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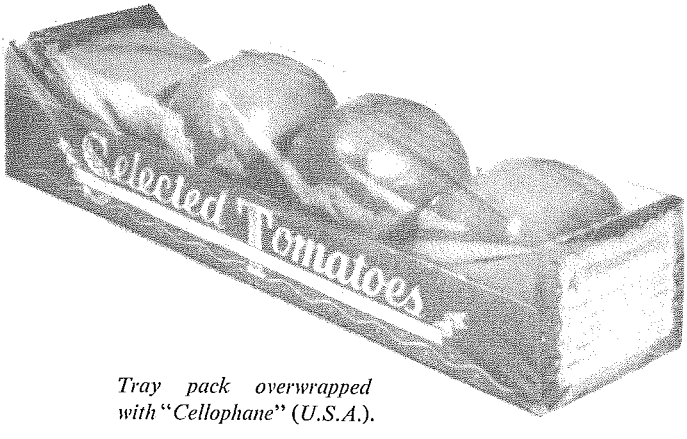

Tray pack overwrapped with "Cellophane" (U.S.A.).

Pre-packaging

PRE-PACKAGING is essentially a merchandising device. Improvement of the keeping quality of produce is not its main purpose, but it does make it possible to market fruit and vegetables in better condition. On the other hand it can have detrimental effects on the produce, and many technical problems have arisen because these effects have been overlooked.

DEVELOPMENT IN THE UNITED STATES

Central pre-packaging of fresh fruits and vegetables for self-service sale was started in 1945 by the Great Atlantic & Pacific Tea Company at Columbus, Ohio, U.S.A. The initial experiment was an immediate success and by 1955 more than 40 per cent. of retail grocers in the United States had self-service departments selling packaged produce. In the same year the U.S. Department of Agriculture estimated that about 15 per cent. of the 75 billion lb of fresh fruits and vegetables grown annually in the United States were being pre-packaged. This proportion is expected to reach 75 per cent. by 1965. In 1955 almost 100 per cent. of berries, 70 per cent. of spinach, 70 per cent. of carrots, and 60 per cent. of tomatoes were pre-packaged. Today almost one-third of the crops of potatoes and apples are being consumer packaged. The accompanying photographs show typical examples of pre-packaging in the United States.

American experience has shown that pre-packaging can be carried out satisfactorily at the point of sale, in terminal warehouses, or by the growers, the choice depending on the type of produce and trade requirements. Initially, pre-packaging was carried out only at the retail level, and most of it still is, but more and more is being done at the shipping point. In general, pre-shipment consumer packaging is more suitable for the least perishable produce such as potatoes, onions, carrots, turnips, and oranges. Vegetables such as lettuce and cauliflowers are being trimmed and packaged on the farm or in nearby packing houses, where they may be stored under refrigeration. Packaging within production areas can effect savings because culls and trimmings, which may comprise as much as 50 per cent. of the harvested crop, can be eliminated.

Under present conditions it is best to package most fruits and vegetables immediately before sale, at either the wholesale or retail level, since some deterioration is likely to occur when shipment takes more than a day or two. Even one bad specimen in a package cannot be tolerated on the display counter. How much will be packaged at the grower level will depend largely on the development of packaging materials and methods, and on the application of refrigeration during shipment. The difficulties of pre-shipment packaging would not be as great in Australia, where most produce can be delivered from the grower to the cities in 24 hours or less, as in the United States, where journeys of several days are common. The important question of where to pre-pack has been discussed recently in a survey of the industry in America (Anon. 1955).

FRUITS AND VEGETABLES ARE LIVING

Fresh fruits and vegetables are living plants or parts of plants, and among the processes

Fresh Fruits and Vegetables

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which continue after harvest are respiration and transpiration. After separation from their natural environment at harvest they must draw on their own reserves for these processes, and, as the reserves cannot be replaced, deterioration is inevitable. Fruits may improve in quality after harvest until they are fully ripe, but they decline rapidly thereafter. Vegetables on the other hand commence to deteriorate as soon as harvested. The loss of quality in peas, beans, and in green, leafy vegetables is so rapid that under warm conditions they may last only one or two days. In packaging vegetables the aim should be to retard but not to stop the living processes, for stoppage or severe retardation usually causes breakdown and fermentation. Fruits and vegetables may also be attacked by fungi and bacteria, causing decay, particularly at high temperatures and humidities. It must also be borne in mind that packaging may cause a rise in the temperature of produce, and a considerable increase in the humidity of the air surrounding it.

A survey made a few years ago by the U.S. Department of Agriculture (Stokes 1947) indicated that the average loss in retailing fresh fruits and vegetables without refrigeration was about 7 per cent., of which 44 per cent. was actual "garbage loss" in the store. With some items such as Brussels sprouts, apricots, and berries the loss was over 20 per cent., and with "hard" vegetables only 2·9 per cent. In the same survey the average loss in stores using open-top refrigerated display cases was only 2·9 per cent. If pre-packaging can reduce the deterioration and wastage of perishable produce it may pay for itself. In many instances this appears possible, provided handling methods and type of package are in keeping with the requirements of the produce and the expected financial return, and provided refrigeration is used where needed.

Ulrich (1955) has made a useful review of the effects of pre-packaging on the physiological behaviour of fruit. The mechanical characteristics of the package must be considered in relation to protection of the contents from bruising, which can hasten ripening and encourage decay. The thermal conductivity of the package, particularly any master shipping container, is important, since respiratory heat must be eliminated, and significant reductions in the rate of cooling under refrigeration should be avoided. Permeability to gases is most important: lack of oxygen, excessive carbon dioxide, and very high humidities can all be harmful. Low oxygen levels in the package induce fermentation, browning of tissue, and decay, and many products are injured by an increase in carbon dioxide levels to a few per cent. Excessive accumulation of water vapour greatly encourages mould attack and, according to Ulrich, disturbs ripening and causes inferior flavour.

THE PACKAGING MATERIAL

The basis of modern retail packaging is the transparent film. It makes an attractive package, permits the buyer to see the produce, protects the contents from contamination, and reduces shrinkage. It may be used as a bag, as an over-wrap, or as windows in a carton or opaque bag. Films for produce must have good transparency, adequate mechanical strength, and generally low per-

Oxygen Permeability of Transparent Films (after Platenius 1946*)*

Type of Film	Thickness (in.)	Permeability (ml/sq. m/24 hr)*
"Cellophane" 300 MSAT	0·0009	240
"Pliofilm" 140 P5F	0·0014	510
Cellulose acetate A	0·0012	3000
Cellulose acetate B	0·0009	3400
"Cellophane" PT	0·0008	6300
Ethyl cellulose	0·0012	16,000

* Measurements were made under the following conditions: Temp. = 75°F, R.H. = 100% and 60%, respectively, on two sides of test film. Difference in partial pressure of 0_2 across test film = $\frac{1}{5}$—$\frac{1}{6}$ atm. The data were recalculated to a partial pressure difference of 760 mm Hg. Vol. of 0_2 was corrected to S.T.P.

meability to water vapour (to reduce shrinkage). They must also be sufficiently permeable to carbon dioxide and oxygen to keep the produce living normally, so avoiding the onset of fermentation processes. Because of their strength, clarity, and comparative cheapness, the films mainly used are "Cellophane" and polyethylene ("Polythene"). They are strong, clean, and comparatively cheap, but they must be ventilated, since their permeability to gases is inadequate at ordinary temperatures. Cellulose acetate is much used for tray over-wraps because of its relatively high permeability to carbon dioxide and oxygen. The applications of other films such as rubber hydrochloride ("Pliofilm"), ethyl cellulose, and polyvinyl chloride are limited.

