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New protein foods

By J. F. Kefford

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Research into foods from textured proteins (TP foods) begins at North Ryde

At the Food Research Laboratory, North Ryde, the Division of Food Research has initiated a research program on new foods based mainly on proteins of vegetable origin. Two experienced food scientists, Mr J. Shipton and Mr J. Last, have been assigned to this project.

The decision to enter the area of research on vegetable protein foods was motivated from two directions. While Australia has ample supplies of animal protein foods, and a high *per capita* consumption of these foods, the increasing demand and rising prices for them in the world market suggested that it would be expedient to investigate vegetable protein foods as competitors with and as extenders for meat. Further, oil seed crops have become important in Australian agriculture, and there is increasing interest in better utilization of the protein components, traditionally regarded as by-products used only for animal feeding.

Background

In discussing the technology of vegetable protein foods it is helpful to distinguish three types of products:

- *Primary products*—in the form in which they are harvested.
- *Secondary products*—derived from the primary products and themselves used for further manufacturing.
- *Tertiary products*—new protein foods intended for direct consumption by humans. Within the category of tertiary products the term textured proteins is applied mainly to foods made by extrusion procedures, and the term meat or fish analogue is probably best used to refer to foods which attempt to reproduce closely the form, colour, texture and flavour of the food imitated.

Primary products

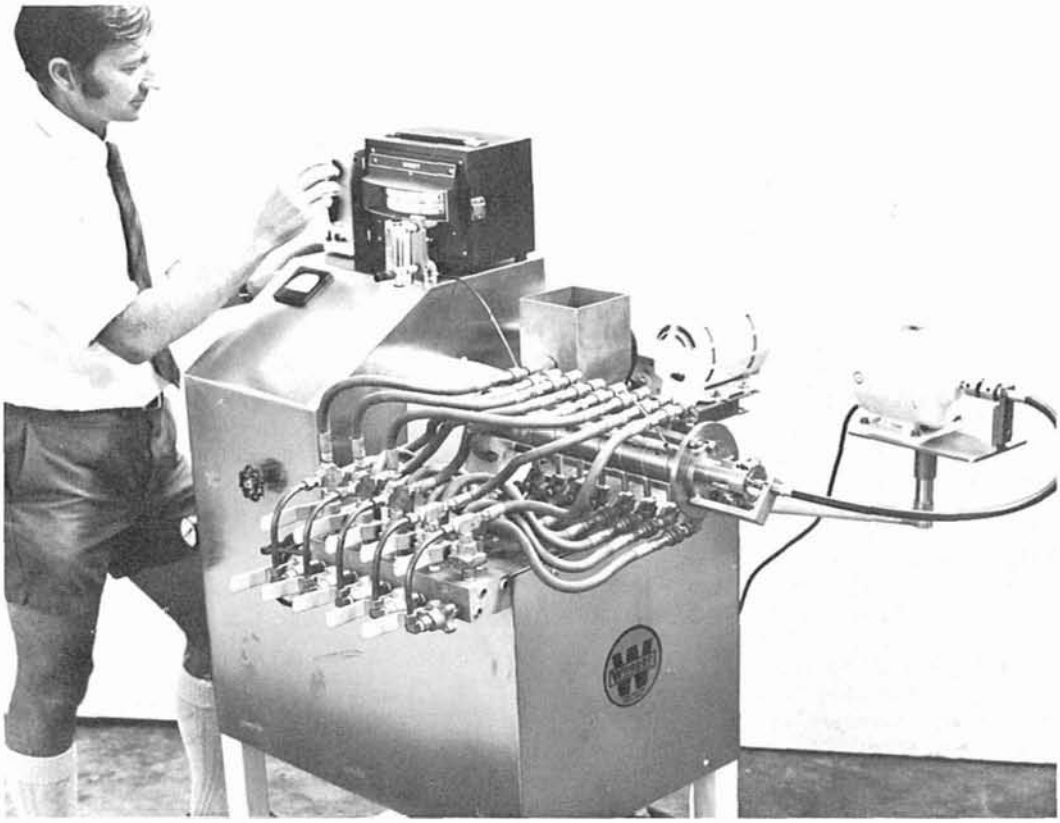
The principal primary products so far used for making new protein foods are seeds—legume seeds, oil seeds and cereals. The soybean, a leguminous oil seed, is by far the most important. Other oil seeds of potential importance include peanut, sunflower, safflower, rape and cotton.

Some of these materials present specific problems, for instance cottonseed contains glands with a high content of the toxic substance, gossypol. However, this difficulty has been circumvented in two ways. The Southern Regional Research Laboratory of the United States Department of Agriculture has devised a liquid cyclone process which efficiently removes the glands. In addition, plant breeders have developed a glandless cotton which is gossypol-free. Although the future of glandless cotton is in some doubt, since the absence of gossypol appears to increase its susceptibility to pests, it has already been planted widely in Central America as a primary product for new protein foods.

Among the legumes other than soybeans, the field bean, *Vicia faba*, is the main product for development in Britain and the alkaloid-free sweet lupin has potential interest here in Australia.

The cereals such as wheat, corn, oats, sorghum and millet may provide high-protein by-products suitable for making new protein foods.

Leaf protein, and microbial and fungal proteins, may become important as primary products for new foods when their technology is further advanced and their nutritional and toxicological status for human feeding established.



Mr John Last with the pilot-scale extruder–cooker installed in the CSIRO Food Research Laboratory, North Ryde.

Secondary products

After extraction of the oil from oil seeds the protein-containing residues are available in a number of forms. For instance, soybeans (Smith and Circle 1972; Cole 1973) provide soy grits and soy flour, which contain about 50% protein on a dry basis and less than 1% residual oil, and are treated with steam to destroy anti-nutritional factors and bitter principles and to remove off-odours. The water-soluble constituents are removed from soy flour by extraction with water or alcohol at the isoelectric point pH 4·2, to give *soy protein concentrate* which should contain not less than 70% protein on a dry basis. From this concentrate, the protein may be extracted by water at pH 7, then reprecipitated at pH 4·2, giving *soy protein isolate* with not less than 90% protein on a dry basis.

In the most advanced technology soy protein isolate is converted into *spun protein fibre*, using patented procedures developed first by Dr Robert Boyer who had been commissioned by the Ford Motor Company to make fibres suitable for car tyres and upholstery from soy protein. The venture was not successful but it did lead to a patent for production of soy fibres for food uses which lay dormant for many years. In Boyer's process (Cole 1973) the soy protein isolate is dissolved in alkali to make a dope which is forced through spinnerets of the type used in the rayon industry. Filaments issuing from the spinnerets are coagulated in acid, stretched to increase their tensile strength, then washed and wrung to form an off-white continuous tow. The tow is chopped into short lengths for use in tertiary products.

In Britain, protein isolate and spun fibre

are being made from field beans by similar procedures, and the spun fibre is incorporated in a new protein food marketed under the name Kesp (Anon. 1973).

Gluten, the crude protein prepared by washing wheat flour, has long been used as a raw material for imitation meat products. When properly handled it has natural fibrous properties which impart a'chewy' character. Gluten may be particularly useful when used in conjunction with soy proteins in TP foods since the soy protein contributes lysine and gluten contributes sulphur-containing amino acids, thus giving a better-balanced product than either protein alone.

Tertiary products

Textured protein foods

Secondary protein products may be converted into tertiary foods in a number of ways, but the basic technology for the manufacture of TP foods is extrusion technology and the essential equipment is the extruder–cooker. In this machine a moist mixture of secondary products is fed continuously into a heated tube through which it is propelled by a rotating screw while being subjected to steadily increasing pressure until it is extruded through a die. The sudden release of pressure when it leaves the die causes the hot product to expand to an open-textured form. The shape of the extruded product is controlled by the nature of the die selected, and it may be cut off to any required length as it leaves the die. Usually the extruded product passes into a drier.

The Food Research Laboratory has installed a pilot-scale extruder–cooker, Model X 5, made by Wenger Manufacturing Company, Kansas City, Missouri, U.S.A. (see figure).

Extruded TP foods are being made from various mixtures of secondary protein products. The cheapest but least satisfactory products are made from soy grits or soy flour only. Additions of soy concentrate, soy isolate, and spun protein fibre improve the quality but also increase the cost. Typical TP foods have about 50% protein, the remainder is water, starch and additives including flavouring and colouring. TP foods may or may not be rehydrated before incorporation into other foods. The protein efficiency ratio of these foods is about 1·8 (casein 2·5). They have a high satiety value, which may be either an advantage or a disadvantage.

TP foods have reached the highest level of commercial development in the U.S.A. Following large research expenditure by several companies and a prolonged lag period, they are now receiving increasing acceptance from the food industry and consumers. A major step in securing general acceptance was gained in 1972 when the USDA Food and Nutrition Services gave approval for the use of TP in the U.S. school lunch program. Hydrated TP may be substituted for 30% of the meat in school lunches provided it is fortified with nutrients to specified levels. These foods are most acceptable when used in conjunction with, rather than instead of, meat, e.g. as meat extenders in hash- or stew-type dishes and hamburgers.

Australia is already seeing some commercial activity in the manufacture and use of TP foods. The Sanitarium Health Food Company, Cooranbong, N.S.W., has for many years prepared meat analogues for a motivated market, and has lately extended the range of these products by incorporation of extruded and spun fibre components (Cole 1973). Two companies, P.T.L. Oilseeds Pty Ltd at Toowoomba, Queensland, and Griffith Laboratories Pty Ltd at Smithfield, N.S.W., are setting up plants for the manufacture of soy flours and TP foods.

