

CSIRO
Food Preservation
Quarterly

Volume 30 Number 2 June 1970

The Australian Prawn Industry

I. Natural resources and quality aspects of whole cooked fresh prawns and frozen prawn meat

By W. A. Montgomery, G. S. Sidhu, and Gwenda L. Vale

Division of Food Preservation, CSIRO, Ryde, N.S.W.

The Australian prawn industry has a growth rate exceeding that of any other primary industry in the Commonwealth, having increased production by 150% over the last four years. Most of this expansion is based on the resources of the Gulf of Carpentaria and the north coast of Western Australia.

As little is known of population size and effect of fishing intensity in the Gulf of Carpentaria and along the Western Australian coast, the State and Commonwealth Governments, aware of the danger of depletion, have combined in an exploratory programme designed to gain a greater understanding of such factors. Although a modest start has been made in artificial prawn culture, more establishments are needed to stabilize fluctuating yields and establish the industry on a sounder basis.

Demand has led to a considerable increase in the importation of canned and frozen prawn products. Inspection systems and quality assurance in imported frozen and locally produced prawns are discussed here in relation to quality and health aspects.

Present Production and Utilization

Australia's catch of prawns, or shrimp (the terms may in this context be regarded as synonymous), was 20 million pounds for the year ending June 1968, or 1.5% of the world catch.

The Australian catch consists largely of the Penaeidae family of prawn, common in tropical to temperate waters. In contrast, the Pandalidae family (e.g. *Pandalus borealis*) is the main type caught in the Northern Hemisphere. The large white-fleshed banana prawn (*Penaeus merguensis*) forms 15% of the total Australian catch. Less important are the western king prawn (*P. latissulcatus*), tiger prawn (*P. esculentus*), eastern king prawn (*P. plebejus*), endeavour prawn (*Metapenaeus endeavouri*), school prawn (*M. macleayi*), greentail prawn (*M. bennettiae*, formerly known as *M. mastersii*), and rainbow prawn (*Parapenaeopsis sculptilis*).

Characteristics

Most Australian prawns vary from 7 to 45 g ($\frac{1}{4}$ to $1\frac{1}{2}$ oz) in weight and from $1\frac{1}{2}$ to 8 in. in length; the number per pound ranges from 10 to 75. Size grades and tolerances for prawns have been designated in a draft standard (Department of Primary Industry, Australia 1969).

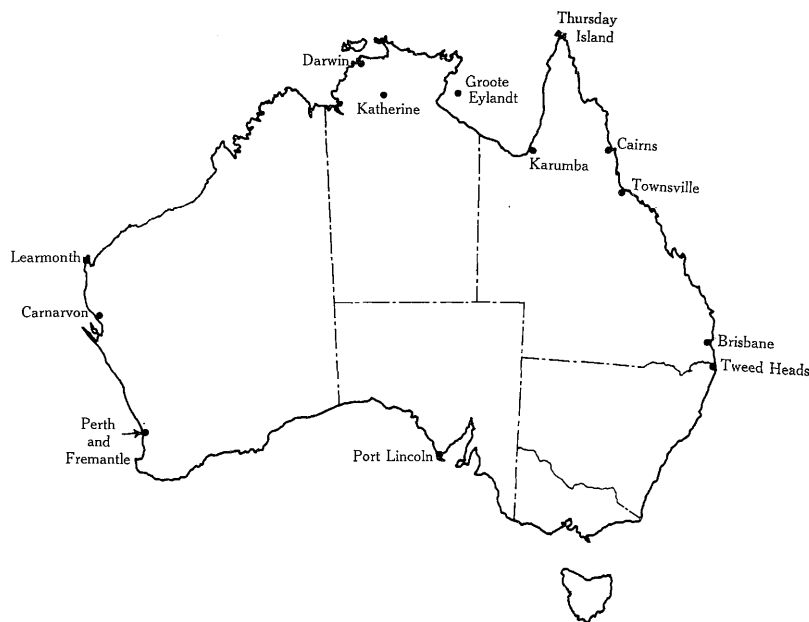
The flesh of the Australian varieties is white with a firm but not tough texture. The green pigment, astaxanthin or astaxanthin-ester pigment, situated in the hypodermis or inner soft skin of the raw prawn, turns deep red on cooking. The shell is mostly transparent and unpigmented. The flesh of the cooked tiger prawn has a slight pink colour, somewhat similar to that of the pink shrimp found in temperate waters of the Northern Hemisphere and in the Gulf of Mexico.

The odour, flavour, and textural characteristics of properly processed Australian prawns are excellent and conform to the requirements of customer countries described in their standards for import (United States Federal Specifications 1955, 1965; Japan Marine Products Importers Association 1968). International standards for canned and quick-frozen prawns in various styles of presentation are being formulated (United Nations Codex Alimentarius Commission, Food Standards Programme 1969). All these standards specify appearance, colour, drained weight, and additives and also include other qualities relating to the workmanship in the finished pack. The price received for export prawns of good quality is related to their size; \$1.60 per pound is an average price for prawns grading 10–15 per pound.

Iodoform Taint

In common with prawns or shrimps caught throughout the world an iodoform or iodine-like taint has been detected in Australian prawns. The taint, when present, is detectable in the cooked flesh. If the prawns are strongly tainted the odour can be detected in the fresh, uncooked flesh.

Territory; Victoria and Tasmania do not possess resources of prawns. South Australia has recently become an exporter of prawns of the Western Australian king prawn variety (*Penaeus latisulcatus*), since the discovery of considerable resources in the Spencer Gulf and Gulf St. Vincent areas. The major fishery, however, is along the east coast from



Location of Australian prawn processing plants.

The taint has been found only in the endeavour species of prawn by some processors, particularly in Western Australia, and for this reason *Metapenaeus endeavouri* was utilized for bait. However, many varieties from different areas have exhibited iodoform odour and considerable loss would be caused if this species, comprising 1.6% of the 1968 catch, continued to be used for bait rather than food.

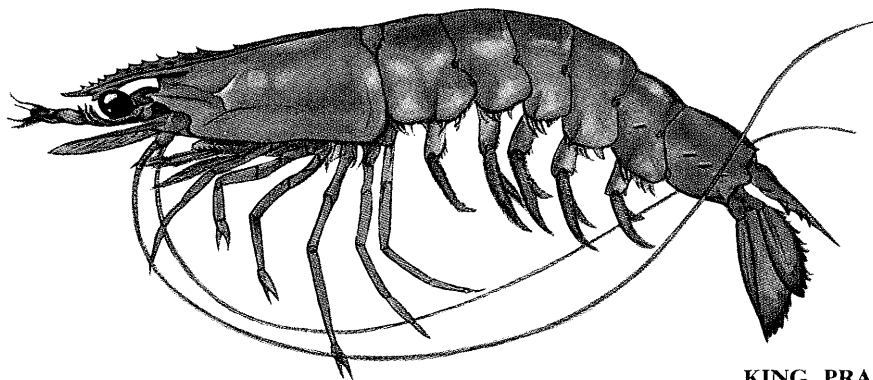
Prawns intended for export are not rejected if they contain iodoform taint in minor degree. According to the United Nations draft specifications mentioned previously, iodoform taint must be 'very intense' before it constitutes a defect.

Local Consumption and Exports

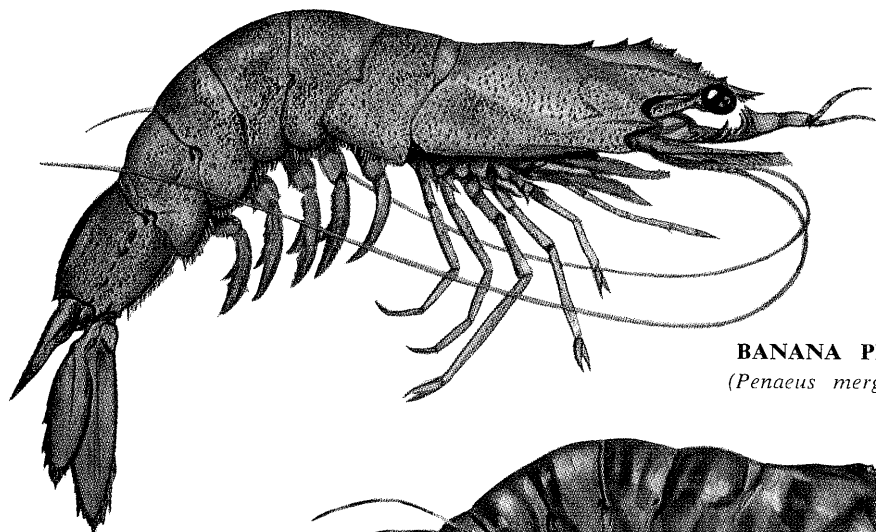
The national prawn catch now comes from New South Wales, Queensland, South Australia, Western Australia, and the Northern

Newcastle in New South Wales to Rockhampton, Qld., where the catch is marketed largely as whole cooked prawns. The largest of the Australian markets is at Sydney, where lake-caught small school and king prawns as small as 1½ in. long are sold. The exploitation of the immature prawns has not been considered to be detrimental. Larger king prawns, up to 8 in. long, caught by off-shore trawling operations, are also retailed as the cooked product.