The relation of film characteristics to the physiological requirements of the produce has been investigated by Platenius (1946), who has listed the oxygen permeability of a number of transparent films used for prepackaging (see table above). It has been established that these films are more permeable to carbon dioxide than to oxygen. Platenius also studied the oxygen requirements of many vegetables and found that they varied greatly, the requirements for spinach, peas in the pod, and green beans being 8–10 times those of tomato, lettuce, and cucumber. Platenius concluded that most films, unless ventilated, are far too impermeable to oxygen to prevent fermentation at ordinary temperatures. In sealed packages of relatively impermeable film the respiration of fruit or vegetables will quickly reduce the oxygen content of the air. This reduction will retard respiration. At the 3 per cent. oxygen level it is about half the rate in air, but below this level, at average room temperatures, there is a sharp change from normal aerobic respiration to anaerobic respiration or fermentation, which does not need a supply of oxygen. It is therefore desirable that the oxygen concentration in the film bag should not fall below 5 per cent. For this reason, films must have a high permeability to oxygen, or they must be perforated. Produce is more tolerant of high carbon dioxide levels than lack of oxygen; the latter is therefore the more common cause of damage in film packages. In general films are sufficiently permeable to the "organic volatiles" given off in small amounts by fruits to make it unlikely that their accumulation will accelerate ripening or cause the development of off-flavours.

"Polythene" is a relatively new film which is strong, cheap, and has good aging characteristics, and is therefore well suited to a wide range of packaging requirements. The use of "Polythene" as a wrapping film for foods has been discussed by Thor and Goldman (1954). It has a relatively low water vapour transmission rate, a relatively high gas transmission rate, and a high tear strength. It is thus very suitable for consumer packaging of fresh produce. Unperforated "Polythene" is safe at low temperatures but if the bags are to be used at higher temperatures they must be perforated.

IMPORTANCE OF VENTILATION

There is a rapid build up of carbon dioxide and loss of oxygen in sealed film packages containing fresh fruits and vegetables at high temperatures. In experiments at C.S.I.R.O., Homebush, Granny Smith apples were sealed in bags of "Polythene" 0·0015 in. thick, and kept at 68°F. Six per cent. of carbon dioxide accumulated in 6 hr and as much as 12 per cent. in 12 hr. In tests with carrots at 70°F, Hardenburg, Lieberman, and Schomer (1953) found 4·6 per cent. carbon dioxide and 12·8 per cent. oxygen in bags similar to the above, and 21·6 per cent. carbon dioxide and 8·2 per cent. oxygen in "Pliofilm" bags of similar thickness. When 1¼-lb bags were ventilated with four ¼-in. holes the atmospheres inside were little different from air.

Schomer (1953) has reported extensive studies on pre-packaging including the use of films. He could find no film which is sufficiently permeable for making sealed packages for the non-refrigerated display of all varieties of fruit and vegetables. Schomer recommended the ventilation of film packages for all except a few special lines such as cherries, which benefit from an atmosphere containing high levels of carbon dioxide. Ventilation can be provided by incomplete closure, "trapdoor" perforations, and holes punched in the film. Punching holes is usually the most practical method.

The degree of ventilation required has been the subject of much speculation and some investigation. Platenius (1946) considered that two ⅛-in. holes per 1-lb package were enough to avoid excessive depletion of oxygen. While it is true that only a few small holes are needed with films like "Polythene", "Pliofilm", or "Cellophane" to maintain satisfactory internal atmospheres, many more holes may be needed to keep the humidity low enough to prevent decay. Hardenburg (1955) studied the ventilation of onions packed in film. In non-vented "Polythene" oxygen did not fall below 10 per cent. In itself this was not harmful, but he concluded that at least 16 ¼-in. holes per 5-lb bag were needed to permit sufficient water vapour to escape. Hruschka and Kaufman (1954) reported that eight ¼-in. holes per 5-lb "Polythene" bag were adequate for citrus. In studies with oranges from Florida and California, Kaufman, Hardenburg, and Lutz (1956) found that "Polythene" bags increased the rate of decay unless ventilated with the equivalent of 64 ¼-in. holes per 5-lb bag. This increased decay could, however, be offset by suitable fungicidal treatment of the fruit. Ventilation has often been used in an endeavour to prevent condensation of moisture on the inner surfaces of a film bag and consequent undesirable fogging. While perforation will reduce fogging, even the provision of a large number of holes will not prevent it. Fogging is mainly a function of temperature changes and can be minimized by avoiding sudden falls in temperatures outside the package.

WATER LOSS AND VENTILATION

The principal effect of the film package in retaining the quality of produce is to reduce moisture loss. This varies according to the permeability of the film to moisture vapour. Films like cellulose acetate, ethyl cellulose, and some types of "Cellophane" are very permeable and allow considerable shrinkage of the contents. Fogging is rarely a problem. Films of intermediate permeability include polystyrene and certain types of "Cellophane", "Polythene", moisture-proof cellophanes (e.g. "Cellophane" M.S.A.T.), some varieties of "Pliofilm", and vinylidene chloride

A popular method of pre-packaging potatoes in the United States. The bag is made of "Polythene".

("Saran") are very resistant to the passage of water vapour. These films are very good for retaining the crispness of produce, but they are commonly subject to fogging.

Perforations made to reduce decay and prevent fermentation do not necessarily increase water loss very much. Platenius (1946) found that each ⅛-in. hole in a 1-lb package increased weight loss by no more than 0·1–0·2 per cent. over the entire storage period. Hruschka and Kaufman (1954) compared weight losses from citrus fruits in mesh bags, perforated "Polythene" (eight ¼-in. holes per 5-lb bag), and non-perforated "Polythene". Weight loss was negligible in sealed "Polythene" but it was still reduced by more than 75 per cent. in the perforated bags. Even with the 5-lb bags ventilated with 64 ¼-in. holes Kaufman, Hardenburg, and Lutz (1956) found that the weight loss from oranges was reduced by 50–60 per cent.

REFRIGERATION NECESSARY

Refrigeration is not essential in retailing fresh fruits and vegetables, but it is of value in extending shelf life and reducing wastage. In general the life of perishable produce is approximately doubled by reducing the temperature by 18°F. The shelf life of peas in the pod, a very perishable line, is 1–2 days at a temperature of 80°F, 5–7 days at 50°F, and 14–21 days at 32°F. Topped carrots will last about 4–5 days at 80°F, 14–21 days at 50°F, and more than 30 days at 32°F. The life of most perishable products is a few days only at temperatures of 70–80°F and about 7–14 days at temperatures of 40–45°F. The latter is accepted as a suitable temperature for refrigerated display or short-term storage. Some kinds of produce are damaged by low temperatures, so that all should not be refrigerated to the same degree. Bananas, tomatoes, sweet potatoes, and a few others keep best at a temperature of 55°F. On the other hand a wide range of leafy and root vegetables, apples, pears, and most stone fruits can be stored longest at temperatures near freezing point.