Meat and fish analogues

While extruded TP foods may imitate more or less closely the colour, texture and flavour of meat or fish, they are usually restricted in shape to resemble chopped or diced products. However, meat and fish analogues are also being made which, without trying to mislead the consumer, offer him simulated products that look like the product being imitated: for instance, imitation meat loaves, breakfast meats, sausages, hams, bacon rashers, chicken legs, fish fillets and shellfish.

Meat and fish analogues may be made from a variety of protein products, which may include various soy fractions, extruded granules, spun fibre and gluten, together with other ingredients such as egg albumen, fats, flavourings and colourings. Some products are frozen, some are canned on orthodox canning production lines, and some are dried.

Research program

In the early stages, the team at the Food Research Laboratory will be occupied in exploring extrusion technology with the pilot-scale machine, using imported secondary soy products as starting materials. It is well recognized that extrusion technology is highly empirical because of the difficulty of defining the physical parameters such as temperature, pressure and shear from point to point within the extruder cylinder and die. For the same reason it is not easy to scale up results from pilot-scale equipment to commercial production.

At the same time as this work is going on, a comprehensive evaluation will be undertaken of TP foods and meat analogues that are being manufactured in other countries. Eventually it is expected to extend extrusion technology to a range of protein sources, both imported and local, as they become available, including oil seed proteins, gluten and other cereal by-products, and meat products. Incorporation of meat components in TP foods will be examined from two points of view: the enhancement of the meaty character of TP foods and the utilization of low-quality meat fractions. Throughout the program close cooperation will be maintained with the Meat Research Laboratory, and considerable joint activity is envisaged.

References

Anon. (1973). The proof is in the eating. *Fd Technol. Aust.* **25**, 325.

Cole, S. J. (1973). Simulated meats from soy protein. *Fd Technol. Aust.* **25**, 388–96.

Smith, A. K. and Circle, S. J. (1972). 'Soybeans: Chemistry and Technology'. Vol. 1. (AVI Publishing Co.: Westport, Conn.)

Superficial scald

By E. F. L. J. Anet

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The role of free radicals and antioxidants in the cause and control of superficial scald in apples and pears

Superficial scald is a storage disorder of apples and pears caused by the death of hypodermal cells, and shows up as brown patches on the outside of affected fruits; certain varieties are more susceptible than others (Fig. 1). Several papers have been published in the *Quarterly* on the various fruit scalds, the most recent being 'Directions for practical scald control' (Hall 1972). The type of scald discussed here is distinguished from other types in that it can be controlled, either by wrapping the fruit in oiled tissue paper or by treating it with antioxidants such as diphenylamine or ethoxyquin. However, oiled wraps are not always successful in controlling scald, especially for fruit stored in controlled atmosphere (C.A.), and while the antioxidants provide complete control they are not permitted as food additives in some countries.

Other remedies are needed; and it is hoped that if we can gain a clearer understanding of the causes of scald we may be able to work out better control measures, or at least be able to define more accurately areas where the search for such measures would be most profitable.

What causes scald?

Volatiles

Soon after World War I, American workers advanced the theory that scald was induced by unknown volatile compounds produced by the apple. The basis of this theory was the observation that loosely packed or ventilated apples developed less scald than tightly packed or unventilated ones, and this suggested the first practical method for controlling scald—wrapping the apples in tissue paper impregnated with fats or oils. The success of this method was consistent with the idea that scald was induced by a volatile compound produced by the apple, which was then absorbed in the oil of the wraps.

For the next 40 years many workers tried unsuccessfully to identify the injurious volatile; they eliminated from consideration a number of compounds produced by the apple, including esters. Different workers obtained conflicting results on the effect of ventilation, largely because in most of the control experiments air movement was high enough to remove the volatile. Much work was also done to determine exactly how the use of oiled wraps reduced scald, and despite initial disagreements it became clear that the wraps were effective because they were absorbing a volatile compound.

α-Farnesene

The next major advance in understanding the cause of scald came from Dr Huelin's group in this laboratory. He and his group isolated from apples, pears and quinces the volatile sesquiterpene hydrocarbon, α-farnesene, and they proposed that it was the volatile compound responsible for inducing scald (Huelin and Murray 1966). This was the first reported natural occurrence of α-farnesene, but it has since been found in some ants where it acts as an alarm pheromone. Recently it has been shown that α-farnesene is the feeding attractant of the apple codling moth, although apples have very little α-farnesene when picked. During storage the concentration rapidly increases, reaching a maximum at 10–15 weeks and thereafter decreasing at varying rates. Most of the α-farnesene is in the skin of the apples; a little is in the underlying cells.

In further experimental work it was shown that in apples from the same pick the concentration of α-farnesene could be lowered by the use of oiled wraps or ventilation, with a consequent reduction in the incidence of scald; but the correlation of α-farnesene concentration with liability to scald did not hold for apples from different picks or of different varieties. Moreover, injecting α-farnesene into apples did not appear to induce scald; here, however, the results were inconclusive because the addition of α-farnesene caused the apples so to reduce their own production of α-farnesene that a lower total amount was reached.

When Dr Huelin and his group proposed α-farnesene as the volatile compound for which many workers had been searching, they also suggested that the causal agents of scald were oxidation products of α-farnesene. Later, they were able to show that the addition to apples of partially autoxidized α-farnesene did increase the incidence of scald when the fruit was stored.

Fig. 1 Superficial scald in Granny Smith apples.

Autoxidation products of α-farnesene

α-Farnesene autoxidizes rapidly, and a thin film exposed to air in the dark at room temperature is almost completely oxidized within 15 hours. The products of autoxidation can be grouped into four classes:

- Volatiles
- Hydroperoxides (monomers)
- Polymers (containing peroxide and hydroperoxide groups)
- Transient free radicals (alkyl and alkylperoxy radicals)

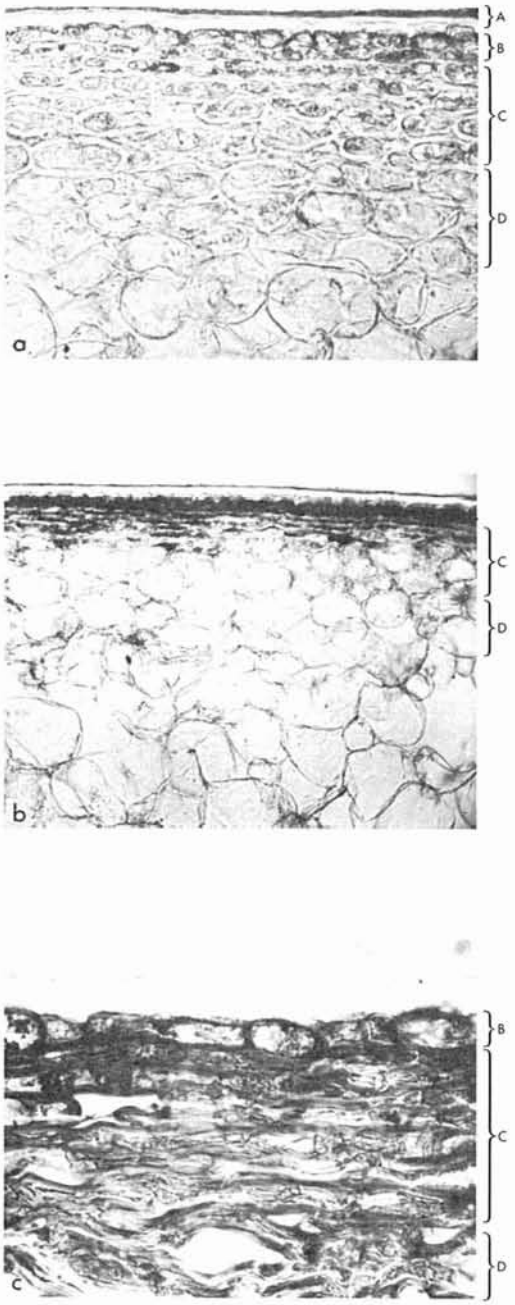

Fig. 2. Sections of Granny Smith apple: (*a*) normal, (*b*) moderately scalded and (*c*) severely scalded. The sections reveal the waxy cuticle (*A*), epidermis (*B*), hypodermis (*C*) and outer cortex (*D*). The cells of the epidermis remain intact whilst those of the hypodermis turn brown in (*b*) and eventually collapse (*c*), together with cells of the underlying outer cortex. (Reprinted, with permission, from *The Journal of Horticultural Science* **31** (4), 234–8.)

The volatile compounds have been identified in this laboratory (Anet 1972) and in England (Filmer and Meigh 1971). It is unlikely that they are responsible for scald in apples because they are formed only in trace amounts, and they belong to chemical groups that are, if anything, slight scald inhibitors. α-Farnesene hydroperoxides (monomers and polymers) have been shown to induce scald when added to apples but they probably act simply as catalysts or initiators of autoxidative reactions. Hence we are left with the transient free radicals as the main agents of cell damage (Fig. 2).

Free radicals

Autoxidations are reactions involving free radicals which proceed by a chain mechanism:

$$RH + ROO^{\cdot} \rightarrow R^{\cdot} + ROOH$$
$$R^{\cdot} + O_2 \rightarrow ROO^{\cdot},$$

where RH is an autoxidizable substance such as α-farnesene or an unsaturated fatty acid. Abstraction of a hydrogen atom from RH yields an alkyl radical $R^{\cdot}$ which is immediately acted upon by oxygen to give the alkylperoxy radical $ROO^{\cdot}$, which then reacts with another RH to continue the chain reaction. Of the two types of free radicals formed, the alkyl radical $R^{\cdot}$ cannot cause cell damage directly since it reacts preferentially with oxygen, which must be present if autoxidation is to occur. However, the alkylperoxy radical $ROO^{\cdot}$ can abstract a hydrogen atom not only from α-farnesene, but also from other cell constituents, including those with vital functions. For these chain reactions to begin, an initiator is required (e.g. RH + initiator → $R^{\cdot}$); one source of initiator is the spontaneous decomposition of hydroperoxides, catalysed by trace metals.