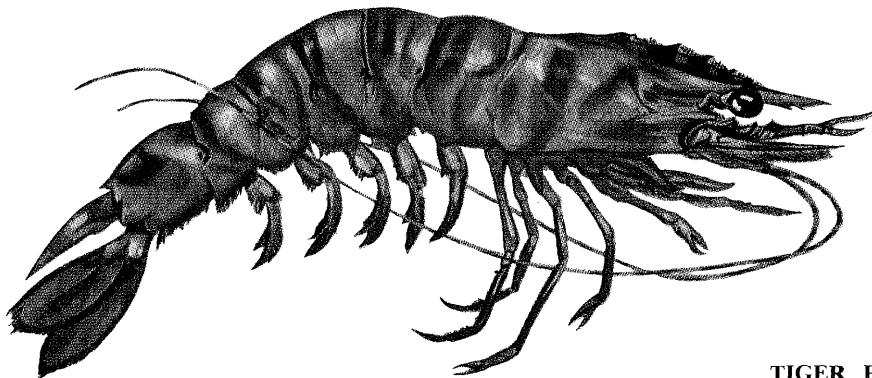
Australian consumption of prawns in 1968 was 15 million lb, most of which was marketed in the loose, cooked form preserved in ice. The prawns are customarily retailed whole because the few hours on board the fishing-boats before cooking do not cause the development of black spot or melanosis. The enzyme polyphenol oxidase, confined mostly to the blood vessels in the cephalothorax (head) and responsible for producing black



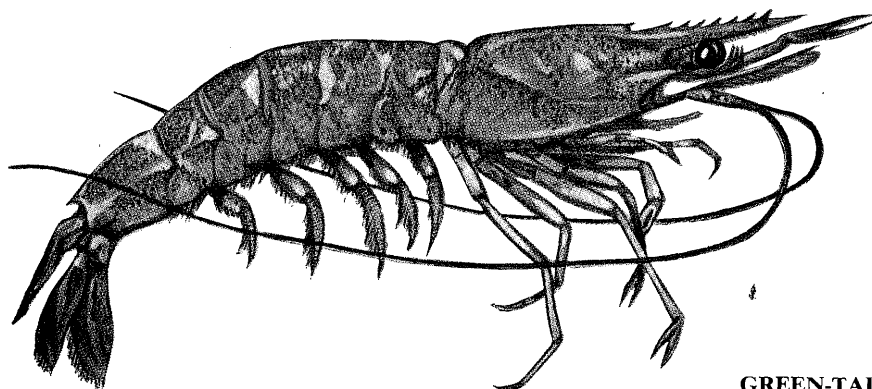
KING PRAWN
(*Penaeus plebejus*)



BANANA PRAWN
(*Penaeus merguensis*)



TIGER PRAWN
(*Penaeus esculentus*)



GREEN-TAIL PRAWN
(*Metapenaeus mastersii*)

discolorations on head, shell, and legs, is inactivated by heat and melanosis does not develop in cooked prawns. In most instances the prawns are cooked at sea or, where the catch comes from estuaries or lakes, at a nearby shore plant. The use of ice containing sodium bisulphite reduces melanosis in uncooked prawn tails; this method of storage is used in some foreign countries. Western Australian fishery regulations, and the Commonwealth Fish (Exports) Regulations, unlike those of other States, prohibit heading at sea, so that headed prawns should not be processed for export. The aim of this legislation is to reduce the uptake of salt from the refrigerated sea-water solutions in which the prawns are held during transport; headed prawns take up more salt than whole prawns under these conditions.

In the 10 months ended April 1969 4.6 million lb of prawns were exported, of which 1.6 million lb went to North America and 1.5 million lb to Japan. The main export production came from Queensland (2.8 million lb) and Western Australia (1.1 million lb) with similar amounts from New South Wales, Northern Territory, and South Australia. The northern States exported prawns of mixed species but the Western Australian export pack consisted almost exclusively of the western king prawn.

Because of their large size and suitability for conversion to 'fantails', a precooked product, most Australian prawns are exported in the raw frozen headless form. The prawns are 'de-veined' (i.e. the intestine is removed during the heading operation) and packed in layers in 5-lb blocks. The blocks are glazed with potable water, and quick-frozen, usually in plate freezers. When stored at or below 0°F deterioration in quality after 180 days is slight. Cooked prawns frozen and stored under similar conditions remain in acceptable condition for approximately 60 days. There is considerable market potential for frozen prawns averaging 40 or more per lb which are cooked and peeled (and preferably de-veined) before freezing. The most convenient form is as individually quick-frozen prawns. Small prawns are also sometimes used for canning and for freeze-dried products.

Production Potential and Development

In 1965 the Food and Agriculture Organization of the United Nations in the Indicative

World Plan stated that world production of shrimp would increase from 0.6 to 1.1 million tons (Hjul 1969) over the ensuing 10 years; Australia's 1965 catch of 13.4 million lb has expanded by a factor of 1.5 up to 1969 and may therefore follow the increase predicted by FAO. The increase in Australia's catch came largely from the 90,000 sq mile area of shallow water of the Gulf of Carpentaria. A preliminary survey of 10,000 sq miles of the south-east portion of the gulf from Mornington Island eastward was made by CSIRO scientists in 1964-66. Considerable resources of banana, tiger, western king, and endeavour prawns were discovered in areas suitable for trawling operations. The survey report described the peculiar 'boiling' or schooling characteristics of the banana prawn (Leyendekkers 1965) which made them particularly susceptible to heavy exploitation.

At present 200 trawlers of Australian or joint-venture (with Japan) ownership and several factory ships are fishing this region. Estimates of the Gulf prawn fishery potential are generally in excess of 25 million lb annually.

The Gulf prawn fisheries have expanded beyond the Gulf to include the entire continental shelf from the mainland to New Guinea and West Irian and in the Gulf of Papua. The discovery of new areas for exploitation will depend on the results of a major survey of the resources to be made by CSIRO Division of Fisheries and Oceanography. It is hoped that the survey will locate areas, similar to the Karumba concentrations found five years ago, where large concentrations of prawns may be easily caught.

Banana prawn and other fish are now extinct in some areas on the Australian coast, which has been attributed to over-fishing or disturbance of the natural habitat. In this context Western Australia's conservation programme regulating the exploitation of its crustacea is a model which might be followed by other States.

Prawn Culture

Scientific studies have been made of the feasibility of culture techniques for the propagation of white, red, and brown varieties of shrimp at Miami, Florida, and Galveston, Texas, in the U.S.A. Other countries have culture farms in operation: Japan has

achieved a 500% increase in commercial prawn production over the last 5 years while Sabah and India have shrimp culture farms yielding up to 800 lb to the acre annually. The N.S.W. State fisheries have commenced an experimental programme of prawn culture at Port Stephens; the project will concentrate on the rearing of prawns from the post-larval stage. However, the many river systems and swamplands surrounding the Gulf of Carpentaria, a habitat which is less likely to be polluted by industrial waste, would provide ideal sites for the establishment of commercial prawn culture.

Quality

Prawns are mainly consumed in the fresh whole cooked form, but imported frozen cooked prawn meats are becoming increasingly important. Quality in the former was once a considerable problem for the processor and consumer (Empey 1954), but improved processing methods have corrected this. Problems relating to quality in the imported product have led to the introduction of specific quality assurance tests (Anon. 1965; National Health and Medical Research Council, Australia 1967).

Locally Produced Prawns

Quality assurance in Australia is maintained by two complementary systems of inspection and analysis; qualified inspectors of the State governments operate at the markets and an analytical and testing facility is supplied by the State Health Department authority. The inspectors have recourse to the Health Department authority to confirm their sensory assessment in cases of doubt.

In most instances local prawns are held in ice on board the trawler for 12 hr after catching. Sixty pounds of crushed ice is usually sufficient to keep 50 lb of prawns at ice temperature during transport in the summer.

Standard plate counts of bacteria in the freshly landed prawns are usually within the range of 50,000 to 80,000 organisms per gramme. The organisms are mainly common soil and water types. Temperatures of iced prawns at landing can range between -2°C and $+5^{\circ}\text{C}$ if held under satisfactory icing conditions. After cooking in vigorously boiling water the count is reduced to below 200/g of sporulating types.

Bacterial counts on cooked iced prawns sold at the Sydney Fish Market have, over a

6-month period of observation during 1959, shown a variation of from 10^4 to 10^5 organisms per gramme and there were no instances of counts less than 10^4 organisms per gramme. The prawns reaching this market had been held from 3 to 8 days in ice. Shipments of prawns in which bacterial counts were in excess of $1 \times 10^6/\text{g}$ were invariably condemned as unfit for human consumption by the market inspectors using sensory evaluation techniques. Moreover the inspectors' assessment of quality always corresponded with tests based on bacterial counts and volatile base content. Condemned prawns had bacterial counts ranging from 2.2×10^6 to $1.6 \times 10^7/\text{g}$. The majority of the organisms present were psychrophilic, 70 to 90% growing at 5°C after 5 to 10 days, or at 1°C after 10 to 20 days. Scott (unpublished report 1948) investigated the bacteriological quality of raw and cooked prawns from the Sydney Fish Market. He found bacterial counts in accordance with those recorded above. The counts varied from 1.5×10^4 to $1.7 \times 10^6/\text{g}$ with most about $5 \times 10^5/\text{g}$. The bacterial counts on two samples of cooked prawns purchased from shops were 3.5×10^6 and 6×10^6 organisms per gramme.

The pH value of freshly landed prawns, handled under optimum conditions and not more than 12 hours old, is in the range 7.2 to 7.4, most measurements being pH 7.25. For ice-stored shrimp, Bailey, Fieger, and Novak (1956) considered a value of 7.7 or below indicated prime quality, 7.7 to 7.95 poor but acceptable quality, and 7.95 or above indicated spoilage.

Operation of the Inspection System

The fish inspection systems of the individual Australian States are based on the suitability of the fish for human consumption; they do not attempt to grade prawns or fish by quality, but merely impose a cut-off point at which the material is considered inedible. Acceptability is assessed on the basis of sensory tests made by the States' fishery inspectors at the principal fish market or at fishermen's cooperatives which are licensed to sell to the public. Tasting tests, except in special cases, are not used for assessing prawn quality, the judgment being made on the odour. For example, the presence of ammonia or putrid odour is sufficient cause for condemnation. In 1954 condemnations of

prawns in New South Wales comprised 10% of the shipments (Empey 1954); today condemnations are rare because of improved processing and storage.