Refrigeration is essential for pre-packaged produce that is being held for more than a day or two, because the high humidities in the package will cause decay unless the temperature is kept low. The value of refrigeration has been clearly demonstrated by Schomer (1953). He has recorded the shelf life of a large number of pre-packaged lines of perishable vegetables at five different temperatures. They range from 1–5 days at 80–85°F, to 2–21 days at 50°F and 6–30 days at 32°F. In a retail store produce can be kept cool with crushed ice, or mechanically refrigerated display cases can be provided. If the latter is not feasible, overnight refrigeration in a special cool chamber is of value: it will lower the daytime temperature of the produce by 10–20°F. The use of refrigeration is highly desirable when the produce is packaged at the shipping point, since a relatively long time elapses before the produce reaches the retail store. Pre-cooling before packing is also useful because packaging reduces the rate of cooling. To gain the full benefit from refrigeration it should be employed throughout the shipping and marketing period.

CONCLUSION

Studies overseas, particularly in the United States, on the effects of various film packages on the quality and appearance of fresh fruits and vegetables have shown that no one type of film was superior to others in all respects. More important than the type of film is adequate refrigeration, ventilation of the package, and care in selecting and handling the produce. Consequently the choice of film should be based mostly on cost, transparency, strength, and ease of handling. Fruit and vegetables for pre-packaging must have high initial quality, and quality standards must be rigidly maintained. In a better package the consumer expects a better product.

As pre-packaging develops in Australia accurate assessment of the protective values of various films and packages will become more important. The C.S.I.R.O. Division of Food Preservation and Transport is keeping in close touch with developments, but research is severely limited by the staff and facilities available. Nevertheless it is clear that to be successful, pre-packaging of fruit and vegetables must be based on a full appreciation of the importance of quality in the produce and of the value of refrigeration in maintaining it.

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Molybdenum Disulphide as a Lubricant

SINCE 1950 molybdenum disulphide lubricants have found a steadily increasing number of applications, including a number in the food industry. The stability of molybdenum disulphide at temperatures up to 750°F in the presence of oxygen and steam, and its resistance to acids and brines, indicate that it would be suitable for lubricating:

- Conveyors, can closers, and fillers in the presence of steam, hot acid juices, or brine.
- Ovens, dehydrators, and high pressure steam equipment.

Molybdenum disulphide comes close to being the ideal lubricant: it is resistant to light, heat, oxidation, and the common solvents. It has a low coefficient of friction, can stand up to extreme pressure, shears readily, and bonds well with the common engineering metals and plastics.

Powdered molybdenum disulphide may be applied to metal surfaces, but it is generally incorporated in a supporting medium to permit its application by conventional lubrication techniques. The supporting agent may be oil, grease, water, soaps, silicones, or bentonite, the particular combination being selected to cope with a specific lubrication problem.

The lubrication properties of molybdenum disulphide are due to its crystal structure and molecular composition. The laminar structure of the crystal is responsible for the low coefficient of friction, the plates sliding upon one another. The crystals are soft and have a low resistance to shear, and therefore offer little resistance to the motion of high spots through the lubricant film. Molybdenum disulphide also has the capacity to make a lubricating surface film on metals having stable sulphides. Residual sulphur valencies form loose bonds with the metal. Such a film also protects the bearing surfaces from chemical corrosion. Molybdenum disulphide should therefore find many uses in the lubrication of equipment in the food and allied industries.

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CORRIGENDUM

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Page 13, table: *the specific gravity at 70 per cent. relative humidity and 0 °C should read* 1·251 *instead of* 1·241.

In this article the author discusses the corrosion of cans, made from hot-dipped tin plate, by a number of typical Australian canned foods.

Internal Corrosion

CORROSION reactions between the product and the tin-plate container in which it is packed occur to some extent with all canned foods. Each food differs in its reactivity with the container, and foods in general can only be broadly classified according to their corrosive powers (Clark and Brighton 1946).

As a result of corrosion reactions, tin and iron from the can may enter the foodstuff and hydrogen gas may dissipate the vacuum in the can. In the course of recent investigations at C.S.I.R.O., Homebush, some observations have been made on tin and iron pick-up and vacuum loss in some typical canned foods, including six foods packed in plain cans and two in lacquered cans. The experiments also served to evaluate the performance of two locally manufactured acid-resisting lacquers.

The results agree with the generally accepted theories of the corrosion reaction, but demonstrate the differences in corrosivity which exist between foods.

METHODS AND MATERIALS

The cans used were 301 × 411 cans made from one batch of Welsh hot-dipped tin plate, specified as cold-rolled, 1·25 lb/base box nominal coating weight, 90 lb substance, and equivalent to American M.R. plate of temper T3. Plain cans were used for peaches, grapefruit juice, plum jam, tomato pulp, green beans and green peas. For beetroot (acidified pack, pH 4·3) and boysenberries, the cans were internally coated with two acid - resisting lacquers of local origin. Lacquer A was an oleo-resinous, stoving lacquer applied by roller-coating to give a dry film weight of 6·2 mg/sq. in. Lacquer B was a synthetic, phenolformaldehyde-modified epoxide stoving lacquer applied by roller-coating to give a dry film weight of 6·9 mg/sq. in.

The cans were selected from the batch at random and packed with the test products in the C.S.I.R.O. laboratory at Homebush. After processing, the cans were stored at 86°F, which represents average temperature conditions more severe than those likely to be encountered by local canned foods during distribution within Australia. Random samples were removed for analysis at intervals (see table below). Vacuum and headspace levels were estimated with a Campden manometer (Kefford 1954). Tin

Examination of Test Packs Stored at 86°F

Product	Examination Intervals (weeks)	Number of Cans Examined	Total Storage Period (weeks)	Initial Vacuum (in. Hg)		Headspace (ml)	
				Range	Mean	Range	Mean
Beetroot	6	4	54	8·3–15·9	12·3	21·4–28·7	24·1
Boysenberries	6	4	54	10·7–21·4	15·8	18·7–33·0	26·5
Grapefruit Juice	6	4	72	9·0–18·5	13·5	19·2–22·2	20·7
Peaches	18	6	72	9·5–16·3	12·9	31·7–38·6	35·7
Green Beans	18	6	72	7·4–16·0	12·0	20·9–26·2	23·1
Tomato Pulp	18	6	72	3·7–13·6	9·2	18·5–25·7	21·7
Plum Jam	18	6	72	—	—	—	—
Green Peas	18	6	72	8·4–16·0	12·0	25·7–30·2	28·0

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# of Food Cans

and iron were estimated by the methods recommended by McKenzie (1945, 1948).

RESULTS

The results of the observations made on the eight test packs are set out in Figures 1–3. They include tin, iron, and vacuum estimations on the six products packed in plain cans, and tin and iron estimations on the two products packed in lacquered cans. Each point on the graphs represents the mean of all the estimations made on the individual cans at the examination interval indicated.