The chain reaction can be terminated in a number of ways. One method is simply to eliminate one of the reactants, oxygen or RH. Another effective method is to trap the $ROO^{\cdot}$ radicals with antioxidants.

Antioxidants

Antioxidants (AH) act by trapping alkylperoxy radicals $ROO^{\cdot}$ as follows:

$$ROO^{\cdot} + AH \rightarrow ROOH + A^{\cdot}$$

$$A^{\cdot} \rightarrow \text{non-radical products}$$

The radicals $A^{\cdot}$ formed from the antioxidant are not reactive enough to abstract

hydrogen atoms from autoxidizable substances RH, and usually disappear through dimerization or dismutation, the antioxidant being destroyed in the process. Since apples have very low levels of antioxidants in the lipid phase compared with many natural systems, e.g. seed oils, and high levels of the readily autoxidizable α-farnesene, it is not surprising that autoxidation frequently occurs during extended storage of apples. This will happen whenever the antioxidants fall below a critical level for a particular condition (Anet 1974).

Before the discovery of α-farnesene, Smock (1957) found that diphenylamine and ethoxyquin were effective inhibitors of scald. Although it was realized that these two aromatic amines could act as they did because of their antioxidant properties, the issue was confused because other antioxidants, those of the phenolic type, were not effective in controlling scald. The mechanism for this control was obscured by the known ability of diphenylamine to alter some biological reactions, and the problem became even more complicated when, later, it was discovered that diphenylamine decreased the production of α-farnesene by the apple, and could thus act in more than one way to control scald.

However, these objections to the antioxidant theory for scald control by diphenylamine were answered by recent results from this Division (Anet and Coggiola 1974). Phenolic antioxidants have been shown to be unable to prevent scald because they do not act as antioxidants for the autoxidization of α-farnesene *in vivo*, although they do so *in vitro*. Several aromatic amines that are more effective scald inhibitors than diphenylamine are more effective *in vivo* antioxidants, and furthermore, these amines do not decrease the production of α-farnesene by the apple.

Treatments of comparable Granny Smith apples with various antioxidants have shown an excellent correlation between the extent of α-farnesene autoxidation and the severity of scald which develops during storage.

How may scald be controlled?

Since scald arises from damage to apple cells by free radicals produced by autoxidation, its control depends on arresting these oxidations. As α-farnesene is the predominant autoxidizable compound in stored apples, the control of scald hinges on our ability to limit the autoxidation of α-farnesene.

The ideal solution would be to breed new varieties of apple which are not scald-susceptible, either because they produce only small amounts of α-farnesene, or because they have an efficient antioxidant system. This, however, would be a very long-term project. Some current varieties are resistant to scald but lack other desirable qualities. For all we know, the presence of α-farnesene may even be desirable for its contribution to flavour and it may also be an important constituent of the wax that prevents the loss of water from apples during storage.

Autoxidation of α-farnesene could be limited by:

- Reducing the concentration of initiators, e.g. trace metals
- Reducing oxygen in the storage atmosphere to very low levels
- Reducing the concentration of α-farnesene
- Trapping alkylperoxy radicals with more or better antioxidants

The problem of scald has increased with the advent of C.A. storage because the fruit can be stored for a longer time, and because evaporative losses of α-farnesene are reduced in the sealed atmospheres.

Reducing the concentration of initiators

Very little is known about initiators of autoxidation in apples but work in this Division has shown that the slight inhibition of scald brought about by ethylenediamine tetraacetic acid (EDTA) is due to chelation of trace amounts of some metals, e.g. copper. The method suffers from two drawbacks: EDTA is not sufficiently effective and it is not a generally approved food additive.

Reducing the oxygen concentration

To be effective, any reduction in the oxygen concentration in the storage atmosphere must bring it down to very low levels (less than 3%). However, when such low levels are reached, other apple disorders begin to appear. Further, this reduction in oxygen concentration must not be achieved by restricted ventilation, or the concentration of α-farnesene will

increase, cancelling the initial beneficial effect. The method is therefore impractical.

Reducing the concentration of α-farnesene

Decreasing the concentration of α-farnesene reduces the number of free radicals formed, and so enables the autoxidation to be controlled by a smaller amount of antioxidant. The only known method of obtaining apples with a drastically reduced α-farnesene content is by selecting a suitable variety. An effective chemical treatment may be found which reduces the α-farnesene in the apple and, as I mentioned, diphenylamine does tend to act in this way. Since the amount of α-farnesene produced by apples varies from season to season, growing conditions, too, may have an effect, but because other factors have a greater influence on the scald susceptibility of apples this seasonal effect is difficult to study.

When apples are placed in C.A. storage the transfer of α-farnesene by evaporation from the fruit to outside the storage space is not practicable and the use of oiled wraps to absorb the α-farnesene does not result in a sufficient reduction in scald. Moreover, the application of oiled wraps is a labour-intensive operation that is becoming increasingly expensive.

Trapping free radicals with antioxidants

Apples that are immature or that are grown in hot dry climates do not maintain their level of antioxidant during storage and are highly susceptible to scald. But there is an export market for such early fruit and hence they are important. It may be possible to find substances that stimulate the production of antioxidants by apples in store; however, none is yet known, and if such a compound were found it would still need to be tested for safety and then approved for use, and so we cannot look for assistance from that quarter for some time yet.

There remains, at present, only one effective treatment for inhibiting scald, the addition of an amine antioxidant to the fruit soon after picking. Two antioxidants, diphenylamine and ethoxyquin, are approved for use in Australia. In some other countries, unfortunately, neither of them, or only one of the two, is approved. With the world-wide trend to limit the number of permitted food additives, the only antioxidants that might have more hope of general acceptance are those already in wide use as food antioxidants, such as the tocopherols and butylated hydroxyanisole. These are phenolic compounds and they appear to be inactive as antioxidants when added to apples; if we can find out why they are inactive we may be able to discover a way of overcoming this, and of realizing their potential usefulness.

References

Anet, E. F. L. J. (1972). *J. Sci. Fd Agric.* **23**, 605–8.

Anet, E. F. L. J. (1974). *J. Sci. Fd Agric.* **25**, 299–304.

Anet, E. F. L. J. and Coggiola, I. M. (1974). *J. Sci. Fd Agric.* **25**, 293–8.

Filmer, A. A. E. and Meigh, D. F. (1971). *J. Sci. Fd Agric.* **22**, 188–90.

Hall, E. G. (1972). *CSIRO Fd Res. Q.* **32**, 33–8.

Huelin, F. E. and Murray, K. E. (1966). *Nature* **210**, 1260–1.

Smock, R. M. (1957). *Proc. Am. Soc. Hort. Sci.* **69**, 91–100.

Banana research

By E. G. Hall

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The achievements of the Banana Research Advisory Committee, 1962–72

The Banana Research Advisory Committee (BRAC) was set up in 1962 to expand research into technical problems seriously affecting the marketing of bananas, and to prepare and distribute to the banana industry up-to-date technical information on handling, transport and ripening. The Committee comprised members from the Commonwealth Department of Primary Industry, the CSIRO Division of Food Research, the Australian Banana Growers' Council, the Queensland Department of Primary Industries and the N.S.W. Department of Agriculture. It had at its disposal a sum of $12,000 per year, which was contributed by the banana industry and the Federal Treasury; the funds were used to assist in financing approved research projects within the State Departments and CSIRO.

Up to the time it was disbanded in 1972, the Committee achieved considerable success, particularly in stimulating interest in banana research. In the 10 years to the beginning of 1973, 45 research papers and 19 popular articles on bananas after harvest were published by research workers in CSIRO, the Queensland Department of Primary Industries and the N.S.W. Department of Agriculture. As a result of the Committee's efforts, we now possess a body of knowledge which, if applied, can solve most of the technical problems in marketing Australian bananas.

In this country, bananas are harvested when hard and green, transported over long distances, and then ripened under carefully controlled conditions before being marketed in the shops. The most common causes of loss are from the fruit beginning to ripen during transport (the condition known as 'mixed ripe') or from the development of rots during ripening; physical damage exacerbates these hazards by increasing the rate of ripening and by opening the way for infections. The work of the BRAC was directed to ways of controlling fruit-ripening and post-harvest diseases and improving practices in preparation for market, all aimed at giving the consumer better bananas and reducing transport and marketing losses which are ultimately borne by the grower.

Studies on fruit ripening

Maturity

It would be possible to avoid the problem of fruit arriving on the market in a 'mixed ripe' condition, i.e. when some bananas are ripening or even over-ripe while others in the same consignment are still hard and green, if we could predict how long after emergence of the bunch the fruit would take to mature. With some other fruits it has been found that a fairly constant number of heat units is required to mature the crop and, when known, this can be used to predict maturity.

However, despite a great deal of research effort it has not been possible to show that there is a constant number of degree-days* needed to bring bananas to maturity in the plantation. In fact, it has not been possible to find any one satisfactory index, physical or chemical, of maturity for this fruit. Nevertheless, both research and commercial experience do show that, in a particular plantation, bunch tagging can be used to predict harvest time and, if done regularly, can enable good control over maturity of the fruit at harvest, and so of the mixed-ripe problem.

* Total heat units above a base temperature of 10°C × number of days.