Objective Testing Procedures.—Objective tests are used where

- disputes arise or litigation occurs over insurance claims for defective shipments of imported fish and crustacea;

- organoleptic procedures are unsuitable due to aesthetic or health reasons;

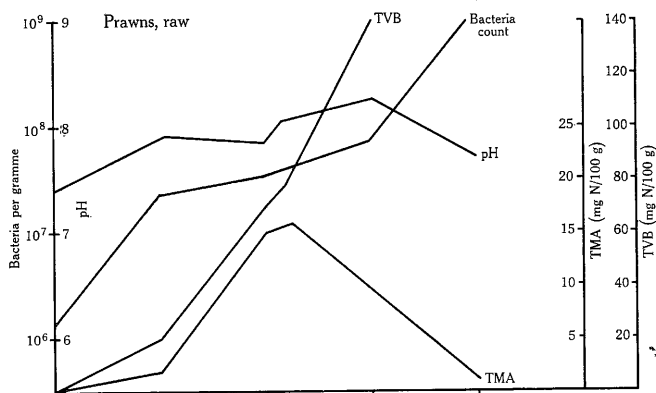
- tests are necessary for the presence of coagulase-positive staphylococci, salmonellae, and *Escherichia coli*.

Laboratory tests of spoiled fishery products have indicated the usefulness of the trimethylamine (TMA) and total volatile base (TVB) measurements and the bacterial count as objective quality control methods. Total volatile base is particularly useful for spoilage measurement in prawns; other objective tests have been proposed (Bailey, Fieger, and Novak 1956; Iyer, Choudhuri, and Pillai 1969).

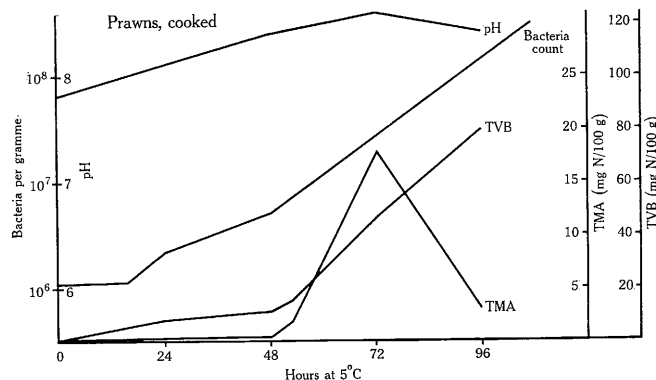
The limit for acceptability used in some sectors of the Australian marketing system is 5 mg TMA nitrogen and/or 30 mg of TVB nitrogen per 100 g of fish or shellfish or crustacean muscle. These limitations are applied to local and imported products where questions of quality are concerned. The specification for TVB nitrogen is the same as that applied to frozen prawns imported into Japan (Japan Marine Products Importers Association 1968). The Japanese standard also imposes the restrictions of standard plate count 100,000 organisms per gramme and *E. coli* count nil per 100 g, using the most probable number technique (MPN).

A sample of prawns for export from a newly established processing plant at the Gulf of Carpentaria when tested for conformity gave the following results:

- Total plate count at 37.2°C: 4050/g.
- *E. coli* (MPN): nil per 100 g.
- TMA: nil (by microdiffusion technique).
- TVB: below 7 mg N/100 g.



Bacteria counts, TVB, TMA, and pH for raw and cooked prawns.



Imported Cooked Frozen Prawn Meats

In addition to microbiological limitations, specifications adopted by the National Health and Medical Research Council for precooked prawns also limit food-poisoning organisms of the salmonella and shigella types (National Health and Medical Research Council, Australia 1967). (For virus infections cooking periods are specified for fish fingers containing milk solids to prevent the transmission of foot and mouth disease.) These specifications have been incorporated in the States' Pure Food Acts; the New South Wales Act (Anon. 1965) for Penaeidae or Palmonidae prawns gives the following limits:

- Total plate count at 37°C not to exceed 500,000 organisms per gramme.
- *E. coli* (faecal type) not to exceed 20/g.
- Coagulase-positive staphylococci not to exceed 100/g.
- Salmonella and other pathogenic organisms absent.

Consultant testing laboratories carry out analytical tests on imported products when required, and State Health Departments routinely test all shipments. Imports of frozen cooked prawns into Australia have increased from 370,000 lb for the 10 months ending April 1968 to 796,000 lb for the corresponding period in 1969. Samples are taken for analysis where questions of quality in these imports have arisen, or in the absence of a certificate of compliance with the States' Pure Food Acts. The samples are subjected to the objective testing procedure outlined. Two examples from an analysis of frozen prawn samples ((a) and (b)) follow; they indicate that an unacceptable level of microbial spoilage has been reached.

- TVB sample: (a) 47 mg N/100 g
(b) 51 mg N/100 g
 - Total plate count at 37°C:
(a) 78×10^6 orgs/g
(b) 56×10^6 orgs/g
 - Faecal *E. coli*: (a) more than 160
(b) more than 160
 - Coagulase-positive staphylococci:
(a) less than 10/g
(b) 120,000/g
 - Salmonella: (a) and (b) absent in 25 g
 - Shigella: (a) and (b) absent in 25 g
- Odour assessment on the samples indicated the presence of ammonia.

Conclusion

Before the introduction of the N.S.W. Act regulating the quality of prawn imports, a voluntary code of compliance was introduced by agreement between importers and the Department of Health. The code worked well in practice; it contained the quality provisions set out above and effectively ensured that health requirements were being met. In general, the quantity of imported prawns rejected on the grounds of spoilage has been very low in relation to the quantity imported; in some instances reprocessing of prawns has enabled requirements to be met.

References

- ANON. (1965).—New South Wales Laws, Statutes, etc. Pure Food Act No. 31, 1908, as amended, and regulations thereunder. Rev. Ed. p. 34. (Govt. Printer: Sydney.)
- BAILEY, M. E., FIEGER, E. A., and NOVAK, A. F. (1956).—Objective tests applicable to quality studies of ice stored shrimp. *Fd Res.* **21**, 611–20.
- DEPARTMENT OF PRIMARY INDUSTRY, AUSTRALIA (1969).—Draft standard for export frozen uncooked (green) shrimp.
- EMPEY, W. A. (1954).—Report on handling of prawns. *Fish. Newsl.* **13**(11), 5, 7, 23.
- HJUL, P. (1969).—FAO predicts 100 m. ton world catch by 1985. *Fishg News int.* **8**(6), 26–8, 30, 54.
- IYER, T. S. G., CHOUDHURI, D. R., and PILLAI, V. K. (1969).—Bacterial aspects of frozen prawn products and their significance in quality evaluation. FAO Tech. Conf. on Fish Inspection and Quality Control, Halifax, Canada, July 1969. Tech. pap. FIC/69/0/56.
- JAPAN MARINE PRODUCTS IMPORTERS ASSOCIATION (1968).—The standard for shrimps (prawns) imported to Japan.
- LEYENDEKKERS, JEAN V. (1965).—Gulf prawn survey. *Aust. Fish. Newsl.* **24**(3), 15, 17.
- NATIONAL HEALTH AND MEDICAL RESEARCH COUNCIL, AUSTRALIA (1967).—Report, 64th session. p. 25. (Govt. Printer: Canberra.)
- UNITED NATIONS CODEX ALIMENTARIUS COMMISSION, FOOD STANDARDS PROGRAMME (1969).—Summary of comments on the draft standard for canned shrimp and prawns. Agenda item 8 (iii) Codex/Fish/8/6.
- UNITED STATES FEDERAL SPECIFICATIONS (1955).—PP-S-316a. Shrimp, raw and cooked; chilled and frozen (June 20).
- UNITED STATES FEDERAL SPECIFICATIONS (1965).—PP-S-316b. Shrimp, raw and cooked; chilled and frozen. Interim revision (April 19).

Comminuted Fruit Drinks from Australian Citrus

By D. J. Casimir and B. V. Chandler

Division of Food Preservation, CSIRO, Ryde, N.S.W.

In the past few years, Australian processors have shown an increasing interest in comminuted citrus products, which have been a feature of the fruit beverage industry for several decades overseas, particularly in Britain (Charley 1963). Whereas conventional citrus beverages use only the juice fraction of the fruit (approximately 50% for oranges) with the addition of sugar, citric acid, colourings, and flavourings, comminuted citrus products utilize a higher total proportion of the fruit by combining various fruit fractions and extracts, not always including the juice, in the formulation of the drink.

Attention is again being given to this type of product in the U.S.A. (Lawler 1969), where it first originated 30 years ago but received no significant consumer acceptance.

In addition to greater utilization of fruit and less waste in processing, there are advantages to including components other than the juice in the preparation of citrus beverages which depend upon the following facts (Kefford 1959; Kefford and Chandler 1970):

- Citrus peels contain about three-quarters of the total ascorbic acid content of the fruit.
- The essential oils of citrus which are responsible for their typical aromatic flavour are mainly located in the oil sacs on the outer peel (flavedo).
- The flavedo also contains a considerable proportion of the natural pigments of the fruit.
- The albedo (white) fraction is high in pectinous materials which increase viscosity and stabilize cloud in prepared beverages.
- The peel fraction contains natural antioxidants which protect ascorbic acid against metal-catalysed degradation and oil constituents against oxidation to products that cause 'terpene' off-flavours.

Two main types of comminuted products are recognized, obtained by two different processes, both aimed at the optimum utilization of the entire fruit in the preparation of the drink; however, in only one of these processes is the fruit actually comminuted.

Procedures Developed Overseas

Preparations Based on Syrup Infusions of Citrus Peel and Pulp

The product that first introduced so-called comminuted drinks to the British public on a large scale incorporated the flavouring constituents of the orange without comminution. The process was based on the U.S. Freshway procedure patented in 1937, details of which were unavailable for 22 years (Anon. 1959). Whole oranges were immersed in water at just below boiling point to clean them and facilitate subsequent oil extraction. The sliced fruit was then thoroughly mixed with warm sugar syrup to extract the soluble constituents from the pulp and peel which were then discarded. Because the whole fruit was utilized in this process, the product was referred to as 'comminuted' and the final made-up beverage was called 'whole orange drink', as distinct from normal products based on extracted juice and added flavouring. More recently a similar process was patented using hot water instead of syrup (Pan-Citrus Corp. 1961).

