C. Brown

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# Chemical Aspects of Food Processing

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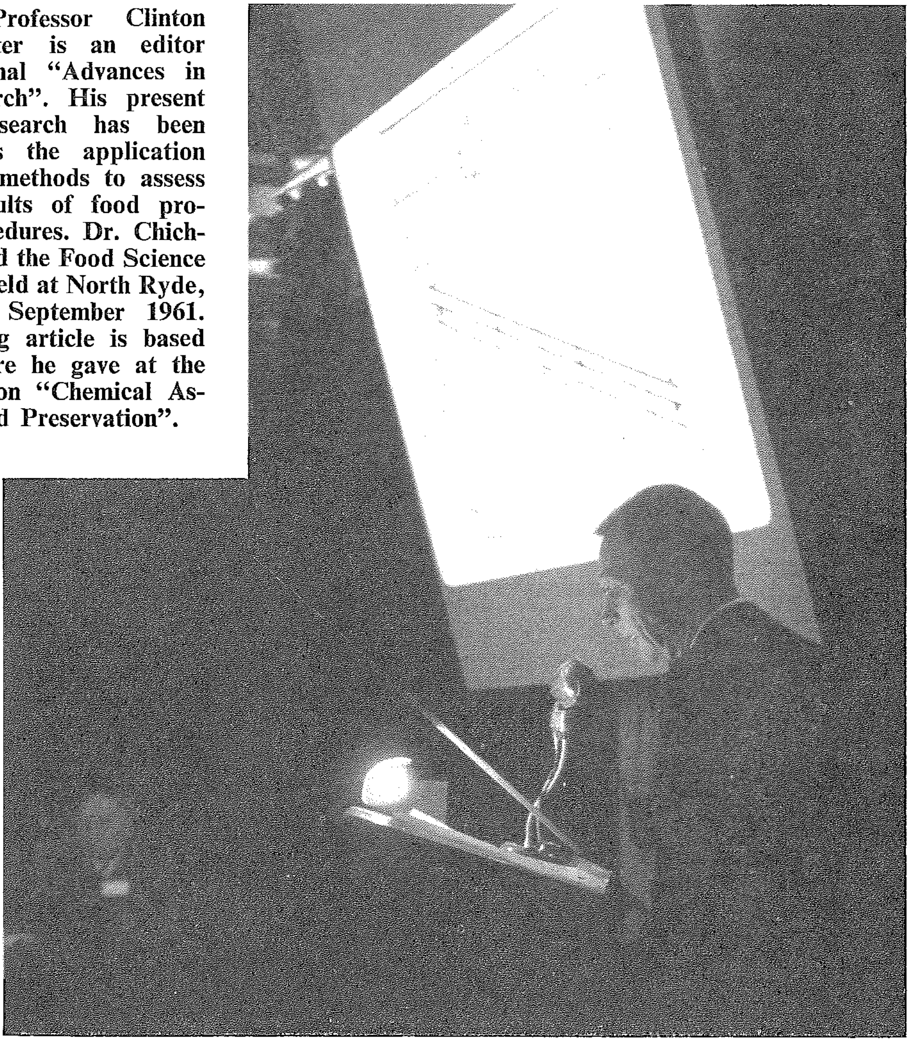

*Dr. Chichester lecturing at the Conference.*

THE preservation of food materials dates back as far as recorded history. Until recently preservation was, to a large measure, the avoidance of spoilage by microbial or enzymatic attack. Quality factors in food supplies were often neglected for the primary purpose of maintaining a food supply despite inclement aspects of the environment. The removal of water, the addition of chemicals or fermentation led to different methods of preservation.

The advent of thermal processing of foods changed the picture immensely. A technology based upon the destruction of enzymes and microorganisms by heat or their inhibition by low temperatures allowed freedom for the consideration of quality factors. The technology of food preservation was advanced in manifold ways by sterilization and the use of the hermetically sealed container. A great amount of effort has been concentrated on increasing the safety, nutritional value, economy, and quality of thermally preserved foods. Since such foods are invariably above 75% moisture, the basic engineering processes concern themselves with the heating or cooling of the water content of food. Most microbes and enzymes exhibit rather narrow temperature ranges for their activities. The temperature coefficients involved in either of these systems are immense over particular temperature ranges. In most instances, having achieved a critical temperature, one can consider that all microbiological or enzymatic activities are halted. Subsequent lowering of the temperature from these thresholds does not, under most circumstances, allow a reversible change to take place. In effect then, destructive processes are halted. This generality does not apply to frozen materials, but since a large number of the materials preserved by freezing are first heated to inactivate enzymes, a similar nonreversible process takes place.