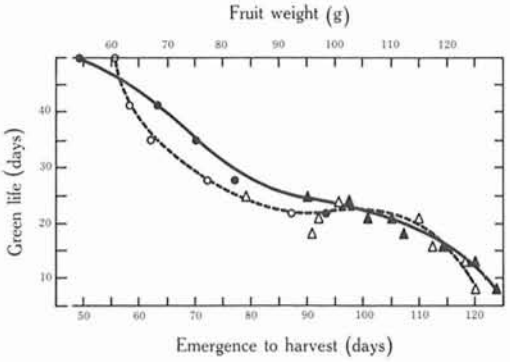

Fig. 1. Relation between length of green life, fruit weight, and days from emergence of the bunch to harvest. Summer fruit (i) 1968 and (ii) 1969 from Alstonville Research Station.
● green life (i) ○ fruit weight (i)
▲ .. .. (ii) △ .. .. (ii)

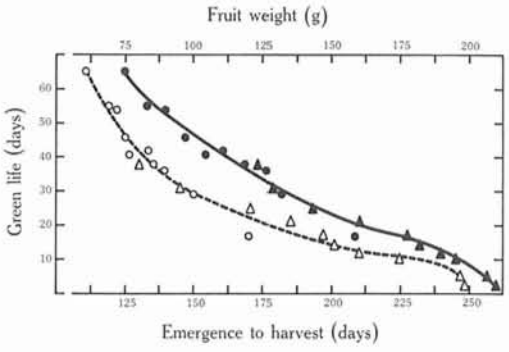

Fig. 2. Winter fruit (i) 1969 and (ii) 1970 from Alstonville Research Station.
● green life (i) ○ fruit weight (i)
▲ .. .. (ii) △ .. .. (ii)

Green life

A major achievement has been development of the concept of 'green life' for bananas, i.e. the number of days after harvest that fruit may be held, provided that no external ethylene is present, without beginning to ripen. This is a measurement of great practical importance, since it gives a means of estimating transport- and storage-life. Research centres now have controlled environments for the accurate measurement of green life, and these are a valuable aid in experimental work on production as well as on post-harvest problems.

It is now known that many factors can affect green life. It varies considerably between plantations and times of the year, even between fruits within a bunch; disease can reduce it by weakening fruit, and similarly any stress—cold, lack of water, poor nutrition—will result in slow 'filling' of the fruit and shorter green life.

What is important commercially is the reliability of a grower's fruit, and this means that his consignments should not contain *any* bananas with a short green life. To increase the life and the capacity to withstand longer transport, the best course is to cut 'back', i.e. to cut the bunches before the green fruit is fully developed. Figures 1 and 2 show the relation between green life, fruit weight, and age of the bunch for summer and winter fruit.

Time–temperature studies

Detailed investigations have provided basic information, previously lacking, which enables prediction of the quantitative effects of temperature on the duration of green life (Fig. 3). One important application of this work is that it enables a proper evaluation both of precooling and of refrigerated transport—topics that will be mentioned later in this article.

Ethylene studies

Ethylene plays a vital role in the behaviour of bananas after harvest. Even a brief exposure to trace amounts of ethylene (less than 1 p.p.m.) will shorten green life, although it is not enough to initiate ripening straight away. It is extremely important to prevent accumulation of these minute amounts, and to provide ways of removing all traces of ethylene from packing houses, stores and

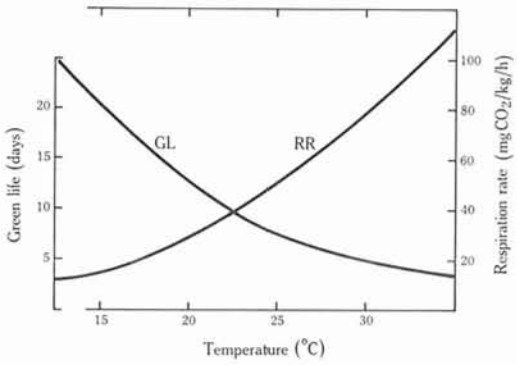

Fig. 3. Effect of temperature on green life (GL) and on respiration rate (RR).

long-distance transport. Since mechanical injuries and anthracnose or other infections increase production of ethylene and so shorten green life, bananas that are intended for distant markets or long storage must be sorted and handled carefully, and must be properly treated with an effective fungicide. It has been shown that an effective means for removing ethylene in polyethylene bag packs is by the use of potassium permanganate, and in storage and transport spaces by passing the atmosphere over suitable combinations of ultraviolet lamps.

Market diseases

Australian workers have been leaders in research on the application of new fungicides for controlling post-harvest fruit rots in bananas (Fig. 4), and effective and complete control of market diseases is now practicable at low cost. Fungicides like benomyl, thiabendazole, and thiophanate methyl have made practicable the packing of bananas in polyethylene bags or in cartons with polyethylene liners, and ripening and storage without the development of fruit rots. Complete rot control is essential to ensure realization of maximum potential green life and for safe long-distance transport.

Although control of market diseases has been achieved, there is still a need for a means of checking whether consignments have been effectively treated with one of the recommended fungicides; it would be invaluable, too, if a fungicide could be found that was water-soluble, and thus easier to use than the present wettable powders.

Fig. 4. Three common fruit rots caused by the fungus, *Gloeosporium musarum*. *Top*, black end; *centre*, harmless speckling of fully ripe fuit; *bottom*, severe anthracnose.

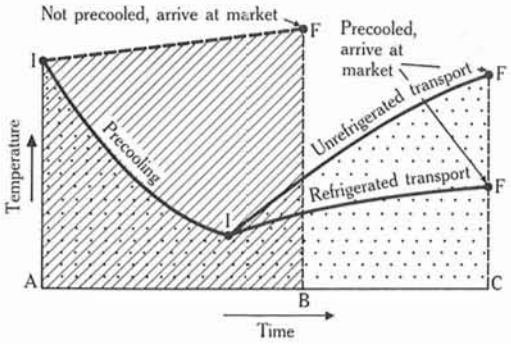

Fig. 5. A diagram like this helps the grower decide whether to precool his fruit before sending it to market. *I*, Initial temperature at start of transport; *F*, final temperature on arrival at market.

Preparing for market, handling, packaging

Cooling

Keeping the fruit cool at all times during hot weather is most important, in order to increase green life and to reduce weight loss from evaporation. It is advisable to exploit every means of cooling, such as cutting early in the day in hot weather, dipping or spraying the bunches with water, and keeping the shed cool, so long as these practices do not increase the time between harvesting and arrival of the fruit at its destination.

Whether or not to precool—that is, whether to spend time before transporting the fruit in removing initial heat from it by mechanical means—has been a contentious issue. A formula has been devised to test whether precooling is likely to be useful or not; it is a matter of comparing total degree-days from packing to market, as shown in Figure 5. It is evident that we must estimate carefully the time to expected arrival at market, since in normal unrefrigerated transport it may be that the extra time used in deliberately precooling will increase the total number of degree-days from harvest to arrival at the market. For precooling to bring about a gain in degree-days and therefore in green life, the dotted area in Figure 5 must be considerably less than the hatched area, to compensate for the extra time (*A–C v.*

Fig. 6. These bananas were cut and packed at the same stage of development. In contrast with the unlined carton (*left*) the polyethylene bag pack (*right*) has kept the fruit hard and green and free from rub injury.

A–B) required for precooling. In many situations refrigerated transport would be necessary to justify precooling.

Handling

In experimental studies about 25% of total mechanical injuries to bananas occurred during cutting and handling in the plantation, and about 20% during transport of the bunches to the grower's shed for packing; the remaining 55% occurred during packing and in the transport shock simulator. In practice, it has been shown that the most severe injuries occur after the fruit is packed, during transport to market.

Packaging

Studies have shown that a fibreboard carton is a better protecting package than the more rigid wooden box, especially for hand packs, and final presentation is better in the carton. But fruit can also out-turn well from a well-packed wooden box of singles, and a decision on the type of pack to use must be based on total costs and returns. In a study of the efficiency of various lining materials in reducing injury, polyethylene film gave the best results, and the bag gave slightly better results than sheet film, in reducing both injury and weight loss.

Prepackaging

There is much promise in the idea of packaging green fruit, as soon as it is picked, into convenient packs ready for ultimate sale on the retail market. It seems probable that a polyethylene shrink wrap will satisfy the necessary requirements for successful ripening, but more work is needed before recommendations can be made.

Polyethylene bag packs

Packing bananas in polyethylene bags inside cartons has proved an extremely good way of preparing them for long-distance transport (Fig. 6). Using this system, bananas have been sent by rail to Adelaide and by ship to New Zealand from north and south Queensland and the north coast of New South Wales. It is a significant breakthrough in dealing with the mixed-ripe problem, and is more effective and cheaper than precooling. The effects of 'polybag' packaging on green life at different temperatures are shown in Figure 7.

Transport

Refrigerated road/rail containers have been tested for transporting bananas and are successful; however, over many years of experience, and in cooperation with the Departments of Railways and the industry, the design of unrefrigerated louvred vans has been made very satisfactory for the transport of bananas and other perishables. This method of transport has been brought to a higher stage of development and is more widely used in Australia than anywhere else in the world.

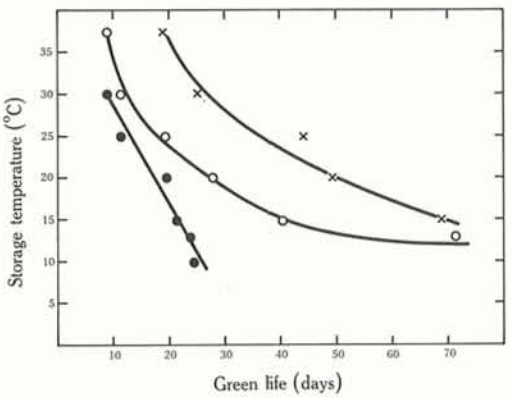

Fig. 7. Effect on green life of packaging in sealed polyethylene film bags (0·0015 mm thick, low density).