Improvements were made on the syrup infusion process (Northern Dairy Engineers 1955a, 1955b, 1958) and the final procedure was described (Anon. 1958) about a year before information became available on the Freshway method. In the later process, the halved oranges were fed between rollers so that the flat side of the halves faced a coarse-toothed high-speed reaming roller, while the

convex or skin side faced a slow-speed, fine-toothed puncturing roller. While passing between these rollers the skin was split and flattened but remained in one piece; the white albedo was left substantially undisturbed and sugar syrup was continuously circulated over the fruit parts to absorb the flavouring oils immediately they were released from the skin. The coarse solids were then screened out to produce from 55 lb of fresh oranges 100 gal/hr of normal ready-to-drink 'squash' or 50 gal/hr of concentrated product for subsequent dilution.

Products Based on Comminution of Whole Fruit or Fruit Parts

In the beverages described above, the amount of flavedo and albedo incorporated into the product depended upon the size of the perforations in the screen which separated the solid fruit particles from the syrup. In the true comminuted product the finely ground albedo and flavedo are incorporated in the syrup base in quantities sufficient to release the optimum amount of flavouring and colouring constituents into the product. In this way, by judicious blending of albedo, flavedo, and juice fractions, most of the natural oils and pigments of the fruit can be utilized in the preparation of citrus drinks, thus avoiding the addition of flavouring and colouring agents.

Whole Fruit.—Comminuted citrus products, obtained by use of Reitz RD-8 disintegrators, were available in the U.S.A. as early as 1939 but since the entire fruit was ground under this process the prepared drink had unacceptable levels of bitterness and other off-flavours. An acceptable product resulted, however, if the disintegrated mass was strained through a coarse sieve or if a controlled secondary discharge from the Reitz mill was used to separate the rag and seed fractions which are the principal source of these undesirable flavours. The incorporation of some albedo into the product by comminution was claimed to result in enhanced flavour, superior even to that obtained by reaming the halved fruit. This operation was employed in an orange comminution plant (Scott and Son (London) Ltd. 1960) which continuously converted 1.5 tons of whole oranges per hour into beverage base in one step. In this process whole oranges were fed into a pre-breaker feeder which crushed the fruit before it went into a 20-hp

disintegrator. Sugar syrup was circulated continuously to 'seal in flavour and prevent oxidation'.

A novel procedure for converting the whole orange into a comminuted product was described by Braverman and Levi (1960). The process consisted essentially of heating the whole fruit in a conical stainless steel pressure cooker provided with a blow-out valve at the base. When the contents of the cooker reached the required temperature, they were removed by rapidly opening the blow-out valve. All cells in the fruit then burst, resulting in complete disintegration of the tissue, with simultaneous sterilization of the product and inactivation of the pectic enzymes. Unwanted fractions such as seeds were removed by passage through a finisher before the comminuted product was ground to a smooth consistency in a colloid mill.

In another procedure (Gluckstein and Money 1962; Lyons and Co. Ltd. 1963, 1965), the fruit was sliced and heated to release the flavouring components from the juice sacs and oil cells, and to inactivate, at least partially, the pectic enzymes. The material was then subjected to gradually increasing pressure to separate the liquid phase, which gave the beverage base on addition of syrup. It was claimed that the process could be made substantially continuous on an industrial scale. Similar laboratory procedures were recently reported by Indian workers (Rao *et al.* 1969) to give satisfactory beverage bases from both oranges and mandarins.

Fruit Parts.—The quality of many of the products described above was unsatisfactory, due to the inclusion of undesirable amounts of objectionable components when all the available albedo was incorporated; and, moreover, high-quality products were more expensive than conventional beverages. Consequently, market acceptance of the 'whole orange' drink was not good and in a review in 1960 on the utilization of citrus fruits, only a brief passing reference was made to comminuted beverages (Smith and Kay 1960).

The exclusion of unwanted albedo components from the beverage, with the inclusion of desirable flavouring constituents, was the aim of a process which separated the liquid and solid fractions of the comminuted whole orange after a certain time (Groves and White 1961). Most methods of overcoming this problem, however, have involved the incor-

poration of adjustable amounts of comminuted flavedo and albedo into the beverage base. In one such procedure (Anon. 1962) the outer peels were removed from the orange by four vertical knives and the remainder was pulped to provide the base in which was incorporated the required amount of comminuted peel.

A recent commercial method for utilizing the oil content of the fruit directly in comminuted products involves setting up the FMC In-line extractor so that orange juice is sprayed through the inlets used during oil extraction operations to spray water onto the fruit while it is being extracted. Small chips of albedo and flavedo, broken from the orange during extraction, are rinsed down with the oil and give desired body and colour to the comminuted product obtained by direct milling of these 'wash-waters'. Some adjustment of the various ingredients is required to meet standard specifications, but the procedure is cheap in operation and finds considerable application in Mediterranean plants.

Because the most desirable flavouring constituents of the orange are contained in the oil sacs of the flavedo, and the least desirable in the albedo, the most satisfactory comminuted products are obtained when these two fractions are added in controlled amounts to the beverage base. Machines are available for efficiently separating the flavedo from the albedo in paper-thin strips so that both fractions can then be comminuted for incorporation into the product in the desired ratio. In this way all the oil in the fruit can be utilized with the incorporation of just enough albedo to give the beverage body (Charley 1963).

Final Treatments

Beverage bases made from comminuted oranges or orange parts must be thoroughly milled, and suitable equipment for this purpose has been reviewed by Charley (1963). To be satisfactory, milling must reduce the components of the base to a fine state of subdivision so that oil and solid phases are held in continued suspension during storage and dilution, and no particles remain large enough to interfere with the 'mouth-feel' of the product. Fragments of juice sacs, considered by some consumers to enhance the appearance of the final drink, may be added after the base is milled.

After milling, the product is usually pasteurized at 195–198°F for 15–30 sec, a slightly more severe heat treatment than normally given to citrus juices, to inactivate the higher levels of pectin esterase present. When the product has been pasteurized during preparation, this step is unnecessary if it is to be preserved chemically with benzoic acid and/or sulphur dioxide. On leaving the pasteurizer the product is filled hot into cans and cooled rapidly to room temperature; alternatively, chemical preservatives may be added at this stage. Freeze drying offers another means of preserving comminuted citrus products, and some preliminary studies in this field have been reported (Tomas *et al.* 1969).

Factors to be considered in the formulation of products from comminuted citrus bases have been reviewed by Charley (1963) and Rao *et al.* (1969). Since it is difficult to assess the actual fruit content of comminuted citrus drinks, they present problems in the setting up of government regulations controlling their quality; suitable standard specifications have been suggested in discussions of this subject by Charley (1963, 1964), Benk (1963), and Rao *et al.* (1969).

Formulations for Australian Processors

Since the production of comminuted citrus beverages depends on the incorporation of desirable flavouring and colouring constituents present in the flavedo of the fruit into the syrup base, and since the amounts of these constituents vary with source of the fruit, it is desirable that formulations for such products be based on the quality of local fruit and not derived simply from formulations evolved in other countries. For example, oranges from Israel generally have thinner skins than Australian oranges, with a higher proportion of flavedo to albedo. Thus, the practice in Israel of using all the peel in the preparation of comminuted drinks is unlikely to be satisfactory under Australian conditions. Again, the skin colour of Australian oranges generally is inferior to that of Mediterranean fruit, with regreening a particular problem in Valencias. Since the use of oranges lacking natural colour or showing regreening would result in comminuted products of inferior colour, local processors will have to take more care in the selection of fruit and pay more attention to colour in the formulation

of the product than do processors using Mediterranean oranges. We, therefore, undertook to develop formulations for comminuted citrus products that are applicable to Australian fruit.

Production of Fruit Fractions

The fruit was washed in a rotary reel washer fitted with high-pressure water jets, and passed over an inspection belt where fruit with skin blemish or poor colour was rejected. No attempt was made to ensure calyx removal.

The following fractions were collected:

- Juice fraction.—Both FMC Model 63 (0.040 in. perforations in straining tube) and Brown 401 citrus extractors were used. The juice was passed through an 18-in. Kason gyratory separator fitted with a 9508-30M-0203-0128W screen with 37.1% open area. In the case of juice from the FMC extractor, the pulpy material held in the screen was retained to become the cell fraction. No water sprays for oil recovery were fitted to the FMC extractor.

- Peel fraction.—The peel residues discharged from the cups of the FMC extractor were collected to provide the peel fraction. The rag, seeds, and plug extruded from the cutting and straining tubes were discarded.

- Flavedo fraction.—The spent peels discharged from the Brown extractor were fed into a Brown citrus shaver where the flavedo layer was shaved off; the thickness of these shavings could be adjusted to vary the ratio of albedo to flavedo, but in the present work a standard thickness of $\frac{1}{8}$ in. was used. The albedo and rag residues were discarded.

- Cell fraction.—The pulpy material removed by screening the juice extracted with the FMC machine was retained as the cell fraction. The solids screened from the juice obtained with the Brown extractor, mostly rag and seeds, were not used in these formulations. The cell fraction could be stored for subsequent use by heating to a temperature of 195–198°F in a CT-1B Centritherm evaporator operated at atmospheric pressure before hot filling into A10 cans; the cans were closed, inverted, water cooled, and stored at 40°F.

Production of Comminuted Material

The amounts of the solid fractions required by the formulations were fed at a constant rate to a Fitzpatrick Model D comminuter fitted with a $\frac{1}{4}$ -in. screen; the required amounts of juice and water were simultaneously metered in with the solids, and the feed rates were adjusted to give an output of 21 lb of blend per min.

The disintegrated material was fed into an HLM/R-I-SUP Fryma colloid mill, fitted with a stationary upper disk of 46 grit carborundum, and a lower disk of 36 grit carborundum rotated at 3000 r.p.m. by a 60-hp motor. The clearance between these disks was reduced, at first fairly quickly but finally cautiously, until a sample of the discharge placed between a glass plate and a white tile showed no visible particles when examined by eye; the discharge prior to this stage was either discarded or returned to the feed tank. Unless care was taken in the adjustment of this clearance, the product would have to be milled again to obtain the required particle size. Some adjustment in setting was necessary during a long run as a result of changes in dimension as the machine heated up.

