qld. 4170
(Cnr. Creek and Wynnum Roads, Cannon Hill)
Telephone: 399 3122 (STD code 07)
Telegrams: Foodresearch Brisbane



Plaque attached to the meeting room commemorating E. W. Hicks.