Chemical reactions occurring in food materials do not, in the ranges of temperature used commercially, undergo a nonreversible change. So long as the various chemical species exist in the food material, reactions (in which they can take part) continue. These reactions are accelerated by higher, and slowed at lower, temperatures.

From a quality aspect, as well as a nutritional one, chemical reactions which continue after thermal preservation are in many cases extremely important. The reacting species in the food may exist only in minute concentration yet their effect on the entire system may be profound. In the case of odour or taste, minute quantities of organic materials have a major effect on the food. The reactions which take place (during storage) may destroy the food or otherwise render it inedible. The biological systems in which these reactions (desirable or undesirable) take place are extremely complicated, containing a multitude of extremely reactive species which are no longer separated as in the original living cell. The investigation of these biological systems as they are related to the quality of the food is a major task which requires a multi-disciplined approach in research, perhaps best typified in the food scientist.

## DARKENING OF ASPARAGUS

Several examples may be cited in which the minor constituents effect a major change in the quality of the food upon processing. In the U.S.A. darkening of canned green asparagus has occurred sporadically for the last 35 years. The asparagus, upon opening the can, appears to be perfectly normal but darkens rapidly within 10–15 min. Within recent years, there has been an ever increasing occurrence of this phenomenon and consequently a concerted effort was made to ascertain its cause with a view to prevention.

Analysis of the darkened vegetable showed that the iron content was high, although exceptions were found. It was found, in almost all cases where there was a significant amount of darkening, that the interior of the can was not appreciably attacked. Campbell (1939), in an investigation of asparagus canned in glass, noted that after storage a precipitate formed in the bottom of the container. He identified this as a flavanone or a flavanol. Later DeEds and Couch (1948) established that the precipitated material found in glass-canned asparagus was the flavanol rutin, a rhamno-glucoside of quercitin. The flavanols, in general, will react with trivalent metals, such as iron and aluminium, to form coloured complexes; in fact, at one time, the flavanols were used as industrial dyes. Thus it was apparent (Stevenson 1950) that the discoloration encountered in the asparagus was due to a metallic flavanol complex.

An investigation was made of the general chemical composition of asparagus and of the effect of a number of growing variables upon the rutin content of the spears. Dame, Chichester, and Marsh (1957*a*) found that the concentration of rutin in the asparagus spear varied directly with the height of the spear above the ground, the age of the spear, and inversely as the spear increased in diameter. The trend towards the canning of tips in small containers and the use of older spears in certain larger packs pointed to a higher average rutin content in the affected asparagus.

The solubility of rutin increases rapidly above 75°C and is some 50-fold higher at 100°C than at normal room temperature (Griffith, Krewson, and Nagliski 1955). In recent years, the industrial practices in the blanching of asparagus have changed. In order to increase efficiency and quality, a steam blanch has been substituted for the former traditional water blanch. Dame, Chichester, and Marsh (1957*b*) reported that while a *water* blanch reduced the rutin concentration in canned asparagus by approximately 22%, the currently used *steam* blanch procedure did not affect the concentration appreciably. These facts would help explain two phenomena. The use of a steam blanch would result in a higher average rutin content in the canned material and would thus increase the probability of darkening. The pronounced change in solubility with higher temperatures would account for the precipitation of rutin in glass containers.

### Container Discoloration

No rutin precipitation is, however, observed in tin containers. Dame, Chichester, and Marsh (1959), as a part of the overall investigation, reported on the solubility of metallic rutin complexes and found that the solubility of a rutin tin complex exceeds by over three times the solubility of rutin in a pH 5 solution at equivalent temperatures, thus explaining the non-precipitation of rutin in the canned product.