Plain Cans

The six products packed in plain cans differed in their reactivity with tin plate. This is indicated by the estimations of the tin content of the products at intervals during the storage period (Fig. 1(*a*)). The least corrosive product was green peas which showed only a small increase in tin content. Green beans were the most corrosive, having an average tin content of 275 p.p.m. after 72 weeks' storage. Two of the six cans of green beans, examined after 72 weeks' storage, had tin contents in excess of 285 p.p.m., the maximum permitted in canned foods by the N.S.W. Pure Food Act. Of the remaining products, plum jam was more corrosive than peaches, tomato pulp, and grapefruit juice.

All six products showed only a very small increase, 5 p.p.m. or less, in iron content over the storage period (Fig. 1(*b*)).

Estimations of the internal vacuum of the cans during the storage period showed some vacuum loss in all products but no obvious differences between products (Fig. 2). Grapefruit juice and peaches showed evidence of a greater vacuum loss than tomato pulp, green beans, and green peas.

Lacquered Cans

In general, beetroot and boysenberries in lacquered cans showed low tin and high iron contents. Figure 3(*a*) provides evidence for a relatively rapid increase in tin content during early storage and a slower rate subsequently. Lacquer B gave rise to a lower tin content than lacquer A with both products. The tin contents of the beetroot pack were in general higher than those of the boysenberry pack with each lacquer treatment.

The results for iron pick-up in lacquered cans are shown in Figure 3(*b*). There were large variations in iron content between cans,

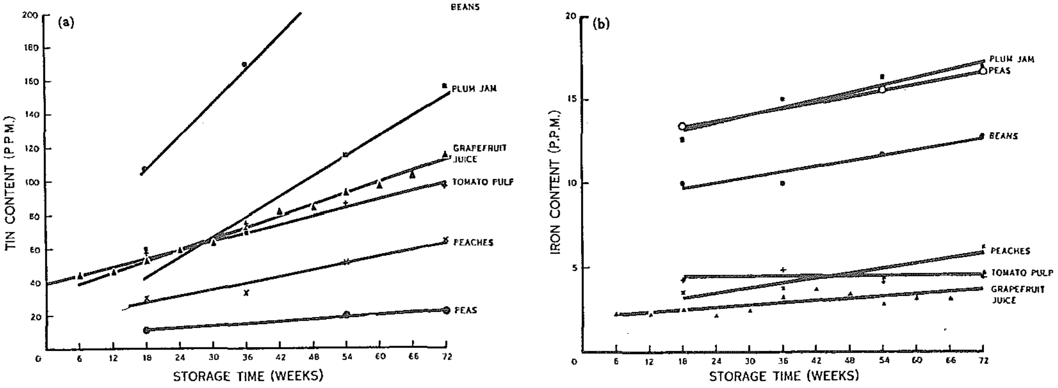

Fig. 1.—*Tin pick-up* (*a*) *and iron pick-up* (*b*) *during storage by products packed in plain cans.*

but in general the results showed that the rate of iron pick-up was slow at the beginning of storage but accelerated towards the end. With beetroot Lacquer B showed evidence of a smaller iron pick-up than Lacquer A. With boysenberries, the differences between lacquers were small.

Vacuum estimations were made on the lacquered cans at intervals over the storage period, but large variations were found. Variability between duplicate cans obscured any differences which may have existed between treatments. The general trend indicated that the vacuum losses were small early in the storage periods but rapidly accelerated towards the end.

DISCUSSION

Mildly corrosive fruits and vegetables such as peaches, pears, apricots, green beans, tomato products, and grapefruit are normally packed in plain cans and some corrosion of the container is tolerated. The normal electrochemical corrosion reaction with these products results in anodic dissolution of tin while hydrogen ions are discharged on small exposed areas of iron, which became cathodic. However the iron cathodes rapidly become polarized, so that hydrogen evolution and solution of iron are greatly retarded, and the tin is able to exert its protective influence over a long period of time (Hartwell 1951). Thus the general picture during storage is a fairly uniform but slow increase in the tin content, no appreciable increase in the iron content, and only a small loss in vacuum in the container.

In general, the present studies indicate that, in the case of products packed in plain cans, the corrosion reaction results in a steady rate of tin pick-up, very little change in the iron content, and a small decrease in internal vacuum. The differences observed in the rates of metal pick-up and vacuum loss illustrate the variation in corrosion behaviour between foods.

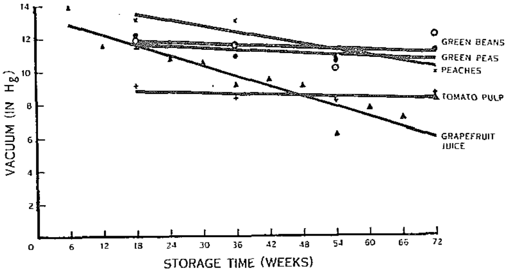

Fig. 2.—Change in internal vacuum during storage of products packed in plain cans.

The storage period of 72 weeks at 86°F was not long enough to show the sudden increases in iron content and vacuum loss which generally occur when most of the tin coating has been removed from the internal surfaces of the can. At that stage, when large areas of iron are exposed, the remaining tin is no longer able to provide electrochemical protection for the iron. Local anodic and cathodic areas begin to function on the exposed iron surfaces, resulting in dissolution of iron and a rapid increase in the rate of hydrogen evolution until the container is finally perforated or becomes a hydrogen swell. Vaurio, Clark, and Lueck (1938), using a test pack of peaches in plain cans, observed that about two years' storage at 100°F was necessary to produce a vacuum loss of 15–20 per cent. and two additional months resulted in complete loss of vacuum.

Analyses of the contents of cans which have failed by corrosion generally disclose a high content of dissolved iron. The tin content may be high or low depending on whether the can was plain or internally lacquered. There are several conditions which can upset the general mechanisms outlined. Sulphur and some of its compounds have the ability to inhibit the corrosion of tin and accelerate that of iron. Hence plain cans packed with products containing traces of sulphur may show a high iron and a low tin content at the time of failure.

The relatively high reactivity between tin and green beans reported here has also been noted by Sampson (1953). On the other hand green peas, which have a pH value similar to beans, show only a slight tendency to react with tin. In the experiments at Homebush the pH values for the green beans was 5·1 and for the green peas 5·6. It is well known that the reaction between a product and its container cannot be explained in terms of acidity alone, but depends more on the chemical nature of the constituents present. With green beans, it appears that some corrosion accelerator, perhaps oxalic acid, is present. The degree of corrosion may

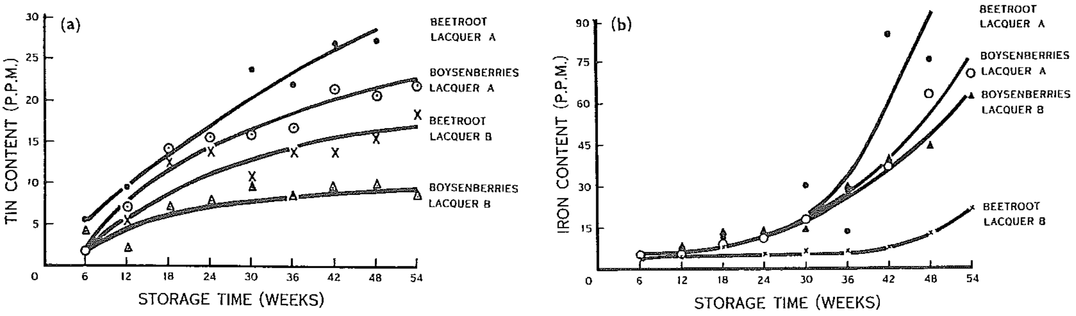

Fig. 3.—*Tin pick-up* (*a*) *and iron pick-up* (*b*) *during storage by products packed in lacquered cans.*

also be affected by the maturity of the product and by the conditions under which it is grown and processed, but these aspects have not been studied in the present investigations.