● stored in air ○ stored in 'polybag' plus permanganate
× stored in 'polybag'

Conclusion

The achievements of the Banana Research Advisory Committee, after ten years of cooperative research, are very creditable. Australia is now a leading country in post-harvest research on bananas, and the industry will reap the full benefit as the findings are more fully applied. Advances have come not only from sponsored projects, but also from the much higher level of general interest in banana research that is now in evidence.

Further reading

Extension Publications from the Banana Research Advisory Committee

The ripening banana: standard colour index numbers for banana ripening. 1969.

Tech. Bull. No. 1. Mixed-ripe problem of bananas. Rev. ed. Apr. 1969.

Tech. Bull. No. 2. Handling bananas in cartons. 1964.

Tech. Bull. No. 3. Banana ripening guide. 1971. (Reprinted as Circular 8 of CSIRO Division of Food Research, available from FRL, North Ryde.)

International Commission on Microbiological Specifications for Foods

This Commission (ICMSF) is a working party formed in 1962 under the aegis of the International Association of Microbiological Societies. It was set up in response to a growing need for internationally acceptable and authoritative statements on microbiological limits for foods commensurate with public health safety. It is concerned particularly with foods traded in international commerce. Currently, ICMSF consists of 19 food microbiologists from 14 countries. Dr H. Lundbeck of Sweden recently succeeded the foundation Chairman, Dr F. S. Thatcher, and the Secretary-Treasurer is Dr D. S. Clark of Canada. Under its Constitution, the members act as individuals chosen for individual reputation; they are not national delegates or government representatives. When required, non-member specialists are coopted as consultants to the Commission. To involve areas not represented on ICMSF, regional subcommissions are formed. Latin American and Balkan Danubian Subcommissions are already established. Liaison with other groups, both national and international, concerned with microbiological methods and standards, is achieved by extensive cross-membership and by the activities of the ICMSF Executive.

The results of all ICMSF projects are published, either as papers or as books. The Commission produced the book, 'Microorganisms in Foods: Their Significance and Methods of Enumeration' (Ed. F. S. Thatcher and D. S. Clark) in 1968. Over 3000 copies have been sold, and an expansion and complete revision of the book is in progress. 'Microorganisms in Foods. II: Sampling of Foods for Microbiological Analysis: Principles and Specific Applications' should be published in 1974. This describes the statistical and microbiological factors pertinent to sampling plans, and gives sampling procedures for all major classes of foods, and sampling plans for each class of foods.

ICMSF conducts a testing program that includes both contract studies of specific problems in the microbiological analysis of foods, and international comparative testing of microbiological methods. In addition, an international computer program aims to provide a more secure basis for establishing acceptance criteria by analysis of microbiological data from wherever available throughout the world.

The Commission believes that an international but not inter-governmental body has a great deal to offer both industry and government in matters relating to the microbiology of foods in international trade. ICMSF is responsible for raising its own funds and hopes that in the future it will receive financial support for its work from the Australian food industry.

J. H. B. Christian

(Dr Christian was elected a member of the ICMSF in 1971.)

Chilled vacuum-packed beef

By B. Y. Johnson

CSIRO Meat Research Laboratory, Cannon Hill, Qld

A guide to processing this high-quality product for the export trade

The most spectacular development in the meat industry in the 1970s has been the growth of the chilled meat trade. In the 1960s exports of chilled meat were negligible but with the introduction of containers the practice has come into common commercial use; for instance, already over 30% of beef for Japan is chilled, and this percentage will increase. The use of containers has given us access to other markets for chilled meat; approximately 7% of all the beef Australia exports is chilled, and there are also exports of small quantities of chilled mutton and lamb.

Meat intended for vacuum packing and chilling requires careful treatment at every step of processing. Particular attention must be paid to preslaughter practices and dressing hygiene and there must be rigid control of cleaning and sanitation, control of temperature in chilling and holding, and elimination of high-pH meat. Care is also essential in choice of bag and carton for packaging and in evacuating and sealing packages. It is only by using sound quality-control techniques to monitor processing operations and production that our overseas markets will be preserved.

Preslaughter practices

The hides of animals should be clean and animals to be slaughtered must be adequately rested beforehand. The importance of these steps will be seen when we consider the serious consequences of bacterial contamination of the meat and of high pH.

Hygiene

It is particularly important to clean and sanitize surfaces that may come in contact with the meat, including hands and personal gear, and the chillers. The evacuating equipment needs careful attention and it is recommended that this be cleaned and sanitized again during the lunch period. The usual hygiene precautions apply during dressing of the carcass. If the meat is visibly dirty as it comes from the slaughter floor then it will also be bacterially contaminated. The whole technology of slaughtering for the production of chilled meat has been developed with the aim of ensuring that the meat will be microbiologically sound. A quality control officer should make routine microbiological examinations of working surfaces and equipment and also of the meat. Quality control officers require some technical training in microbiological methods, and they need laboratory space and proper equipment. In return they can ensure that the quality of the meat is maintained.

Aspects of temperature control

The number and type of bacteria initially present will depend on the considerations outlined above. Strict temperature control is necessary after the carcass is dressed to ensure that multiplication of the bacteria already on the meat is kept to a minimum.

Temperature measurement

Meat temperatures can be measured with bimetallic spear thermometers but these may have considerable errors. A better, although more expensive, method is to use thermistor systems with stainless-steel probes; these should be more than 15 cm long and less than 3·1 mm wide. They are battery-operated and can be easily read from a distance (Fig. 1).

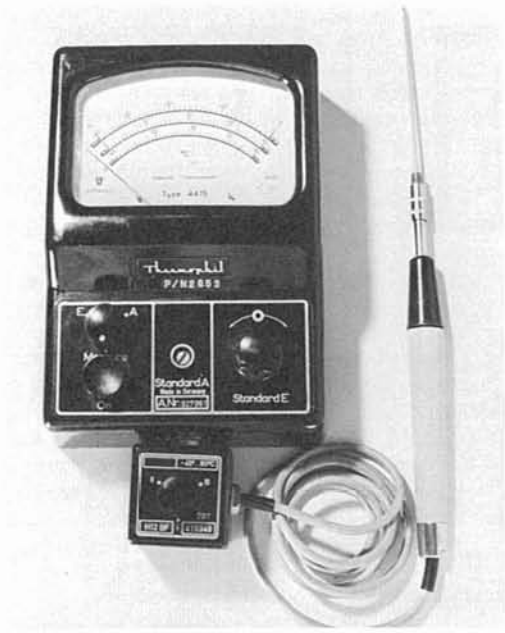

Fig. 1. Portable electronic thermometer.

Temperature in beef-side chillers

The chiller room should be precooled to a temperature that can be maintained during the loading phase and the fans kept running during loading; the doors should always be kept closed when the room is not in use. Sides or carcasses should be spaced so that they are not touching and air movement around them should be sufficient to assist drying; hot carcasses must not be mixed in with cold. At the end of loading the air temperature and the temperature of the meat surface should be quickly reduced to 7°C or below, due care being taken that the meat does not freeze. Appropriate air temperatures and velocities are then employed so as to reduce the temperature of the side of beef, measured at the thickest point, to below 15°C in 20 h.

A fast rate of carcass cooling, particularly in the early stages of chilling, tends to minimize weight loss and reduce weep or drip in the vacuum pack during storage. Ideally, this rate of chilling should be maintained until all the meat is 7°C or below. Thus, the deep butt temperature should be to the left of the line shown in Figure 2.

Temperature in processing

Processing is carried out in a room of air temperature < 10°C. Sides should be boned at a temperature of 7°C or less for both meat *and* fat, since at this temperature food-poisoning organisms will not proliferate and the meat will be fully in rigor and firm. The bone-in meat is deboned and trimmed to specification. The cut is then placed in an air-impermeable bag, and the bag is evacuated and sealed. Some types of bags are then heat shrunk. The cuts are placed fat surface upwards, generally direct into the carton, the carton strapped, and then placed in a storage chiller on racks or dunnage to allow ample air movement.

Temperature in cartoned-meat chillers

In order to ensure rapid chilling, chillers for cartoned meat should be precooled to about -5°C before loading, but this temperature should be raised before any freezing of the meat can occur. Meat freezes at about $-1{\cdot}5$°C and so a holding temperature as close as possible to this but not below is aimed at; in practice $-0{\cdot}5$°C $\pm$ 1°C is good. A satisfactory rate of chilling would achieve a meat temperature below 2°C within 24 h of boning. If meat temperatures of $-0{\cdot}5$°C are not reached within 48 h then the air circulation probably needs improving.

The kill and boning should be scheduled so that meat temperatures of $-0{\cdot}5$°C are attained at the time of loading from the chiller room into the container, but at the same time the schedule should ensure that

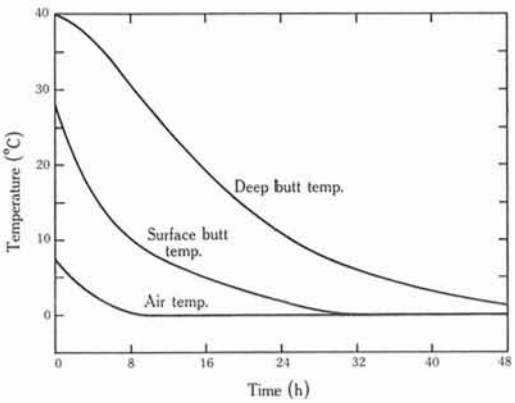

Fig. 2. An example of cooling rate of beef sides using good manufacturing practices.