As a part of the attack on the discoloration problem, it was found that certain batches of tin containers were far more susceptible to discoloration than others. In most cases, these proved to be containers which had been stored for a considerable time prior to usage. The effect has been ascribed to the formation of a moderately resistant oxide coating on the tin plate. The susceptibility to discoloration could be reduced significantly by washing the container prior to use with a light acid solution. Davis *et al.* (1961) reported that if the ratio tin : iron in the brine falls appreciably below 15, discoloration is apt to occur. They suggested that tin in the stannous state functions to prevent the oxidation of ferrous iron to the ferric form, thus holding the ferric concentration below that needed for discoloration.

### Citric Acid as a Preventative

The National Canners Association, in cooperation with the University of California, suggested that a preventative measure for the discoloration might lie in the addition of citric acid. In test procedures, it was found that 0·1% citric acid effectively prevented discoloration of asparagus in the presence of large amounts of added iron. The 0·1% solution of citric acid added to asparagus was, however, detectable organoleptically. As a consequence, a recommendation for commercial practice was that either the acid level be reduced to 0·05% or a portion of the citric acid be replaced with sodium citrate.

The citrate ion probably has a twofold effect. It is known that citrate will effectively sequester iron even in the presence of high quantities of calcium, consequently rendering it less available for the darkening reaction. Secondly, a decrease in pH will promote the solubility of tin during processing and maintain a ratio tin : iron in the container which will effectively prevent the discoloration. The addition of this small amount of acid does not materially affect the shelf life of the containers. It is to be noted in this case that the discoloration problem is caused by compounds whose concentration is, under the most adverse conditions, less than 0·001%.

## CHLOROPHYLL COLOUR CHANGES

A second chemical problem with which we have been concerned is the change in colour of green vegetables when canned. The literature on chlorophyll is extensive and a number of patents have been issued for processes said to preserve the colour of green vegetables during processing (Lesley and Shumate 1937; Arnoff 1953). The basic change in chlorophyll during heat processing is its conversion to phaeophytin through the replacement of magnesium by hydrogen. The formation of phaeophytin causes an undesirable change in colour. The rate of conversion of the chlorophylls to phaeophytin is a function of both pH and temperature since it is, like many other deteriorative changes, a normal chemical reaction. With the advent of aseptic processing techniques, it proved possible to produce a green food product which had undergone only a minimal heat treatment and yet was sterile. Under these conditions, the green products retain a relatively high percentage of their chlorophyll in an unreacted form. The storage stability of the products, however, is very poor.

With this impetus, a general investigation of chlorophyll during processing was initiated. Borodin (1882) at an early date postulated a slower rate of conversion of the chlorophyllides to their respective phaeophorbides than that of chlorophyll to phaeophytin. A patent was issued to Lesley and Shumate (1937), on this speculation, for the prevention of storage, or processing, deterioration of green vegetables.

## High pH Processing

Another approach suggested by Blair and Ayres (1943) was processing at a relatively high pH in the presence of magnesium. This is known as the Blair process, or simply as high pH processing. It produces, under normal circumstances, an extremely attractive product but, upon storage, the conversion of chlorophyll to phaeophytin still takes place. In the first instance, no data as to the relative stability of the chlorophyllides were available and, as a consequence, an investigation of their relative stability was made. The chlorophyllides differ from chlorophyll in that they no longer possess a phytol alcohol in position 7. Nevertheless the two have identical absorption spectra. Figure 1 shows the absorption spectra of methyl chlorophyllide *b*, ethyl chlorophyllide *b* and chlorophyll *b*. Since most green plants contain the enzyme chlorophyllase, which is capable of initiating the removal of the $C_{20}$ alcohol from the ring, it is conceivable that this reaction could be induced to occur during processing. If the chlorophyllides were appreciably more stable than their parent compounds, the colour of the product would be retained. Ethyl, methyl, and free acid chlorophyllides were prepared from both chlorophyll *a* and *b* by enzymatic hydrolysis in the presence of the appropriate solvent. The rate of hydrolysis was then observed in the presence of various acids and at a series of differing temperatures. The rate of conversion of chlorophyll *b* was found to be 5·5 times slower than chlorophyll *a*, rather than 9 times as previously reported. The chlorophyllides, ethyl, methyl, and free, were found to have stability of the same order of magnitude as the chlorophylls themselves and the changes in rate of conversion which were observed were in the wrong direction, that is, a slight increase in the rate of hydrolysis occurred with the shortening of the side chain. Figure 2 shows the rate constants for chlorophyll *a* and its derivatives, Figure 3 illustrates the rate constants for chlorophyll *b* and its derivatives. The result, which would not be encouraging from the food processor's view, is of some basic value. The difference found in rates of hydrolysis in the chlorophyllides can be related to the chlorophylls. It rules out steric hindrance as the cause of the difference between the rate of hydrolysis of chlorophyll *a* and *b* since the $C_{20}$ side chain should exert a greater steric effect than the formyl group of chlorophyll *b*.