Products which are highly corrosive or contain anthocyanin pigments, for example, pickles, berry products, beetroot, and certain varieties of cherries and plums, require a can lined with an acid-resisting lacquer. The corrosion reaction in lacquered cans differs from that in plain cans, since the relative amounts of tin and iron exposed to the product have been changed. Discontinuities in the form of pinholes or fractures caused by mechanical damage of the lacquer film during fabrication of the can are always present in commercially lacquered cans. Corrosion commences at these discontinuities and in a relatively short time there is not sufficient available tin exposed to the product to give protection to the exposed iron surfaces. Dissolution of iron then begins together with evolution of hydrogen gas, and the can finally fails.

Products normally packed in lacquered cans generally show low figures for tin content and high figures for iron after lengthy storage periods. In the present studies, this has been observed with beetroot and boysenberries. By using cans lacquered with two types of lacquer, it has also been shown in the case of these products that the corrosion reaction is influenced by the type of can lining. Both beetroot and boysenberries picked up less tin and iron from a can lined with an epoxide lacquer. The results show that the epoxide lacquer reduced the tin content by 10–12 p.p.m. as compared with the oleo-resinous lacquer over a storage period of one year at 86°F. The superior performance of epoxide lacquers over other types has been observed in other tests made in this laboratory on a number of highly corrosive products (Davis 1955). Products containing anthocyanin pigments are sensitive to tin salts derived from corrosion of the container; and the pigments generally discolour or bleach in the presence of excess tin. With such products, it is therefore important to reduce the tin pick-up as much as possible.

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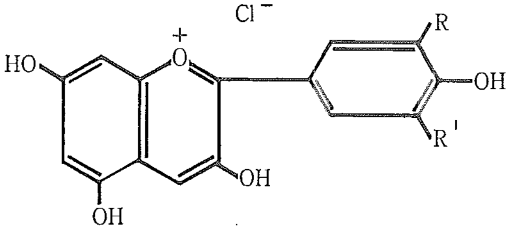
The chemical behaviour of anthocyanins, the naturally occurring pigments which impart the red, blue, or purple colour to many fruits, must be taken into account by the processor wishing to retain these attractive colours in his products.

Anthocyanin

MOST of the deep red, blue, and purple colours of berries, fruits, and flowers are attributed to the presence of pigments known as anthocyanins. These pigments are glycosides and can by hydrolyzed fairly readily to yield sugars and the aglycones which are called anthocyanidins.

Chemically, the anthocyanidins are benzopyrylium salts and they are related to many other flavonoid compounds which occur widely in foods (Bate-Smith 1954). Most of the anthocyanidins conform to the general formula shown below and differ from each other only in the number of hydroxyl and methoxyl groups on the phenyl ring. An exception worthy of special mention is betanin, the deep red colouring matter of the beet. Its structure has not been completely elucidated but it appears to contain nitrogen, and the presence of an ornithine (amino-acid) residue attached to the benzopyrylium skeleton has been postulated.

The occurrence of some common anthocyanidins in fruit and vegetables is indicated in the table on page 69. Generally the pigment in a particular fruit or vegetable consists of a mixture of anthocyanins.



Typical structural formula of an anthocyanidin.

The naturally occurring glycosides are formed by the attachment of sugar groups to hydroxyl groups at certain positions on the aglycone. Usually the sugar is glucose but galactose, rhamnose, xylose, and the disaccharide, gentiobiose, have also been found. Because of the attached sugars, the anthocyanins are fairly soluble in water, and differ in this respect from the other common plant pigments, the carotenoids and chlorophyll. Some anthocyanins also occur as esters, which are formed by combination of an hydroxyl group, either on the sugar or the anthocyanidin, with an organic acid such as *p*-hydroxy-cinnamic acid or malonic acid.

In acid solutions (pH less than 3) the anthocyanins exist as red cations, but change to blue anions in alkaline solution. The shade of colour in acid solution depends upon the type of anthocyanin and increases in "blueness" as the number of hydroxyl groups increase; thus delphinidin and its glycosides are much more bluish in appearance than pelargonidin derivatives.

At approximately neutral pH values the anthocyanins form a colourless leuco-base, so that on dilution of a weak acid solution a greater colour loss occurs than can be accounted for by the dilution effect alone. Sondheimer and Kertesz (1948) made use of this effect to develop a method for the estimation of strawberry anthocyanin. The sample is dissolved in citrate buffers at pH 3·4 and 2, and the difference in absorption at 500 mμ is a measure of the anthocyanin content. The method has proved very useful for following the changes in anthocyanin content during processing and storage, since it avoids the effect of other substances absorbing at about the same wavelength.

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Pigments in Foods

STABILITY IN FOODS

The anthocyanins are relatively unstable compounds and many agencies may bring about decomposition which becomes apparent as a marked colour change in the food product.

Hydrolysis

One of the reactions that may occur is hydrolysis to the aglycone. In the laboratory, boiling for 3 min with 20 per cent. hydrochloric acid results in complete hydrolysis. It is thus reasonable to assume that hydrolysis can readily occur during the processing of foods containing anthocyanins, which may involve treatment at boiling point for up to 30 min. The aglycones so formed have a different colour from the original anthocyanin and, being less soluble, may precipitate from solution causing a general cloudiness and an overall loss of colour. What is perhaps more important, however, is the fact that the aglycones are less stable than the glycosides and decompose more rapidly, giving rise to brownish discolorations.

Ascorbic Acid

It was noticed by Beattie, Wheeler, and Pedersen (1943) that the addition of ascorbic acid to an anthocyanin solution caused a greater loss of colour, and that this change was accelerated by high temperatures and the presence of air. Sondheimer and Kertesz (1953) showed that the presence of ascorbic acid alone was not sufficient to cause decomposition, since anthocyanin and ascorbic acid

Occurrence of Anthocyanidins

Anthocyanidin	Formula	Occurrence
Pelargonidin	$R, R' = H$	Strawberries, mulberries, red radish
Cyanidin	$R = OH, R' = H$	Peach, cherry, plum, raspberry, blackberry, red currant, red cabbage, red onion
Peonidin	$R = O.CH_3, R' = H$	Cranberries
Delphinidin	$R, R' = OH$	Bilberry, egg fruit, blackcurrant
Petunidin	$R = O.CH_3, R' = OH$	Blue grape
Malvidin	$R, R' = O.CH_3$	Grape

kept together under anaerobic conditions did not show any increased deterioration.