The comminuted product was collected in a tank fitted with a slow-speed stirrer from which samples were taken for quality control examination. The following analyses were made: soluble solids content as °B by refractometer, titratable acidity as percentage by weight of anhydrous citric acid, and oil content as percentage by weight of limonene determined by the bromate titration method (Scott and Veldhuis 1966). Blending of batches was carried out as soon as analyses became available, to obtain products of consistent quality.

The product was pasteurized in a Centritherm CT-1B evaporator operated at atmospheric pressure heated by steam at 10 psig (approximately 240°F). The heated material was discharged at 195–200°F and filled directly into GP2 lacquered cans; the cans were closed without headspace, inverted for 1 min, and water cooled. Excellent quality was maintained during storage for two years at 40°F.

Production of Beverage Bases and Fruit Drinks

It is a common but incorrect belief that comminuted citrus products make use of any fruit, irrespective of such considerations as variety, and that all of the fruit may be con-

verted into an acceptable drink — 'whole orange drink'. As with other citrus products, however, quality considerations arise in their preparation. Thus, the albedo of Navel oranges contains appreciable amounts of the bitter principle, limonin, even at an advanced stage of maturity, and bitterness will be apparent in comminuted products using such material. This was confirmed with Navel oranges picked at the very end of the season in early December which gave a comminuted

0.6–0.7% and 0.6–0.8%, respectively; similarly formulated products from Mediterranean oranges required no such treatment. As shown in Table 1, however, incorporation of the flavedo fraction from a second batch of fruit resulted in a product of the desired colour and flavour; the amount of this fraction needed depended upon the quantity of the highly coloured and flavoured cell fraction available from the first batch of fruit. Thus, in the production of satisfactory com-

Table 1
Formulation and Quality Characteristics of Comminuted Citrus Products

	Comminuted Orange		Comminuted Lemon	
	Normal	Low Acid	Normal	Low Acid
Formulation (% wt)				
Peel fraction	18	15	26	26
Flavedo fraction	14–20	17	19.5	19.5
Cell fraction	10–4	2.5	11.5	4.5
Juice fraction	58	—	—	—
Water	—	65.5	43	50
Quality characteristics				
Soluble solids (°B)	12.5–13.5	4.5–5.5	6.0–7.0	5.0–6.0
Titrate acidity (g citric acid/100 g)	0.6–0.7	0.25–0.30	0.60–0.70	0.30–0.40
Brix : acid ratio	17.5–20.0	15.0–22.0	9.0–11.0	12.5–17.5
Oil content (g limonene/100 g)	0.6–0.8	0.6–0.8	0.08	0.05
Specific gravity	1.058–1.065	1.025	1.032	1.034

product (peel fraction 39%, cell fraction 5%, juice fraction 49%, water 7%) which was still bitter and quite unsuitable for the preparation of drinks and cordials compared with products from Valencia oranges. We could not prepare a non-bitter beverage from this fruit by varying the formulation of the comminuted product or the derived beverage base without losing orange character.

Since Valencia oranges in Australia tend to be paler in skin colour and lower in oil content than Mediterranean fruit, comminuted products from representative local fruit using only the peel, cell, and juice fractions of the one batch (peel fraction 26%, cell fraction 9%, juice fraction 65%) were lightly flavoured and required addition of acid and oil to bring their contents into the desired ranges of

minuted products from Australian oranges less than half the naturally available albedo can be used.

For the preparation of certain orange-flavoured products such as ice cream, yoghurt, and pastry mixes, a low-acid base is required. Such bases can be prepared in the same way as comminuted orange products for beverages simply by substituting water for juice in the formulations. Table 1 gives representative formulations for both types of comminuted orange products, with details of their quality characteristics.

In the preparation of comminuted lemon products the use of the highly acid juice is unnecessary and undesirable, since sufficient flavour and acid can be derived from the cell and flavedo fractions, and products of high

and low acid content can be obtained by varying the amount of cell fraction used (Table 1). For grapefruit, the presence of considerable amounts of the bitter principle, naringin, in the peel and cell fractions pro-

hibits their inclusion in any large quantity in comminuted grapefruit formulations. Satisfactory products, however, can be prepared by incorporating the flavedo fraction alone in an acidified syrup, since this part of the fruit is particularly rich in flavouring constituents.

After some initial studies, three citrus fruit drinks (orange, lemon, and orange-lemon)

Table 2
Formulation and Quality Characteristics of
Comminuted Citrus Drinks

	Orange	Lemon	Orange- Lemon
Formulation (% wt)			
Acidified syrup	92.0	94.5	94.0
Comminuted orange product	4.0	—	2.0
Frozen orange juice concentrate	4.0	—	2.0
Comminuted lemon product	—	4.0	1.5
Frozen lemon juice concentrate	—	1.5	0.5
Quality characteristics			
Soluble solids (°B)	13.0	12.0	12.5
Titrate acidity (g citric acid/100 ml)	0.50	0.67	0.55
Brix : acid ratio	26.0	17.9	22.7
pH	3.0	2.5	2.8
Vitamin C (mg ascorbic acid/100 ml)	36.4	18.2	22.7
Oil content (g limonene/100 ml)	0.0052	0.0012	0.0032
Taste panel evaluation*			
Colour			
Good	45	32	42
Satisfactory	43	49	55
Poor	12	19	3
Sweetness			
Too much	40	19	36
Just right	57	62	60
Not enough	3	19	4
Fruit flavour			
Too much	22	23	22
Just right	52	57	61
Not enough	26	20	17
Acidity			
Too much	8	26	—
Just right	59	55	81
Not enough	33	19	19

*Percentage of panel who reacted as indicated to the sample.

Table 3
Some Promising Formulations (% wt) for Other
Comminuted Citrus Products

Grapefruit drink	
4.5 comminuted grapefruit product (flavedo fraction only)	
5.0 grapefruit juice	
8.5 sugar	
1.0 citric acid	
81.0 water	
Orange cordial	
9.5 comminuted orange (normal as per Table 1)	
4.7 frozen orange juice concentrate (6-fold)	
85.8 syrup (48°B) containing 1.6% citric acid and 0.44% sodium benzoate	
Lemon cordial	
9.5 comminuted lemon (normal as per Table 1)	
4.7 frozen lemon juice concentrate (6-fold)	
85.8 syrup (48°B) containing 1.8% citric acid and 0.44% sodium benzoate	
Dried comminuted citrus powder (for ready-mixed bakery products, etc.)	
8.2 drum-dried comminuted orange or lemon (from normal comminuted products as per Table 1)	
89.1 sugar	
2.4 citric acid	
0.3 sodium benzoate	

were prepared from the comminuted 'high-acid' products, frozen juice concentrates (orange 45°B, lemon 32°B), and an 11.0° Brix syrup containing 0.3% citric acid. The comminuted material and the concentrate were first mixed with 50 lb syrup at room temperature and passed through a Model D Fitzpatrick comminuter to ensure complete blending before the remainder of the syrup was added. The product was pasteurized by heating to 186°F in a CT-1B Centritherm

evaporator operated at atmospheric pressure and then filled hot into GP2 lacquered cans; the cans were sealed, inverted for 30 sec, water cooled, and stored at room temperature. The formulations of these drinks and their quality characteristics are recorded in Table 2. Formulations for other citrus products that gave promising results in preliminary tests are recorded in Table 3.

The three canned fruit drinks (orange, lemon, and orange-lemon) were presented to a 53-member consumer panel under controlled taste test conditions; the results shown in Table 2 indicate the acceptability of the drinks as prepared according to the formulations given in Tables 1 and 2. These formulations meet the limit for fruit juice content required for sales tax rebate to Australian beverage manufacturers, but drinks containing less fruit juice could be quite acceptable in certain circumstances. Indeed, such products are accepted by consumers in Britain, where the commercial success of comminuted citrus drinks has depended, at least partly, on the fact that all fruit material (and not only juice) could be considered as 'potable fruit' in determining whether the beverage met the limits set by the food regulations. Therefore, the formulations given in this paper should not be regarded as fixed but merely as a guide to beverage manufacturers who may vary them in accordance with their own quality and price considerations.