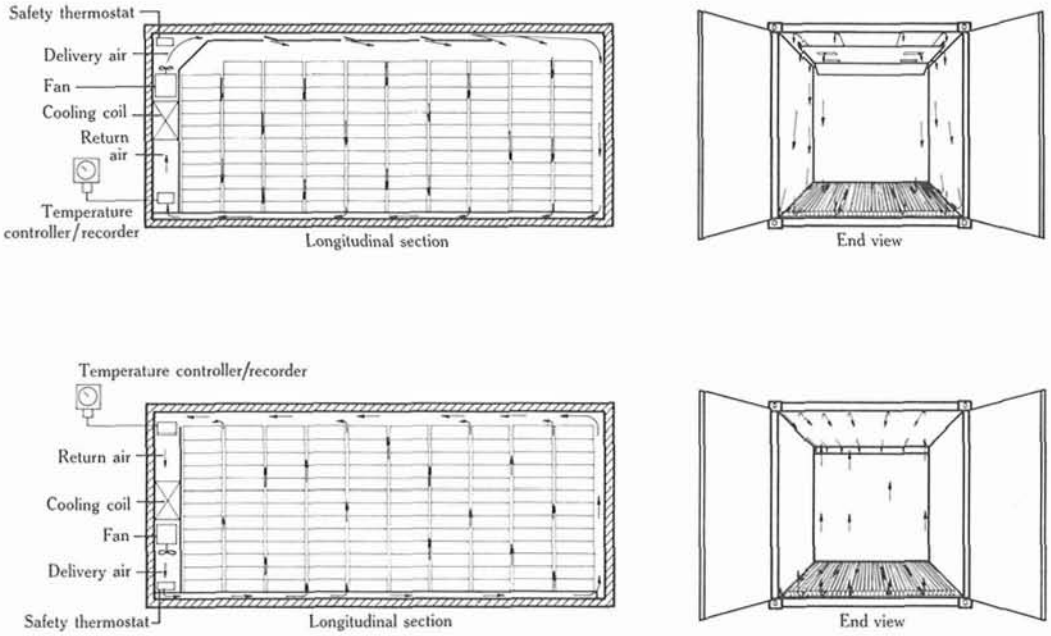

Fig. 3. Pattern of air flow in refrigerated containers. *Above,* top air-delivery; *below,* bottom air-delivery. (With acknowledgments to Overseas Containers Australia Pty Ltd.)

the meat will not have been held unduly long while awaiting shipment.

Temperature in shipping containers

At load-out the cartons are stacked one on top of the other into the container. Vertical battens are taped in position between tiers of cartons to provide for an air flow throughout the load. Care should be taken to ensure that the battens do not rest in the floor channel as air flow will be impeded.

The temperature of the meat at load-out should be lower than the return air temperature (Fig. 3) required for transportation.

For maximum distribution life without freezing the meat, the temperature of air delivered into the container should be as close as possible to $-1{\cdot}5°C$ but not below. In containers, the return air temperature is higher than the temperature of the delivered air, and is the temperature of the air at, or at least very close to, its highest level. The mean air temperature should be about $-1°C$.

There are two main types of refrigeration system used in container shipping.

▶ *Containers with integral refrigeration units.* These have a direct expansion refrigeration system with air-cooled or water-cooled condensers, which can be operated by connection to any convenient electric power supply of appropriate wattage. The Australia Japan Container Line Ltd operates integral containers with one of two air-flow systems.

In the top air-delivery system the air is delivered into the container over the top of the stow by means of ducting positioned on the underside of the roof. The air passes vertically downwards through and around the stow and is returned along the T-section floor to the machinery space where it is cooled and recycled. To ensure that air flow is not impeded, the cargo in a top air-delivery container should not be stowed above a line level with the bottom of the air ducting.

In the bottom air-delivery system the air travels along the aluminium T-section floor and passes upwards, through and around the stow. This air is then returned along the top of the stow to the machinery space where it is cooled and recycled.

Control is achieved by monitoring the

return air temperature and applying refrigeration when it rises above the preset value. It is the return air temperature that is recorded on the chart; in order to maintain temperatures at a constant level it is necessary to cool the air a further 2°C or so, depending on the temperature of the meat on loading and on ambient conditions, before the air is delivered back into the container.

▶ *Containers without integral units.* These are cooled by attaching special clip-on units (which operate by connection to an electric power supply) or by connecting up the containers to a central refrigeration system, either on land or in special container ships, which circulate cold air through the containers by the bottom air-flow system. Most of the chilled meat going to Britain and Europe is carried in containers of this type, kept refrigerated by air from the ship's system.

The delivery air temperature to all containers in a vertical stack is identical. Control is achieved by monitoring the temperature of the air *delivery* which will be the temperature of the air in the container at or very close to its lowest level.

High-pH meat

Greening of chilled, vacuum-packed meat has generally been found to occur on meat with pH values of 6·0 or higher. This may take place within four weeks of packing, and is caused by bacterial production of hydrogen sulphide in the closed environment of the package. The hydrogen sulphide reacts with the meat pigment to produce a green pigment,

Fig. 4. Greening of meat due to high pH. Note the green weep, around the dark-cutting section of the cube roll.

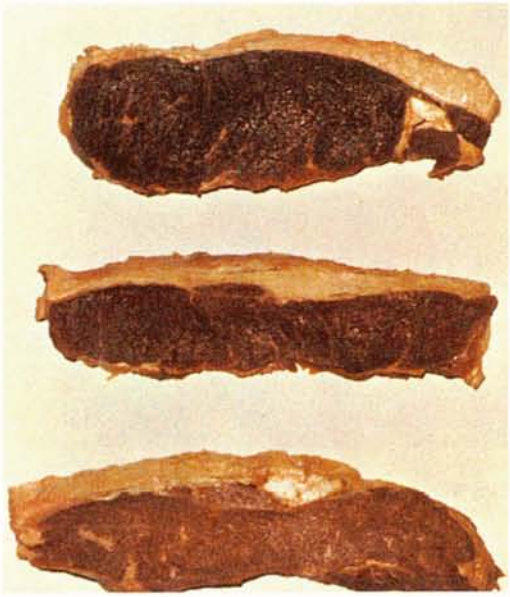

Fig. 5. Dark-cutting beef. The lower striploin is of normal colour; the top two are dark-cutting and have a pH above 6·0

sulphmyoglobin (Fig. 4). In order to overcome or avoid this problem it is necessary to have some understanding of what pH is and how the pH of meat is determined.

pH is defined as the logarithm of the reciprocal of the hydrogen ion (H^+) concentration in a solution. Consequently, it is a measure of the degree of acidity or alkalinity of that solution; as the solution becomes more alkaline the pH number increases, as it becomes more acid the pH number drops. The neutral position on the scale is 7, the pH of pure water. Muscle tissue in the live animal has a pH slightly above neutral, i.e. about 7·3.

The amount of acid produced in a muscle *post mortem*, and therefore the ultimate pH, is dependent on how much glycogen is present at slaughter. If an animal has been handled and slaughtered correctly and the carcass held at suitable temperatures, then the pH in the primal cuts will decrease from 7·3 to 5·6–5·8 in the first 24 h after death, and will drop to 5·4–5·6 in the second 24 h. This is the normal pH of beef muscle. Exhausted animals and those that have been disturbed or excited just before slaughter may have insufficient time to regenerate muscle

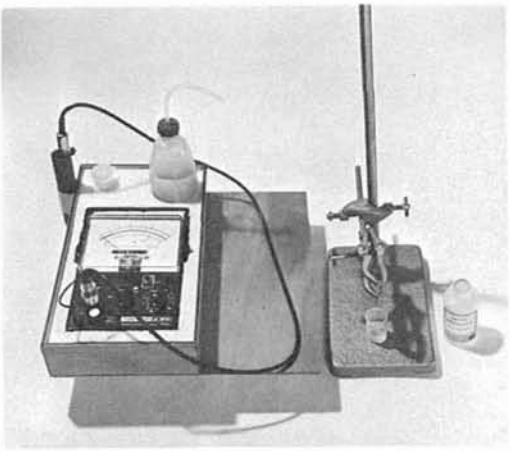

Fig. 6. pH meter in carrying tray, together with stand, clamp and buffer solution.

glycogen levels to normal, and this will limit acid production and result in an increase in the final pH of the meat.

The aim of the processor must be to detect meat *with a pH of 6·0 or above* and thus prevent it from being processed as chilled vacuum-packed beef. There are two ways of doing this.

Meat of low acidity (high pH) is dark (Fig. 5) and a trained operator can pick out a great deal of high-pH meat by its colour. Such a person can be trained to detect meat of pH 6·0 or higher by comparing visual appraisal of colour with a pH meter reading of that particular cut of meat. Training can be given over a period of days and repeated at intervals to maintain the correct standard. A drawback with the procedure, however, is that at least 10 min and preferably 30 min should elapse between cutting the meat and appraising the surface. When side boning is used, it is not always practicable to allow this time interval.

A more certain way of ensuring that meat with high pH does not go into a pack of chilled meat is to use a pH meter (Fig. 6). The striploin or cube roll is a convenient cut for appraisal as its pH can be measured in the side, or quarter, before boning and can be related to the pH of other primal cuts. Since the pH of meat falls progressively after slaughter, measurements should not be taken until it has chilled for at least 20 h. It is recommended that the carcass should not

Fig. 7. Nozzle evacuating equipment (Kartridge Pak).

be used for this particular type of export if the pH of the eye muscle 24 h after slaughter exceeds 5·9. If the pH values are measured later than 36 h after slaughter then the acceptable pH value for the eye muscle should be reduced and carcasses with a value above 5·8 (rather than above 5·9) should be rejected for vacuum packing.

The shins, neck muscles and intercostals generally have a higher ultimate pH than other muscles and therefore these should not be vacuum packed.