In the presence of oxygen, however, ascorbic acid greatly increases the rate of destruction of the anthocyanin and there is good evidence that breakdown occurs in the following manner. The ascorbic acid is first decomposed into dehydroascorbic acid and hydrogen peroxide. This reaction requires oxygen and is greatly accelerated by the presence of cupric ions. The hydrogen peroxide then reacts with the anthocyanins to produce compounds from which the characteristic red colouring is absent. In model experiments Lukton, Chichester, and MacKinney (1956) showed that even in the absence of ascorbic acid, strawberry anthocyanin was decomposed by oxygen to form a red-brown precipitate and a brown soluble material. It is therefore important that oxygen be excluded from processed foods containing anthocyanins, for the sake of retaining colour and preserving vitamin C.

Metals

In the pigments which are glycosides of cyanidin, delphinidin, or petunidin there are two adjacent free hydroxyl groups on the benzene ring, which are capable of combining with metals, such as aluminium, tin, lead, iron, and copper, to form very deep blue or purplish insoluble salts. Hence certain products packed in unprotected cans will deteriorate very rapidly and assume a purplish, cloudy appearance which renders the product unacceptable.

Metals may also hasten both the oxidation and decolorization of anthocyanins. Copper catalyses the oxidation of ascorbic acid, and Sondheimer and Kertesz (1952) have shown that ferrous ions hasten the oxidation of anthocyanins by hydrogen peroxide. In the laboratory it has been shown by Charlesworth, Chavan, and Robinson (1933) that zinc ions, in the presence of dilute acids, can cause the reduction of anthocyanins to what are believed to be chromenes. A similar reaction may account for the yellow colours or decolorization observed when anthocyanin solutions are kept in the presence of tin or tin salts. For these reasons it is essential to pack anthocyanin-containing foods in cans protected by an acid-resistant lacquer (Davis 1955).

Sugars

Experiments carried out by Nebesky *et al.* (1949) indicated that the addition of sugar to fruit juices and to solutions of strawberry and currant pigments had no effect upon the loss of colour during storage. On the other hand, Meschter (1953) considers that decomposition products of sugars, such as furfuraldehydes, could reduce anthocyanins to colourless compounds, resulting in bleaching of the product. Markakis, Livingston, and Fellers (1957) confirmed this view when they found that 5-hydroxy-methyl-2-furfuraldehyde caused increased decomposition of pelargonidin-3-glucoside, the anthocyanin of strawberries.

Enzymes

Some specific enzymes may cause decolorization of anthocyanins. Following observations of the decolorization of strawberries treated with "Pectinol", a mould pectinase in common use in the food industry, Huang (1955, 1956) isolated an enzyme which he termed "anthocyanase". He also found this enzyme in strains of the mould *Aspergillus*, but it is not always produced by moulds causing spoilage. Thus Bennett (1954) observed that, although enough spoilage had occurred among strawberries to give a marked colour change, there was no actual loss of anthocyanin pigment.

Under this heading might be mentioned the apparent protective action of anthocyanins against the enzymatic destruction of ascorbic acid. Hooper and Ayres (1950) noted that the ascorbic acid in blackcurrants was remarkably stable. This stability was not due to lack of ascorbic acid oxidase in blackcurrants, but to the presence of a factor that inhibited the enzyme reaction. They were able to isolate the inhibitor and found that it could be associated with two fractions, one of which contained the anthocyanins and the other the closely related flavonoids.

Light

There is some confusion in the literature as to how great a part, if any, light plays in the deterioration of anthocyanin colours. It has been shown by Nordström (1956) that the aglycones are readily affected by light. A solution of cyanidin in weak acid could be kept almost indefinitely in the dark, but exposure to diffuse light decreased the concentration by 10 per cent. in 6 hours, and in direct sunlight 95 per cent. of the colour was lost in the same time. Just how great an effect light has upon the naturally occurring glycosides has yet to be determined.

Additives

Certain substances have been found to have a stabilizing effect upon anthocyanin solutions. The most important of these are the tannins which occur naturally as copigments, modifying the colour of the anthocyanins, and which have been shown by Sastry and Tischer (1952) to decrease the rate of loss of colour of anthocyanin solutions on exposure to ultraviolet light. Certain colloids have been found to improve colour retention when added to strawberries and raspberries intended for quick freezing (Wegener, Baer, and Rodgers 1951; Bennett 1954). Substances found useful in this respect were pectins, gum tragacanth, a kelp extractive, and an Irish moss extractive.

CAN CORROSION

It has often been stated that anthocyanins function as accelerators in the corrosion of tin plate. In an attempt to find specific factors which influence the rate of corrosion, the role played by anthocyanin pigments is being carefully reviewed by a team of British workers. Salt and Thomas (1957), working with specimens of pure tin under anaerobic conditions, have shown that the rate of corrosion of tin by citric and malic acid solutions is increased by the addition of chrysanthemin (cyanidin monoglucoside), a pigment present in Victoria plums and raspberries. The pigment acts as a cathodic depolarizer, possibly by taking up two electrons and being reduced subsequently to a chromene.

Dickinson and Gawler (1956) found, however, that as the concentration of chrysanthemin increased in Victoria plums the corrosivity with respect to tin plate decreased. The influence of malic acid was also studied, and a similar result obtained. The time for 25 per cent. of the cans to become hydrogen swells was taken as a measurement of corrosivity. The explanation is probably connected with the fact that Victoria plums are packed in lacquered cans. Only small areas of tin are exposed at discontinuities in the lacquer film, and internal corrosion of the cans commences at these discontinuities. The initial reaction involves the removal of tin to expose the iron. Attack then commences on the iron, resulting in evolution of hydrogen. The shelf life of the cans, as measured by the hydrogen evolved, is governed by the attack on the iron. Although chrysanthemin may accelerate the corrosion of tin in acid media, it evidently acts as an inhibitor in the corrosion of iron.

CONCLUSION

It is apparent that our knowledge of the chemistry of anthocyanins is not yet complete. A considerable amount of work is being done by overseas workers, and recently the C.S.I.R.O. Division of Food Preservation and Transport instituted a programme of research in this field, with emphasis on those aspects of importance in food preservation. In the meantime the food processor who wishes to retain the colour of foods containing anthocyanin pigments should adopt the following procedures:

- During preparation avoid bringing the food into contact with all metals except stainless steel.
- Minimize the heat treatment of the product, for example, by high-temperature short-time cooking (Markakis, Livingston, and Fellers 1957), and by rapid cooling.
- Exclude oxygen from the product and the container headspace.

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NEWS from the Division of Food Preservation and Transport

PERSONAL

Mr. L. J. LYNCH, Senior Principal Research Officer, who is in charge of investigations on fruit products and canning in the Division of Food Preservation and Transport, has been granted leave to take up the post of Acting Director of the Food Technology Laboratory in the College of Agriculture, University of Hawaii. Mr. Lynch left Australia for Hawaii on September 12, 1957. He will occupy the position until June 1958.