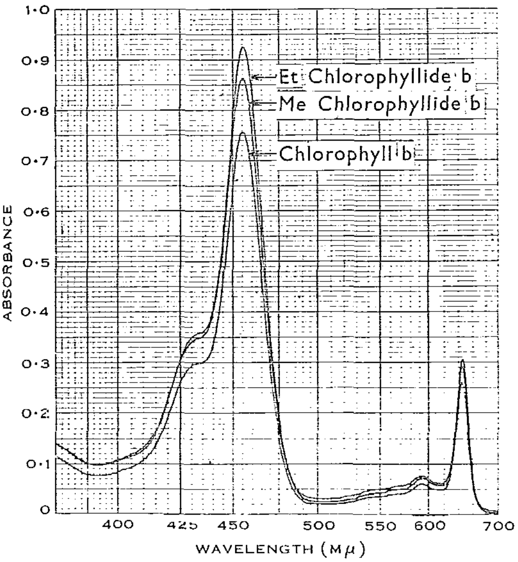

*Fig. 1.—Absorption spectra of methyl chlorophyllide* b, *ethyl chlorophyllide* b, *and chlorophyll* b.

## Canning Trials

In canning trials of various processes for the stabilization of chlorophyll, it was observed that, in both commercial and experimental packs, an occasional container (usually glass) would retain its green colour to a remarkable degree. On other occasions (after prolonged storage) the typical fresh green colour would return to vegetables which originally had been olive drab in colour. Chromatographic analysis of the chlorophyll derivatives present in these containers indicated the presence of no unreacted chlorophyll, but did indicate the

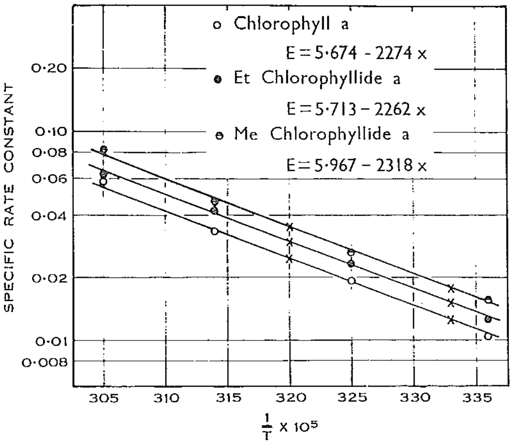

*Fig. 2.—Rate constants for chlorophyll* a *and its derivatives.*

presence of a number of species of phaeophytin. Phaeophytin as such, of course, would not account for the colour found. As a consequence, the study was extended to consider the metallic ion complexes of chlorophyll. The presence of copper, in a processed food, will convert the chlorophyll containing magnesium to a copper derivative, which is remarkably resistant to the removal of the metallic ion by acid. The colour of the product, however, is readily distinguished from a product containing only chlorophyll. As a consequence, the use of copper to stabilize chlorophyll in processing has not been of particular advantage. Analysis for metallic ion in the stored green vegetables revealed the presence of considerable amounts of zinc and copper. Separation of the phaeophytin-like compounds by chromatography and their analysis on an emission spectrograph also indicated the presence of both zinc and copper.