Choice of equipment and packaging materials

Equipment

There are two main types of packaging equipment—nozzle evacuating equipment (Fig. 7) operating on vacuums of 250–600

Fig. 8. Chamber evacuating equipment (SwissVac).

mmHg, and chamber evacuating equipment (Fig. 8) operating on vacuums of around 700 mmHg. Whichever of these is chosen appears to make little difference to the storage life of meat packed in conventional packaging materials.

Bags

Vacuum packaging restricts the growth of the normal spoilage organism (*Pseudomonas*). This organism needs oxygen for growth and its growth is retarded by the presence of carbon dioxide. The meat and bacteria inside an impermeable bag consume oxygen and release carbon dioxide, which cannot escape and therefore accumulates, so that eventually the oxygen level inside falls below 2%, while the carbon dioxide level rises to 15–30%. High carbon dioxide and low oxygen levels are desirable. To achieve this, bags of low permeability are used and an optimum size is chosen so that there will not be an excessive area of film available for gas permeation. Organisms resistant to carbon dioxide can grow but they grow only slowly at the temperatures employed. It is interesting to note that if the meat is held too long, these resistant organisms produce a cheesy souring of the product instead of the usual slime associated with spoiled meat that has not been vacuum packed.

Since the method relies on depletion of oxygen and release of carbon dioxide, the meat should be packed and sealed as quickly as possible, preferably within 30 min of boning. If this is done the pigment will be retained in the purple myoglobin form, with minimal production of brown metmyoglobin, and the myoglobin will revert to red oxymyoglobin when the pack is eventually opened.

Films commonly used in Australia are not totally impermeable to gases; in permeability to oxygen they range from 19 to 147 cc (STP) $\times$ m^{-2} $\times$ 24 h^{-1} $\times$ 76 $cmHg^{-1}$ at 25°C, 75% relative humidity. In this range there is no evidence of differences in storage life. However, since production of undesirable metmyoglobin is insignificant at very low oxygen percentages (less than 0·2%) the films with lower permeability are likely to be better for meat colour.

The permeability to carbon dioxide of bags commonly used ranges from 82 to 844 cc (STP) $\times m^{-2} \times 24\ h^{-1} \times 76\ cmHg^{-1}$ at 25°C, 75% relative humidity. There is probably no advantage in using films of much lower permeability since concentrations of over 30% carbon dioxide may cause grey discoloration of the meat.

There are no figures available on permeability to hydrogen sulphide of the meat films in use in Australia, but it is possible that the occurrence of greening of the fat on meat of normal pH (Fig. 9) is dependent on the amount of hydrogen sulphide retained in the pack. This problem may show up after less than 10 weeks' storage and therefore films with relatively high permeability to hydrogen sulphide are likely to have advantages.

The film chosen should be mechanically strong, puncture-resistant and free from pinholes; it should have high clarity. Most important of all, it should be capable of producing a good seal; the seal is generally the weak point of a bag. When sealing the packages, the size of bag should be carefully chosen, and the meat positioned so that it does not exert any force on the seals. It is important to follow suppliers' instructions as to clip sizes and clipping pressures in the case of clipping machines, and temperature, pressure and dwell time of the sealer bars in the case of chamber evacuating machines.

Cartons

The most popular style of carton is a solid fibreboard box and lid, with a corrugated-fibreboard lining inserted around the sides and ends. The size depends on the cuts of meat, but it should also suit the loading pattern of the shipping container. The fibreboard needs to be strong enough to allow stacking 19 cartons high, since stacking to this height has been reported from Japan. In several instances lower cartons have been crushed, particularly those at the container sides where the air distribution channels in the floor are wider. There is no crushing if wooden cases are used.

A clearance of at least 6 mm should be allowed between the top of the meat and the top of the liner of a carton, or between the top of the meat and the top of a case, if cases rather than cartons are used.

Weep

Weep is the fluid from the meat which comes out during storage. To Japanese buyers a normal amount of weep is considered to be around 1–2% while 4% is

considered excessive. Several factors have an important bearing on the quantity of weep.

Age of cattle

The greater the age the less the weep. This ties in well with the Japanese requirement for heavy oxen, over 295 kg.

Chilling

To minimize weep, the hot carcasses must be chilled quickly, and immediately after slaughter, and this rate of chilling *continued* until the stipulated temperature for the shipping container is reached. The meat should not be boned until it is fully in rigor (36 h after slaughter) and well set (deep butt temperature 7°C or below). Temperature fluctuations should be avoided and surface freezing must not occur.

Cutting style

Cutting has an important bearing on amount of weep since it is natural that the greater the number of cut meat surfaces the greater the amount of weep. As many as possible of the surfaces should be left covered by connective tissue and fat.

Handling

Cuts must be handled as little and as carefully as possible. This means that some thought must be given to smooth flow in the production line. Stacking of cuts may cause build-up in temperature and excess weep. Cartons must not be overpacked.

Storage life

Chilled vacuum-packed beef is a highly perishable product, but if properly processed it will keep for approximately 11 weeks when stored at 0°C. Bacteria continue to grow at these temperatures and reach maximum numbers of the order $10^7/cm^2$

Fig. 9. Greening of the fat on meat of normal pH.

Fig. 10. Brown spots on the fat surface of a cut of vacuum-packed meat.

during the fifth week. After 11 weeks, meat that has been properly packed and handled may begin to develop flavours considered undesirable by some consumers; spoilage of meat in less than 11 weeks is generally due to the presence of unpleasant colour and smell.

Japanese reports indicate that some chilled beef will keep for a total of 13 weeks. However, most Japanese retailers expect a maximum storage life of $8\frac{1}{2}$ weeks, stating that after this time discoloration and bad odour may become evident when the meat is sliced or prepacked for retail purposes.

Reports have come back from overseas that under certain conditions, some cuts have developed black or brownish black spots on the fat surface (Fig. 10) after about six weeks' storage. The spots themselves consist largely of a breakdown product of a haem-containing blood component (haematin). They do not seem to be associated with any unusual number or type of microorganisms and are harmless if eaten.

Once the vacuum-packed meat is opened it is subject to the common forms of spoilage which take place in air. However, because vacuum packing prevents the common spoilage organisms from growing above about $10^6/cm^2$, the life on opening is largely independent of the time spent in the vacuum pack. It should be possible to keep the meat after opening for four to five days at 5°C before any off-odours are detected. During storage and retail display the meat should be held at temperatures as close to −1°C as possible.

Single-puncture maturometer

By J. N. Huntington and P. J. Rutledge

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

An improved instrument for measuring texture in a wide range of foodstuffs

Mitchell, Casimir and Lynch (1961) described a modified maturometer for measuring the maturity of peas. This machine forced 143 blunt pins simultaneously through the same number of peas held on a sample plate, and the force required to puncture the peas was measured by means of ring springs and an engineer's dial gauge. An instrument known as a single-puncture maturometer, using the same principle of measurement, was also constructed to measure the force required to puncture individual peas. This maturometer was later converted to transducer and recorder readout, and it has been used to measure the resistance to puncture of such products as canned apricots, dried fruits, prawns, bakery products and meat.

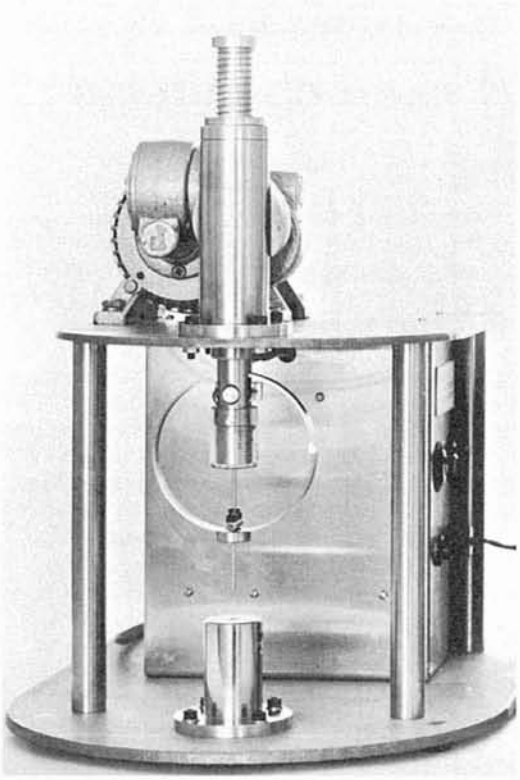

Fig. 1. Front view of single-pin maturometer showing the top-mounted drive motor, ring spring and transducer assembly, and the sample holder. The power supply is housed in the case at the rear.

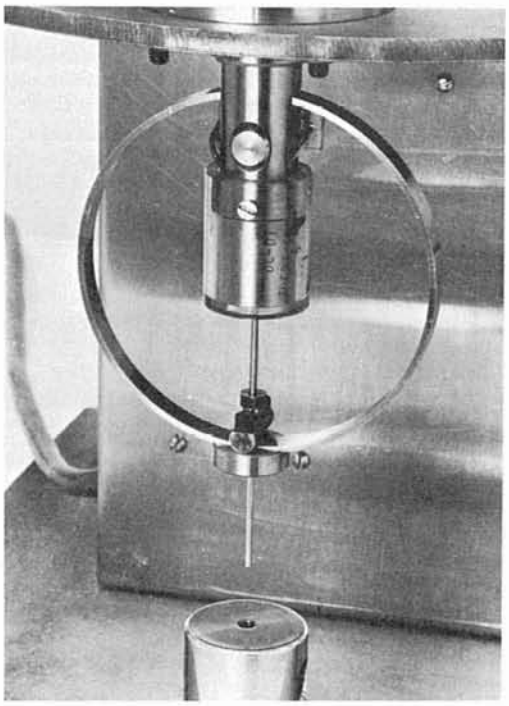

Fig. 2. Details of measurement section of the single-pin maturometer.