References

- ANON. (1958).—Plant for comminuting oranges. *Perfum. essent. Oil Rec.* **49**, 96–8.
- ANON. (1959).—How Fryco's make 'Sun-fresh'. *Fd Mf.* **34**, 99–103, 120.
- ANON. (1962).—Schweppes' new factory. *Fd Mf.* **37**, 197–9, 224.
- BENK, E. (1963).—Composition, production and assessment of so-called 'whole fruit' orange juices. *Riechstoffe Arom.* **13**, 18–21. (*J. Sci. Fd Agric. Abstr.* **14** (ii), 42 (1963).)
- BRAVERMAN, J. B. S., and LEVI, A. (1960).—Comminuted orange. A novel process for its manufacture. *Fd Technol., Campaign* **14**, 106–9.
- CHARLEY, V. L. S. (1963).—Some technical aspects of British comminuted juice production. *Fd Technol., Campaign* **17**, 987–94.
- CHARLEY, V. L. S. (1964).—Observations on the production and composition of citrus comminuted bases. Rep. scient. tech. Comm. int. Fed. Fruit Juice Prods. Vienna, 1964, 15–26.
- GLUCKSTEIN, L., and MONEY, R. W. (1962).—Manufacture of beverages and the like. U.S. Pat. 3,069,271.
- GROVES, O. R., LTD., and WHITE, P. (1961).—The manufacture of foodstuffs, beverages and the like. Inventor: P. White. Br. Pat. 860,946. (*BFMIRA Abstr.* **14**, 666 (1961).)
- KEFFORD, J. F. (1959).—The chemical constituents of citrus fruits. *Adv. Fd Res.* **9**, 285–372.
- KEFFORD, J. F., and CHANDLER, B. V. (1970).—The chemical constituents of citrus fruits. *Adv. Fd Res. Suppl.* **2** (in press).
- LAWLER, F. K. (1969).—What's new in unit operations: new citrus processes. *Fd Engng* **41**(11), 116.
- LYONS, J., & CO. LTD. (1963).—Process and apparatus for the manufacture of citrus beverages and the like. Br. Pat. 937,581. (*BFMIRA Abstr.* **16**, 2046 (1963).)
- LYONS, J., & CO. LTD. (1965).—The manufacture of citrus beverages and the like. Inventors: L. Gluckstein and W. T. Everington. Br. Pat. 981,211. (*BFMIRA Abstr.* **18**, 743 (1965).)
- NORTHERN DAIRY ENGINEERS LTD. (1955a).—An improved method of preparing citrus fruit liquors or beverages. Inventor: J. W. Shearman. Br. Pat. 729,199. (*BFMIRA Abstr.* **8**, 930 (1955).)
- NORTHERN DAIRY ENGINEERS LTD. (1955b).—Apparatus for preparing citrus fruit liquors or beverages. Inventor: J. W. Shearman. Br. Pat. 729,200. (*BFMIRA Abstr.* **8**, 931 (1955).)
- NORTHERN DAIRY ENGINEERS LTD. (1958).—A method of and apparatus for preparing citrus fruit beverages and concentrates. Inventor: J. W. Shearman. Br. Pat. 799,258. (*BFMIRA Abstr.* **11**, 1553 (1958).)
- PAN-CITRUS CORP. (1961).—Process and apparatus for preparation of citrus flavour bases. Br. Pat. 868,973. (*BFMIRA Abstr.* **14**, 1134 (1961).)
- RAO, S. P. V., PRASAD, P. S. R. K., RAO, N. G., and GIRIDHAR, N. (1969).—Comminuted citrus beverages. *Int. Bottler Pckr* **1969**(5), 54, 56, 58, 60, 62, 64.
- SCOTT, G., & SON (LONDON) LTD. (1960).—Processes and apparatus for the manufacture of fruit and vegetable juice preparation. Inventor: T. S. Ling. Br. Pat. 830,760. (*BFMIRA Abstr.* **13**, 922 (1960).)
- SCOTT, W. C., and VELDHIJS, M. K. (1966).—Rapid estimation of recoverable oil in citrus juices by bromate titration. *J. Ass. off. anal. Chem.* **49**, 628–33.
- SMITH, E. H. G., and KAY, D. E. (1960).—The utilization of citrus fruit. *J. Sci. Fd Agric.* **11**, 181–91.
- TOMAS, J., PINAGA, F., LAFUENTE, B., and PRIMO, E. (1969).—Freeze-drying of comminuted citrus. I. Studies on their eutectic and hygroscopic behaviour. (In Spanish.) *Revta Agroquim. & Tecnol. Aliment.* **9**, 406–14.

Low-temperature Breakdown in Apples

By K. J. Scott
N.S.W. Department of Agriculture

and R. B. H. Wills
Division of Food Preservation, CSIRO, Ryde, N.S.W.

Cool storage induces browning in the cortical tissue of many varieties of apples. The condition is known as internal browning or internal breakdown and several types are recognized depending on the appearance and location of the brown tissue and the conditions of storage under which browning occurs (Carne 1948).

Low-temperature breakdown is one form of browning (Fig. 1) which severely limits the storage life of susceptible varieties (Hall and Scott 1969). The disorder was defined by Kidd and West (1928) as one in which 'the causal conditions are set up in the tissues when fruit is held at temperatures below the limit of tolerance and result in premature death, i.e. death before senescence has advanced to the normal extent such as is attained at higher temperatures'. The disorder first appears in the outer cortex and gradually spreads towards the core and skin, but the core is affected only in very advanced cases (Carne 1948). Storage experiments carried out in many countries have shown considerable differences between and within varieties, e.g. for the same variety when grown in different countries or even in different districts. Thus local storage experiments have been necessary in each country.

Since the initial studies by Powell and Fulton (1903), partial control of low-temperature breakdown has been possible, but the specific cause of the disorder has not been determined. Control measures must also take into account the possibility that other forms of physiological wastage (e.g. superficial scald) and deterioration (e.g. skin yellowing) may also be important.

Control Methods

Large fruit and fruit from trees carrying a light crop are susceptible to breakdown. Maturity at harvest is also important as fruit picked late commonly develops low-temperature breakdown more severely. Since the consumer, however, prefers large apples and, in coloured varieties, a good development of red skin colour, the grower is inclined to

delay harvesting. As attention to preharvest factors alone does not eliminate breakdown and certain market requirements may increase it, there is a need for post-harvest treatments to reduce the possibility of breakdown during cool storage.

Use of a Higher Temperature

Storage of apples at low temperatures leads to a reduction in the rate of aging and yellowing, losses from rots, and senescent disorders of the fruit. If it were not for the occurrence of physiological disorders at low temperatures all fruit would be stored at temperatures as close as possible to the freezing point of the tissue. Commercial practice is to store at 36–38°F the most highly susceptible varieties,

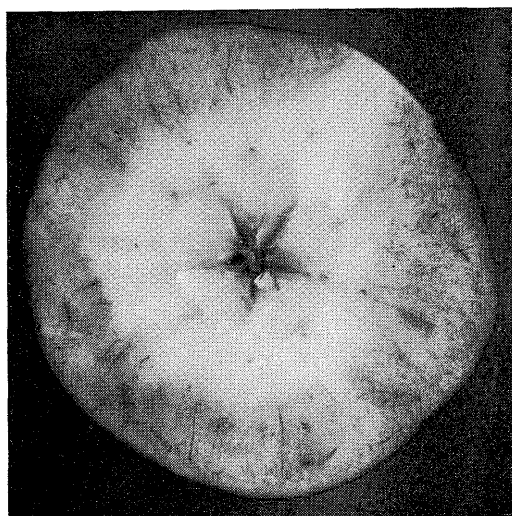


Fig. 1.—Low-temperature breakdown.

viz. Cox's Orange Pippin in Britain, McIntosh in North America, and Jonathan in New Zealand. Less susceptible varieties such as Delicious grown in New South Wales are stored at 32°F, while varieties of low susceptibility such as Granny Smith grown in New South Wales are stored at 30°F. Treatments that delay breakdown would enable susceptible varieties to be stored at a lower temperature and thus retain desirable quality for a longer period.

Slow or Stepwise Reduction in Temperature

This is a technique designed to reduce the period spent at higher temperatures, and so reduce losses associated with the higher-temperature method of storage that was developed by Trout, Tindale, and Huelin (1940) for Jonathan apples grown in Victoria. The temperature is reduced from 36°F to 32°F by 2-degF steps over 2 months, but storage operators who have adopted this method have found that more yellowing occurs than when the storage temperature is maintained at 32°F.

Warming during Storage

Smith (1958) reduced breakdown in Bramley's seedling apples stored at 32°F by holding the fruit at 59°F for 5 days after 6–8 weeks' storage. Other workers have confirmed these results but there is considerable uncertainty in estimating the best time for treatment which usually is about half way between picking and the time that the disorder first appears. If it is not carried out at the proper time, the treatment may have no effect. Even if it were possible to decide the best time for treatment, considerable effort and expense would be required to carry out the treatment during commercial operation.

Delayed Storage

Inconsistent results have been obtained by holding fruit for a time at ambient temperatures before cool storage, possibly due to the different conditions of ambient temperature and humidity used in the various experiments. The treatment is not now recommended.

Modified-atmosphere Storage

Storage of apples in atmospheres containing a higher carbon dioxide concentration and a lower oxygen concentration than air has given variable results. A common view is that when the atmosphere contains more carbon dioxide than air breakdown is increased, but some workers, e.g. Tomkins

(1961, 1963), have reported that breakdown is reduced under these conditions. We have observed both effects and consider that the apparently conflicting results may be due to the presence of brown heart, a disorder that may resemble breakdown in appearance.

Modified atmospheres can be developed in a variety of ways and it is possible that the effects observed are not due only to the levels of carbon dioxide and oxygen. The effects could be associated with the method of obtaining the atmosphere, e.g. caustic soda used to reduce the carbon dioxide level will also reduce the humidity.

The use of polyethylene bags produces a modified atmosphere around apples, but it tends to increase low-temperature breakdown, particularly when the bags are not sealed. Scott *et al.* (1964) found breakdown increased as the composition of the atmosphere approached that of air. Since the development of the most favourable atmosphere in each bag cannot be guaranteed,

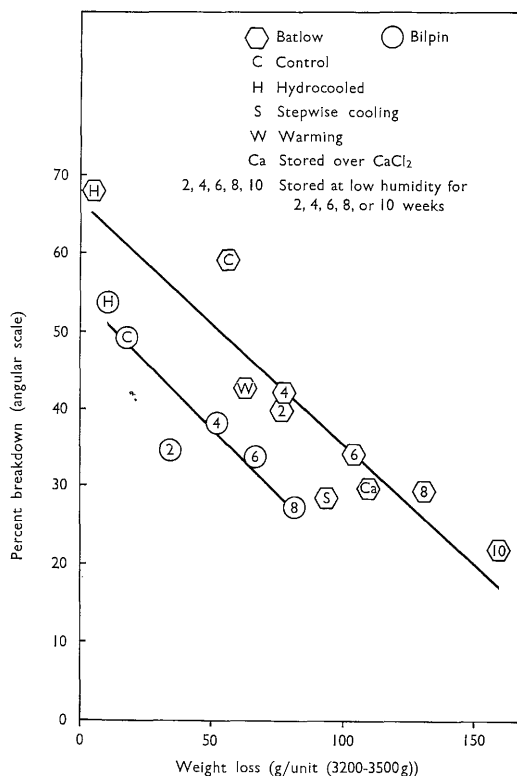


Fig. 2.—Reduction of breakdown by known control measures depends upon the loss in weight of the fruit.

polyethylene bags are suitable only for fruit known to have a low susceptibility to breakdown.