Dr. C. A. MCCHESNEY, a graduate of the University of Leeds, has been appointed Research Officer at the Division's Meat Research Laboratory at Cannon Hill, Queensland. He will investigate the metabolism of psychrophilic microorganisms, and study the application of the results to the microbiology of chilled and frozen meat. Dr. McChesney reached Sydney on the *Stratheden* on November 6, 1957. He is spending three months at the Divisional Headquarters at Homebush, N.S.W., before entering on his work at Cannon Hill.

Mr. N. D. COWELL has joined the Physics Section at Homebush as an Experimental Officer. He will take part in investigations on the water loss from foods in cold storage, and on other physical problems involved in food preservation. Mr. Cowell graduated in Science at the University of London, and subsequently worked with Edwards High Vacuum Ltd., Sussex, and in the Mining Research Establishment of the National Coal Board. He arrived in Sydney on September 23, 1957, on the *Himalaya*.

Mrs. AMPAI ANGKAPINDU, a Junior Colombo Plan Fellow, was attached to the staff at Homebush from June to October

1957 to enable her to gain experience in food technology. Mrs. Angkapindu is a graduate of Chulalongkorn University, Thailand, and of the University of Medical Sciences, Bankok, where she took her M.Sc. degree in Pharmacy, and was for seven years instructor in Pharmacology in the Department of Medical Sciences. She came to Australia in April 1955, and first studied Food Technology at the New South Wales University of Technology. Later she studied Pharmaceutical Science and Food and Drug Analysis in the Pharmacology Department at Sydney University.

Mr. LAM VAN VANG, one of the technical experts who accompanied the President of South Vietnam on his visit to Australia in September 1957, spent a few days at Homebush. Mr. Lam Van Vang is Director of Research in Agronomy, Forestry, and Animal Husbandry in the Ministry of Agriculture, South Vietnam. At Homebush he devoted most of his time to the study of food processing, and visited several food processing establishments in the neighbourhood.

PUBLICATIONS BY STAFF

STUDIES ON BEEF QUALITY. PART IV. THE EFFECT OF BLAST-FREEZING OF HOT BEEF QUARTERS AND PRE-SLAUGHTER INJECTION OF MAGNESIUM SULPHATE. *A. Howard and R. A. Lawrie*, C.S.I.R.O. Aust. Div. Food Pres. Transp. Tech. Pap. No. 3 (1957).*†

It was shown by the authors in Part I of this series (see *C.S.I.R.O. Food Pres. Quart.* **17**: 18–19) that, contrary to expectation, the freezing of hot beef quarters in a blast tunnel operating at 250 ft/min and −35°C (−31°F) did not cause excessively high drip on subsequent thawing. In fact, tentative data from two carcasses studied in certain ancillary experiments suggested that when this freezing treatment was combined with pre-slaughter injection of relaxant doses of magnesium sulphate, the drip from butchers' joints on thawing, as well as that from pieces of muscle cut to standard size, was less than that from untreated controls. On the other hand, the eating quality of beef which had been blast-frozen as quarters without a period of prior chilling was not as good as that of control material which had been chilled and frozen by normal commercial practice. These results were considered of sufficient interest to warrant further investigation, which was carried out in a more powerful blast tunnel operating at 1000 ft/min and −40°C (−40°F).

Beef quarters from 10 steers of first-quality export grade were used to compare the relative effects on "drip" during thawing and on palatability after cooking, of the following four treatments: blast-freezing without prior chilling, after pre-slaughter injections of relaxant doses of magnesium sulphate; normal chilling and freezing after such injections; and corresponding non-injected controls for both methods of freezing.

Blast-freezing of hot quarters, in a tunnel operating at 1000 ft/min and −40°C (−40°F) significantly lowered butchers' drip from hinds on thawing after 14 weeks' frozen storage, and also lowered laboratory drip in psoas and longissimus dorsi muscles and drip from 6-in. cubes in both injected and non-injected material. This technique showed a more marked effect in reducing drip than the rather slower blast-freezing previously employed. In addition, and contrary to the effects obtained with the less powerful blast, the eating quality of roasts and grills from the blast-frozen beef was as high as that from the controls, which had been chilled and frozen in the normal manner. It was presumed that beneficial changes took place in the muscular tissues at a microstructural level, and that these changes offset the effect of the absence of a chilling period.

Although the combination of pre-slaughter injection with blast-freezing significantly reduced the drip from 6-in. cubes, and from smaller standardized samples of psoas muscle, drip from butchers' joints was unaffected by the injections.

The absence of significant differences in eating quality between roasts from the leg and sirloin and grills from the rump was attributed to the generally high quality of the beef investigated.

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* Low Temperature Station for Research in Biochemistry and Biophysics, University of Cambridge and Department of Scientific and Industrial Research of Great Britain.

† Also published as Food Investigation Special Report No. 64 by the D.S.I.R.

PHYSIOLOGY OF PEA FRUITS. III. CHANGES IN STARCH AND STARCH PHOSPHORYLASE IN THE DEVELOPING SEED. *Donella H. Turner and J. F. Turner. Aust. J. Biol. Sci. 10: 302–9 (1957).*

During the growth of pea seeds there is a period in which they change from sweet succulent peas to harder seeds because there is a fall in their sucrose content and a rapid increase in starch. This change is of considerable commercial importance and the present paper describes a study of the control of this starch synthesis. A method was developed for the assay of starch phosphorylase in peas and the changes in enzyme activity during development of the pea seed were followed. Over most of the period of development a linear relationship existed between the rate of starch synthesis and starch phosphorylase activity. It is suggested that the activity of starch phosphorylase may be a major factor in controlling the rate of starch formation in the pea. The rate of starch synthesis began to decrease when the pea ceased to gain water and the linear relationship then no longer held. The bearing of these observations on sugar-starch relationships and on the general problems of growth is discussed.

RESPIRATION OF THE SPADIX FROM THE AROID ZANTEDESCHIA AETHIOPICA SPRENG. *M. D. Hatch and Adele Millerd*. Aust. J. Biol. Sci. 10: 310–19 (1957).*

WATER-SOLUBLE CONSTITUENTS OF FRUIT. VI. THE AMINO ACIDS IN APRICOTS AND PEACHES. *T. M. Reynolds. Aust. J. Chem. 10: 198–202 (1957).*

The amino acids in apricots and peaches were fractionated by displacement chromatography on columns of cation-exchange resins and then examined by paper chromatography. The same 18 amino acids were identified in both species. Except for a much lower concentration of proline in peaches the amino acids were present in similar proportions in the two species.

CHEMISTRY OF NON-ENZYMIC BROWNING. I. REACTIONS BETWEEN AMINO ACIDS, ORGANIC ACIDS, AND SUGARS IN FREEZE-DRIED APRICOTS AND PEACHES. *E. F. L. J. Anet and T. M. Reynolds. Aust. J. Chem. 10: 182–92 (1957).*

To increase knowledge of the browning of dried fruits and other foods during storage the water-soluble constituents of apricot and peach purées were examined qualitatively and quantitatively before and after storage for 4 to 16 months at 25°C and 70 per cent. R.H. All samples contained all the amino acids, organic acids, sugars, and polyols previously detected in the two species of fruit (see *C.S.I.R.O. Food Pres. Quart.* **15**: 80 and **16**: 40).