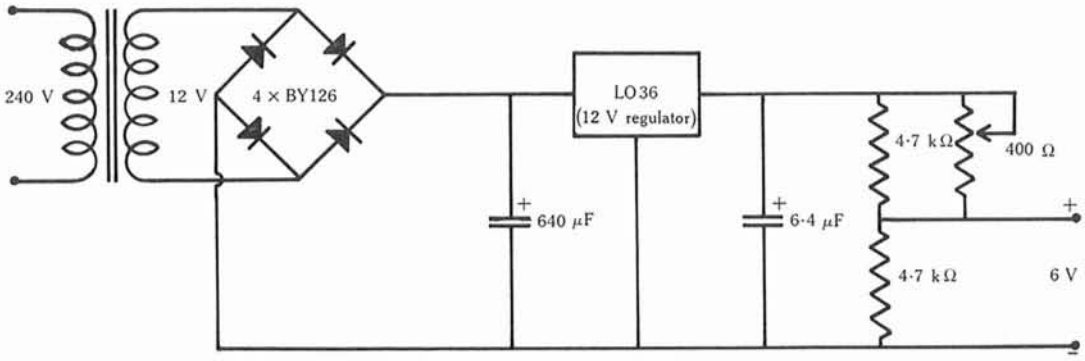

Fig 3. Circuit diagram of the power supply for the differential transformer.

A new model of the single-puncture maturometer has recently been constructed and is being used for making extensive measurements on grapes and dried sultanas. This instrument (Fig. 1) again uses the transducer system for measurements of force but several mechanical refinements have been made to improve sensitivity.

Essentially the instrument carries out two main operations: it moves a pin vertically at a constant rate through the sample, and it continuously measures the resistance to penetration of the sample by the pin.

The instrument is built into a stainless-steel frame consisting of two horizontal plates and four 203 mm × 19 mm (8 in × 0·75 in) diam. pillars. A geared electric motor (30W (1/25 hp), 10 r.p.m.) is mounted on the top plate and drives a cam having a constant diameter, a constant speed and a throw of 2·54 cm (1 in) in a slotted shaft of 19 mm (0·75 in) diam. The shaft moves in two bronze bushed bearings located above and below the cam and is lightly preloaded to minimize backlash. The ring spring shown in Figure 2 is mounted in a groove in the lower end of the shaft so that there is a line contact across the spring. The transducer is mounted on the end of the shaft in a Perspex holder. The 1·6 mm (0·0625 in) diam. pin is clamped to the side of the spring diametrically opposite to the shaft, and the transducer core is screwed into the lower clamp and locked with a nut. The pin moves freely through a 4·8 mm (0·1875 in) diam. hole in the sample holder.

The regulated power supply for the transducer (Fig. 3) is housed in the case mounted at the rear of the unit. The power supply is adjustable between 5 and 7 V and the output from the transducer (7DC-DT 050) with a 6-V input is 1·5 V for a movement of 1·3 mm (0·050 in). The dimensions of the ring spring are calculated so that a response of 0·2 V can

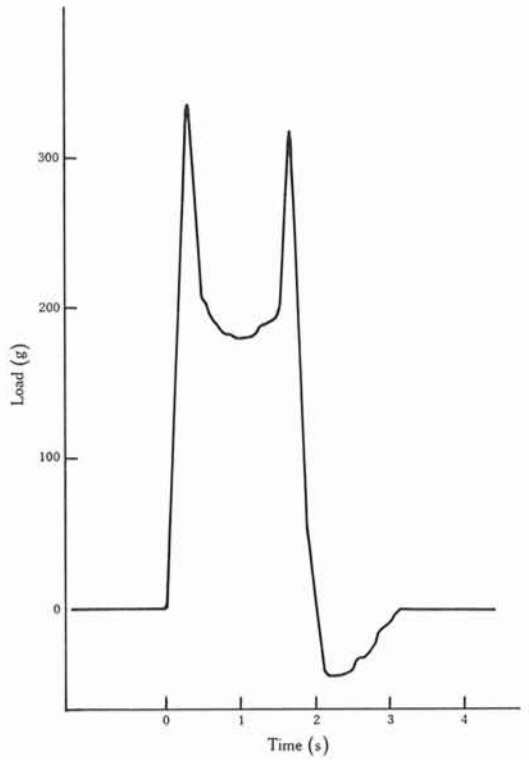

Fig. 4. Force curve for puncturing a sultana.

be obtained from the transducer when the spring is subjected to a load of 1 kg (2·2 lb).

The calculations were done using the expression

$$\text{Deflection (in)} = 0{\cdot}224\ P\ d^3/E\ L\ t^3,$$

where P = load (lb),
d = mean diam. (in),
t = wall thickness (in),
L = length (in),
E = Young's modulus of the steel in the ring spring.

The dimensions of the spring are 85·573 mm (3·369 in) outside diameter, 1·753 mm (0·069 in) wall thickness and 7·722 mm (0·304 in) width. The spring was turned from welded tube of 316-grade stainless steel.

The instrument gives a linear response with load to within ±0·5%, which is equal to the sensitivity of the transducer. The output is fed to a pen recorder and by selecting suitable sensitivities of the recorder, usable ranges between 0 and 100 g (0 and 0·22 lb) and 0 and 2·5 kg (0 and 5·512 lb) may be obtained.

A typical trace from the recorder is shown in Figure 4 for puncturing a sultana. The first peak is formed as the pin punctures the top skin of the sultana. The load is reduced as the pin enters the flesh of the fruit with a final peak as the bottom skin is punctured. A small reverse peak occurs as the needle is withdrawn from the sample.

Reference

Mitchell, R. S., Casimir, D. J. and Lynch, L. J. (1961). The maturometer—instrumental test and redesign. *Fd Technol.* **15**, 415–8.

Specialist courses for the food industry

The course on Sensory Evaluation of Food and Beverages, held at FRL on 16–18 October 1973 and organized jointly by the AIFST Food and Beverage Group and the Division, was fully subscribed, and was judged to have been successful. Some of the lectures will be published in the *Quarterly*, and the course will probably be repeated in about a year.

The next course will be a seminar on Gouda cheese, to be held at DRL on 3 May 1974; the proceedings will be published. Then, during the week commencing 8 July 1974, No. 6 in the series, entitled 'Methods for the detection of food-borne micro-organisms of public health significance', which is to be run as a joint venture with the AIFST Food Microbiology Group and the University of New South Wales, will be held at that University. Further details of this course may be obtained from the Technical Secretary, FRL.

Other courses are in the planning stage and will be announced in future issues of the *Quarterly*.

News from the Division

Appointments

Since the last issue of the *Quarterly* went to press, the Division has made a number of professional appointments:

Research Scientists. Dr A. Lane to FRL's Microbiology Section, to initiate microbiological research on waste disposal in food processing plants. The wastes include whey, abattoir wastes and wastes from fruit- and vegetable-processing plants. The production of marketable by-products from the disposal processes will be an important aspect of Dr Lane's research. Dr N. L. R. King to MRL, to study physico-chemical interactions between muscle proteins and proteins derived from plant sources. Dr R. R. Hull to DRL, to investigate (with Dr J. Czulak) the replication of bacteriophages, particularly those associated with the lactic bacteria used as starter organisms in the manufacture of cheese.

Experimental Officers. Mr S. C. Marshall to DRL, to carry out experimental work on the development of a range of whey products. Miss B. J. Hitchener to MRL, to participate in a research program on the properties of the component layers of the bacterial cell envelope and their relationship to the growth and survival of the cell under various environmental conditions.

In addition, Dr Mogens Jakobsen of the Technical University of Denmark, who had been attached to FRL's Microbiology Section as a Visiting Scientist, was granted a short-term CSIRO appointment to enable him to conduct a series of germination experiments in foods, as part of an investigation on the effect of water activity on bacterial spore germination, outgrowth and sporulation.

Transfers

Dr E. H. Ramshaw transferred from DRL to FRL for about a year, to carry out headspace studies of volatiles of cooked vegetables.

Mrs Sue M. Collins transferred from the CSIRO Division of Building Research to take the place of Mrs J. Restarick as DRL's Librarian.

Visiting workers

Among overseas workers to receive training in the Division over an extended period were two Colombo Plan Fellows from Indonesia: Mr D. Sembel obtained a B.Agr.Sc. degree from the University of Tasmania and then received training in various aspects of food microbiology at FRL; Mr Endang Rosadi is currently attached to FRL's Food Chemistry Section to gain experience of instrumental techniques as applied to analyses of foods.

Mr A. Shakoor, Colombo Plan Fellow from Pakistan, having completed a post-graduate course in Food Technology at the University of New South Wales, is now receiving training in the dehydration of vegetables at FRL.

PPU was host to Dr J. S. Knypl of the University of Lodz in Poland, who examined the interaction of potassium and cytokinin levels of polyribosome content in cucumber cotyledons.

Work overseas

Dr J. H. B. Christian, Associate Chief, returned recently from London after a 15-month study of developments in microbiological food standards. During this period he served as Liaison Officer for the International Commission on Microbiological Specifications for Foods. The aims and activities of this Commission are outlined elsewhere in this issue.

Dr F. H. Grau of MRL is spending about six months at the Roche Institute of Molecular Biology in Nutley, N.J., U.S.A., and will visit research centres in Canada and New Zealand before returning to Cannon Hill.

General

Mr M. V. Tracey, Chief of the Division, has become a member of a committee created to advise the CSIRO Executive, through its Programme Committee, on research into human nutrition.

The CSIRO Film Unit, in collaboration with the Division and State Departments of Agriculture, has produced a new 16-mm colour film on the post-harvest treatment of citrus. The film, which deals with picking, disinfestation, handling and transport of the fruit, will be available on loan or for purchase.