Increasing Loss in Weight during Storage

It is generally accepted that evaporation from the fruit should be kept to a minimum after harvest in order to avoid shrivelling of the fruit. It is now known, however, that high relative humidity and consequent low weight loss in storage favour the development of internal breakdown. McClelland and Tiller (1926) were the first to report that a low relative humidity during storage appeared to be an important requirement for the successful control of breakdown, but this observation was not confirmed until much later, e.g. Rasmussen (1963) and Scott *et al.* (1964).

Relative humidity is difficult to measure accurately at low temperatures, but it may be readily studied by measuring the weight lost by the fruit during storage. Martin, Lewis, and Cerny (1967) and Scott and Roberts (1967) found that an increase in weight loss resulted in a quantitative reduction in the occurrence of breakdown.

Many of the treatments used to reduce breakdown would be expected to increase the loss in weight from the fruit. Scott and Roberts (1968) compared initial storage for 2–10 weeks in a room operating at 65% R.H. with slow cooling, warming during storage, and hydrocooling. They showed that the effects of all treatments on breakdown were accounted for by the loss of weight occurring during storage (Fig. 2). Hydrocooled fruit took up some water during cooling, lost least weight during storage, and developed most breakdown. Least breakdown occurred in fruit held for the longest time at low humidity. Scott, Wills, and Roberts (1968) found that increased weight loss also resulted in reduced incidence of the disorder in Red Jonathan apples stored in controlled atmospheres (Fig. 3).

Some of the older European cool stores operated at low humidities and considerable shrivelling of fruit took place. To overcome this excessive loss in weight the storage atmosphere was humidified by use of water sprays (Rasmussen 1963; Hansen and Kuprianoff 1961). This treatment, however, increased breakdown. Golden Delicious apples have a low susceptibility to breakdown but shrivel badly. Ginsburg (1961) found that

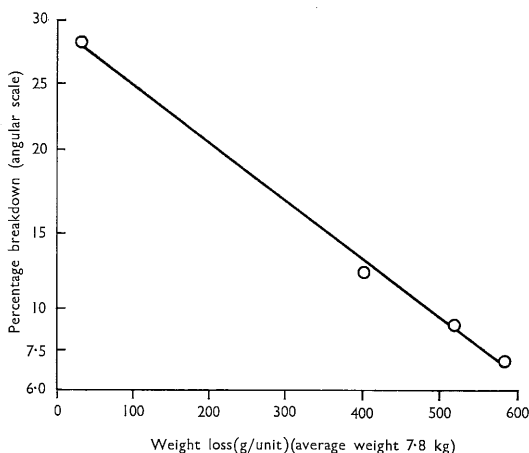


Fig. 3.—Relation between breakdown and weight loss in controlled-atmosphere storage.

waxing this variety to reduce shrivelling induced breakdown.

In New Zealand a negative correlation between wilting and breakdown has been observed over many years. Jackson (1967) found that breakdown tended to increase as the harvest was delayed whereas the incidence of wilted fruit decreased. He also found susceptibility to wilt during cool storage varied between districts and even between different parts of the same tree.

Lentz and Rooke (1964) reported considerable differences in weight loss between certain varieties when stored under controlled conditions and Hicks and Evans (personal communication) found that the rate of weight loss in storage of Granny Smith apples from several districts in New South Wales ranged from 0.10 to 0.42 g/150 g apple/week. We have also found a similar range in weight loss for Jonathan apples from the same orchard. Such effects of growing conditions on weight loss during subsequent storage would markedly alter the level of breakdown on the basis of data from Scott and Roberts (1967) and Scott, Wills, and Roberts (1968) and could help explain district-to-district variations in breakdown susceptibility.

Some of the effects due to growing conditions may also be partly due to induced differences in weight loss in storage. In long-term fertilizer trials Tiller, Roberts, and Bollard (1959) found that application of phosphorus to the soil resulted in increased

wilting of the fruit during storage but breakdown was reduced. Immature fruit and russeted fruit have been observed by Martin (personal communication) to be less susceptible to breakdown and are known to shrivel more than other fruit in storage. It is therefore clear that loss in weight must be taken into account before other treatment effects can be correctly assessed.

Methods for Increasing Weight Loss

While it is a relatively simple matter to restrict weight loss, the promotion of increased evaporation is more difficult. Weight loss has been increased by polishing to remove wax (Hall 1966) or by scraping (Hilkenbaumer 1961) but such methods appear to be impracticable under commercial conditions. A commercial treatment for increasing the rate of evaporation from the fruit should be convenient and economical and preferably not involve changes in temperature during storage. These requirements could be met by a simple treatment applied to the fruit before storage. Scott and Wills (unpublished data) have investigated a method of dipping the fruit in an alkaline solution before storage and the results appear very promising.

Recommendations

While a number of treatments and conditions of storage reduce breakdown, attention to any one factor alone is usually insufficient to control the disorder in very susceptible fruit. Therefore until a far more acceptable control measure has been developed a number of measures should be adopted in varying degrees depending upon liability of the fruit to develop breakdown. For very susceptible varieties, crops with a high proportion of large apples, fruit from light-crop trees, over-mature fruit, or those from trees that have received a heavy application of nitrogenous manures should be avoided or the fruit should not be stored for long periods.

In view of recent findings, loss in weight should not be minimized unless the fruit has a very low susceptibility to breakdown. The use of low humidity during the initial storage period rather than lowering the temperature gradually is worth testing under commercial conditions. As low oxygen storage cannot always be relied upon to reduce the incidence of breakdown a moderate loss in weight during controlled-atmosphere storage should also be of benefit.

The present methods for reducing breakdown are far from ideal and much more research will be required before the disorder can be considered as having been controlled.

References

- CARNE, W. M. (1948).—The non-parasitic disorders of apple fruits in Australia. Bull. Coun. scient. ind. Res., Melb. No. 238.
- GINSBURG, L. (1961).—Internal breakdown in South African apples grown in the Cape Province. Bull. int. Inst. Refrig. Annexe 1961-1, 93.
- HALL, D. M. (1966).—A study of the surface wax deposits on apple fruit. *Aust. J. biol. Sci.* **19**, 1017.
- HALL, E. G., and SCOTT, K. J. (1969).—Storage and market diseases of fruit. *CSIRO Fd Preserv. Q.* **29** (2) Suppl.
- HANSEN, H., and KUPRIANOFF, J. (1961).—Some experiences with air-washing in cold and gas stores of pears and apples. Bull. int. Inst. Refrig. Annexe 1961-1, 337.
- HILKENBAUMER, F. (1961).—The importance of the cuticle for the maturation and storage of fruit. Bull. int. Inst. Refrig. Annexe 1961-1, 195.
- JACKSON, D. I. (1967).—Storage of Sturmer in relation to date of harvest. *N.Z. Jl agric. Res.* **10**, 301.
- KIDD, F., and WEST, C. (1928).—Two types of storage internal breakdown in apples. *Rep. Dep. sci. industr. Res., Lond.* **1927**, 42.
- LENTZ, C. P., and ROOKE E. A. (1964).—Rates of moisture loss of apples under refrigerated storage conditions. *Fd Technol., Champaign* **18**, 1229.
- MCCLELLAND, N., and TILLER, L. W. (1926).—Cool storage investigations in season 1925. Cold Storage Publ. Cawthron Inst. scient. Res. No. 3.
- MARTIN, D., LEWIS, T. L., and CERNY, J. (1967).—Nitrogen metabolism during storage in relation to the breakdown of apples. I. Changes in protein nitrogen level in relation to incidence. *Aust. J. agric. Res.* **18**, 271.
- POWELL, G. H., and FULTON, S. H. (1903).—The apple in cold storage. Bull. U.S. Bur. Pl. Ind. No. 48.
- RASMUSSEN, P. M. (1963).—The influence of air humidity in the store on the storage behaviour of apples. (In Danish, with English summary.) *Tidsskr. Plavl.* **66**, 862.
- SCOTT, K. J., HALL, E. G., ROBERTS, E. A., and WILLS, R. B. (1964).—Some effects of the composition of the storage atmosphere on the behaviour of apples stored in polyethylene film bags. *Aust. J. exp. Agric. Anim. Husb.* **4**, 253.
- SCOTT, K. J., and ROBERTS, E. A. (1967).—Breakdown in Jonathan and Delicious apples in relation to

- weight lost during cool storage. *Aust. J. exp. Agric. Anim. Husb.* **7**, 87.
- SCOTT, K. J., and ROBERTS, E. A. (1968).—The importance of weight loss in reducing breakdown of Jonathan apples. *Aust. J. exp. Agric. Anim. Husb.* **8**, 377.
- SCOTT, K. J., WILLS, R. B. H., and ROBERTS, E. A. (1968).—Breakdown and weight loss in Red Jonathan apples in controlled atmosphere storage. *Aust. J. exp. Agric. Anim. Husb.* **8**, 630.
- SMITH, W. H. (1958).—Reduction of low-temperature injury to stored apples by modulation of environmental conditions. *Nature, Lond.* **181**, 275.
- TILLER, L. W., ROBERTS, H. S., and BOLLARD, E. G. (1959).—The Appleby experiments. *Bull. N.Z. Dep. scient. ind. Res.* No. 129.
- TOMKINS, R. G. (1961).—The relative effects of temperature and the conditions of carbon dioxide and oxygen in the refrigerated gas storage of fruits and vegetables. *Bull. int. Inst. Refrig. Annexe* 1961-1, 259.
- TOMKINS, R. G. (1963).—Small scale storage trials. *Rep. agric. Res. Coun., Ditton & Covent Garden Labs.* **1962/3**, 9.
- TROUT, S. A., TINDALE, G. B., and HUELIN, F. E. (1940).—Investigations on the storage of Jonathan apples grown in Victoria. *Bull. Coun. scient. ind. Res., Melb.* No. 135.

News from the Division

New Appointments

Mr. J. P. McNamara joined the Division as an Experimental Officer on April 3, 1970, to work with Mr. D. J. Casimir on flame sterilization of food, details of which were given in the previous issue. Mr. McNamara holds the degree of B.Sc. in Chemical Engineering from the University of N.S.W.

Mr. Neil Wade, Fruit Officer of the N.S.W. Department of Agriculture, has been attached to the Fruit Storage Section of the Division since March 19, 1970. His interests are in post-harvest physiology of fruits and vegetables.