The stored samples also contained the following compounds: eleven 1-(*N*-amino acid)-1-deoxyfructoses, traces of two 2-(*N*-amino acid)-2-deoxyglucoses, nine by-products of unknown constitution formed from the reaction between glucose and aspartic acid and glucose and asparagine, three compounds formed from ammonia and glucose, two series of sucrose, glucose, and fructose mono-esters of malic acid, traces of a sorbitol mono-ester of malic acid, and some sugar mono-esters of citric acid.

The free amino acid or organic acid lost was equal, on a molar basis, to the amino acid-deoxyfructoses (and related compounds) and sugar esters formed. After allowing for these derivatives, as much as 7 per cent. of the total sugar (calculated as hexoses) originally present could not be accounted for.

II. SOME CRYSTALLINE AMINO ACID-DEOXY-SUGARS. *E. F. L. J. Anet. Aust. J. Chem. 10: 193–7 (1957).*

From the reactions of glycine with glucose, fructose, and xylose, 1-deoxy-1-glycino-D-fructose, 2-deoxy-2-glycino-α-D-glucose, and 1-deoxy-1-glycino-D-*threo*pentulose respectively have been isolated pure and crystalline. Similarly glucose and β-alanine gave 1-β-alanino-1-deoxy-D-fructose.

Copies of the papers mentioned above may be obtained from the Librarian, Division of Food Preservation and Transport, Private Bag, P.O., Homebush, N.S.W. (Telephone: UM 8431, UM 6782, UM 8938).

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Glass-like Deposits in Canned Foods

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OCCASIONALLY, consumers of canned foods encounter, with some alarm, hard transparent particles which are taken to be fragments of glass. Generally, however, these particles are found to be crystalline salts which have precipitated from the product during storage.

Recently four grapes from a can of Sultana grapes of Australian manufacture were submitted to the C.S.I.R.O. laboratories at Homebush for examination. Each grape had glass-like fragments adhering to its skin. These deposits were of a crystalline nature, being hard, transparent, and apparently cubic or rhombic in shape.

Qualitative tests on one of the crystals after separation from the grape skin showed that potassium and tartrate ions were present. The remaining crystals were then recrystallized from water and the equivalent weight and potassium content of the recrystallized material determined by alkaline titration and flame photometry respectively. Within the limits of the experimental error of the determinations, the recrystallized material had the same equivalent weight and potassium content as pure potassium hydrogen tartrate:

	Crystals	KH tartrate
Equivalent Weight	190	188·2
Potassium content	20·7%	20·8%

With the material available it was obviously not possible to investigate the factors influencing the formation of the crystals. However it is interesting to note that in a report of similar deposits of potassium hydrogen tartrate in canned grapes of South African origin, Manley and Alcock (1950) stated that "The presence of cream of tartar in unfermented grape juice and the grape itself was somewhat surprising insomuch as its deposition was understood to take place during the later stages of fermentation."

Two other types of glass-like material have been reported in canned foods. Dickinson and Fowler (1955) identified crystalline deposits in French canned cherries as calcium *dl*-tartrate. The crystals were prisms resembling calcite and some were 12 mm long and 5 mm wide. The authors suggested that the crystals were formed from tartaric acid, which was used to fix the colouring matter, and from excessive quantities of calcium, possibly picked up from cement storage and treatment silos.

A third type of glass-like material is struvite (magnesium ammonium phosphate) which has been found in a number of canned marine products including crayfish (rock lobster), shrimp, and salmon (Purcell and Hickey 1922; James 1933; Hess 1942). The factors influencing the growth of struvite crystals and methods for preventing their formation have been investigated extensively overseas (Dreosti and van der Merwe 1949; McFee and Swaine 1953). This Division, however, has not heard of struvite occurring in Australian canned fish or crustacea.

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REPORTS ON FISH STORAGE

A USEFUL set of reports entitled "Refrigeration of Fish", prepared by Charles Butler and others, was issued by the Fish and Wildlife Service of the United States Department of the Interior in 1956. Part 1 (Fishery Leaflet 427) deals with cold storage design, refrigeration equipment, package and product factors in freezing, refrigeration-system factors in freezing, and freezing methods. Part 2 (Fishery Leaflet 428) is concerned with the handling of fresh fish at sea and on shore. Part 3 (Fishery Leaflet 429) deals with changes taking place during freezing and cold storage of fish, and protective coverings for frozen fish. Part 4 (Fishery Leaflet 430) describes the preparation, freezing, and cold storage of fish, shellfish, and pre-cooked fishery products. Part 5 (Fishery Leaflet 431) covers distribution and marketing of frozen fishery products.

FOOD SCIENCE ABSTRACTS

CHEMISTRY AND TECHNOLOGY OF CITRUS, CITRUS PRODUCTS, AND BY-PRODUCTS. *E. A. Beavens and others. U.S. Dep. Agric., Agric. Handb. No. 98, 1956. 99 pp.*

A review of 495 papers on: the structure and chemical composition of citrus fruits; the processing of canned juices and sections, chilled and sulphured juices, pasteurized concentrates, bases for beverages, frozen concentrates, purées, and powdered juices; citrus by-products, such as pectin, citric acid, seed and essential oils, flavonoids, citrus vinegar, marmalades, and brined and candied citrus peels; uses for citrus waste products as feeding-stuffs, and for the manufacture of yeast, alcohol, and lactic acid; and disposal of unused wastes. This Handbook supersedes Circular 577.

A SALT-TOLERANT DENITRIFYING BACILLUS STRAIN WHICH "BLOWS" CANNED BACON. *B. P. Eddy and M. Ingram. J. Appl. Bact. 19: 62–70 (1956).*

A strain of *Bacillus* isolated from a "blown" can of bacon was found to tolerate 15 per cent. of sodium chloride, and to reduce nitrate and nitrite to nitrous oxide and nitrogen. The pH-salt relations, tolerance to nitrite under aerobic and anaerobic conditions, and heat-resistance of the spores were investigated. Gas was not produced from carbohydrates. The spores of the organisms were not very resistant to heat, but should any of them survive the processing of a cured meat, they would be able to tolerate any likely concentrations of salt, nitrate and nitrite, any likely pH, and ordinary storage temperatures. Their subsequent development and the spoilage of the product seem therefore almost certain.

EFFECT OF A FUNGICIDAL WAX COATING ON THE STORAGE BEHAVIOUR OF MANGOES. *P. B. Mathur and H. Subramanyam. J. Sci. Food Agric. 7: 673–6 (1956).*

Mangoes were dipped in aqueous emulsions containing 1·7 to 2·7 per cent. of a fungicidal wax (microcrystalline petroleum wax 40 parts, low-melting-point thermoplastic terpene resin 31 parts, oleic acid 7 parts, triethanolamine 17 parts, *o*-phenylphenol 5 parts). After drying in a current of hot air, the fruits were stored at 79 to 86°F (26 to 30°C) and relative humidity 55 to 87 per cent. The treatment lessened physiological loss of weight and rate of respiration, increased retention of vitamin C and moisture, delayed ripening, and decreased percentage loss from decay. Treatment with the highest concentration of the wax increased storage life by 50 per cent.

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