Awards

Mr. M. V. Tracey, Chief of the Division, has been elected President of the Australian Biochemical Society for a two-year term commencing from July 1.

Mr. L. E. Brownlie, who heads the Industry Section of the Division's Meat Research Laboratory at Cannon Hill, Qld., has been awarded the degree of M.Sc.Agr. by the University of Sydney for his thesis on the 'Effect of some environmental factors on the growth of *Microbacterium thermosphactum*'.

Mr. M. L. Rooney's paper, 'The influence of packaging variables on the loss of sulphur dioxide from dried fruits', was judged by the Research Awards Section of the Australian Institute of Food Technology as the best contribution presented at the Institute's Convention in Melbourne during April.

Overseas Visitors

Miss Leda Pupo, FAO Fellow, completed a 12 months' attachment to the Taste Testing Laboratory at Ryde and returned to the Instituto de Tecnologia de Alimentos at Campinas, Brazil, at the end of March.

Dr. George F. Stewart, Director of the Food Toxicology Centre at the University of California, Davis, spent several weeks in Australia during April and May. Dr. Stewart is well known in the poultry industry, which adopted many of the ideas he imparted during a former visit while he was Professor of Food Science and Technology at the University of California, Davis. Much of Dr. Stewart's current work is in the fight against pollution and his audiences in Australia benefited from his breadth of knowledge.

Dr. G. W. Butler, Director of the Division of Applied Biochemistry of DSIR, Palmerston North, New Zealand, attended meetings in Queensland during May and was able to include the Meat Research Laboratory at Cannon Hill and the Division's laboratories at Ryde and the University of Sydney in his itinerary.

Miss S. P. Chen, of Malayan Frozen Foods Ltd., spent three weeks in the Animal Products Section, studying the processing and preservation of fish and fish products.

Mr. K. S. Jayaraman, Colombo Plan Fellow from India, is augmenting his studies at the University of New South Wales by working in the Food Technology Section.

Resignation

Dr. Max Shaw has resigned from his position as Research Scientist at the Division's Meat Research Laboratory to succeed Mr. Don Grover as Superintendent of Research at the Bourke Street, Darlinghurst, N.S.W., laboratories of Mauri Bros. & Thomson Ltd.

Overseas Travel

Mr. M. V. Tracey, Chief of the Division, visited food science centres in the U.S.A., Canada, and Britain from mid April until the end of May. He was guest speaker at a Research Branch Seminar on 'The State of Water in Foods' at the Food Research Institute of the Canada Department of Agriculture, Ottawa. He also spoke on this topic in the Department of Food Science of the University of Strathclyde, Glasgow, and the Unilever Research Laboratory at Sharnbrook, Bedford. In addition to renewing numerous other contacts in the spheres of biological science and food technology, Mr. Tracey attended the meeting of the Institute of Food Technology in San Francisco, on his return journey to Australia.

Dr. J. H. B. Christian, Assistant Chief, accepted an invitation to participate in a joint FAO/IAEA Research Coordinating Meeting on Microbiological Aspects of Food Irradiation in Vienna in mid May. While travelling to this conference he interrupted his journey to visit research laboratories in

Singapore and Kuala Lumpur. Dr. Christian also attended a meeting of the Society of Applied Bacteriology in Bristol, England, in June, and the 10th International Congress for Microbiology in Mexico, in July and early August.

Dr. B. V. Chandler, Principal Research Scientist in the Division's Food Technology Section, inspected citrus production centres in the Mediterranean area and the U.S.A. in April and May he visited Israel, Greece, and Spain and gave a talk entitled 'Solubility Relationships of Limonin' at the meeting, in Sicily, of the International Federation of Fruit Juice Producers. Whilst in the U.S.A., Dr. Chandler took the opportunity of calling at the important citrus-growing areas in Florida and California.

Dr. R. M. Smillie, joint leader of the Plant Physiology Unit at the University of Sydney, departed on May 8 for the U.S.A., where he attended the International Conference on Photosynthesis at Gatlinburg, Tennessee. He also visited the universities of Kentucky, California, Harvard, and Chicago, and the Oak Ridge National Laboratory of the U.S. Atomic Energy Commission, as well as the photosynthesis research group at the Kettering Laboratory in Yellow Springs, Ohio. On the return journey Dr. Smillie visited the Universities of London and Oxford, and the Institute of Photosynthesis at Leningrad.

Selected Publications of the Division

Copies of most of these papers are available from the Librarian, CSIRO Division of Food Preservation, P.O. Box 43, Ryde, N.S.W. 2112 (telephone 88 0233).

ATKINS, R. (1970).—Construction and operation of controlled atmosphere cool storages for fruit. Pap. Conf. Aust. Inst. Refrig. Air Condit. Heat., Vict. Div., No. 2.

BEATTIE, B. B., and OUTHRED, N. L. (1970).—Packaging treatments for the storage and export of Australian grapes. *Aust. J. exp. Agric. Anim. Husb.* **10**, 124-8.

CASIMIR, D. J. (1970).—New equipment for the thermal processing of canned foods. *Fd Technol. Aust.* **22**, 8-19.

DAVIS, E. G. (1970).—Evaluation and selection of flexible films for food packaging. *Fd Technol. Aust.* **22**, 62-7.

HALL, E. G., and COFFEY, M. F. (1970).—The refrigerated transport of fresh fruit in insulated ISO containers. Pap. Conf. Aust. Inst. Refrig. Air Condit. Heat., Vict. Div., No. 18.

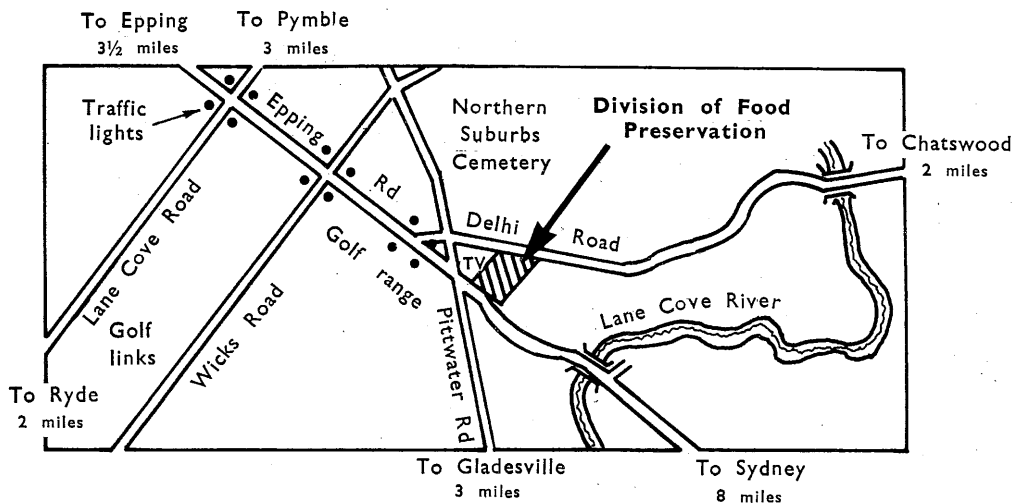
SIDHU, G. S., and MONTGOMERY, W. A. (1969).—Current trends in fish handling and processing. *Fd Technol. Aust.* **21**, 510-15, 642-5.

SMILLIE, R. M., and SCOTT, N. S. (1969).—Organelle biosynthesis: the chloroplast. In 'Progress in Molecular and Subcellular Biology'. Vol. 1, pp. 2403-10.

SYKES, S. M., and KELLY, F. H. C. (1969).—Kinetics of drying apple slices. *J. Sci. Fd Agric.* **20**, 654-9.

WILLS, R. B. H., and MCGLOSSON, W. B. (1969).—Association between loss of volatiles and reduced incidence of breakdown in Jonathan apples achieved by warming during storage. *J. Sci. Fd Agric.* **20**, 446-7.

Division of Food Preservation, CSIRO, Box 43, P.O., Ryde, N.S.W. 2112
Telephone 88 0233

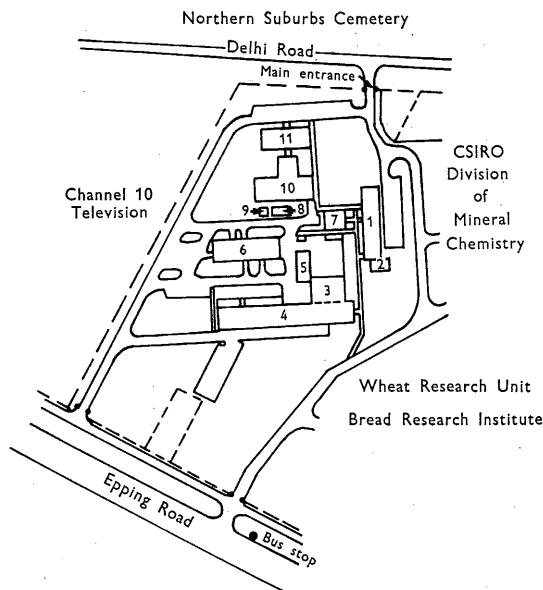


The main entrance to the Division is in Delhi Road, but the grounds may also be entered from Epping Road.

Buses on Routes 285-290 running between Wynyard and Epping railway stations pass the Epping Road entrance. Alight near Channel 10 television studios.

Buses on Barnes Coach Bus Route 54 from Chatswood railway station either terminate at the Northern Suburbs Cemetery near the Delhi Road entrance to the Division or continue on to Macquarie University.

Buses on Hunter's Hill Bus Co. Route 43 from Chatswood railway station running to Top Ryde pass the Epping Road entrance. Alight near Channel 10 television studios.



- 1 Administration and library
- 2 E. W. Hicks meeting room
- 3 Controlled-temperature rooms
- 4 Food science building
- 5 Boiler house and engine room
- 6 Workshops and store
- 7 Canteen and taste test room
- 8 Sulphuring room, liquid air plant
- 9 Refrigeration plant for blast freezer
- 10 Food processing building
- 11 Food technology building