It was found possible, in model system experiments, to replace, rather easily, the hydrogen in phaeophytin or phaeophorbides by zinc or copper, with a subsequent change in colour to one quite closely resembling the original chlorophyll. An extension of this work on a pilot scale indicated that, at extremely low copper–zinc concentrations, it was possible to change the colour of the processed green vegetables from the typical phaeophytin colour to a remarkably natural green. The reaction is thought to be a replacement and complexing reaction at the level of a phaeophorbide. The colour produced under these circumstances does not resemble copper chlorophyll. The conditions for this chemical reaction are rather drastic, requiring a reheat treatment after complete conversion of the chlorophyll to phaeophytin or phaeophorbide. The concentration of metallic ions is approximately 12–20 p.p.m., resembling the natural concentration of these ions in vegetables quite closely.

## HEAT DAMAGE TO TOMATO PRODUCTS

There has been a trend in the canning industry towards the packing of higher solids tomato products. As the average solids content of paste or concentrate has increased to above 26% its corrosivity has become a problem. Studies conducted in the laboratories of the University of California indicated that part of the effect could be ascribed to "heat damage" of the product. "Heat damage" is a rather ill-defined term which refers to undesirable changes initiated by a high rate of chemical reaction during or after processing. It was found (Luh, Leonard, and Marsh 1958) in these studies that the storage life of tomato products could be estimated by the examination of the light absorption of the separated serum. "Heat damage" results, at least in part, from an

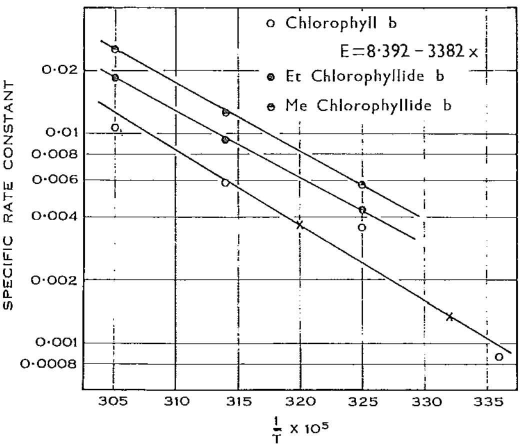

*Fig. 3.—Rate constants for chlorophyll* b *and its derivatives.*

accelerated Maillard reaction or browning reaction, the net effect visually being an increase in pigmented materials absorbing in the blue region of the spectrum.

The corrosive effects of copper in tomato pastes were neglected in these investigations since it has long been known that copper derived from various alloys in the processing line can significantly shorten the life of canned products. Since the commercial processing of paste has been carefully controlled for some time to avoid copper contamination, the corrosiveness now experienced must be ascribed to other causes.

In cooperation with the Department of Food Science and Technology at Davis, the American Can Company has recently completed a study (Hernandez, unpublished) of other factors affecting the corrosivity of tomato paste. The factors studied were aeration of the product, resulting in oxidation of ascorbic acid coupled with other as yet uninvestigated oxidations: pectin breakdown as it is affected by process variables and the rate of cooling of the canned tomato concentrates.

It is well known that dehydroascorbic acid and diketogulonic acid in fruit juice will attack the tin coating of containers rapidly. Since fresh tomato products contain moderately high concentrations of ascorbic acid (20 mg per 100 g of juice) the concentrated product contains very significant amounts.

## High Corrosivity

The effects of dehydroascorbic acid in the concentrates was determined by the direct addition of various amounts of dehydroascorbic acid to 603 × 700 plain bodied cans of tomato paste which had been commercially packed. In all cases there was an increase in corrosivity and thus the service of the container was reduced. The effect of aeration was determined by whipping air into a 26% solid paste at 190–200°F for a period of 10 min just before filling and cooling in 603 × 700 cans. An increase in corrosivity was again noted. In all cases the tin loss of the can was determined electrolytically, by stripping samples of cans whose tin coating had initially been determined by X-ray thickness gauge measurements.

It also had been shown in 1955 (Vosti, unpublished data) that low methoxy pectin was a factor in the corrosion of pear nectars. The effect of process variables on pectins was studied by the investigation of commercial samples of tomato paste whose history was

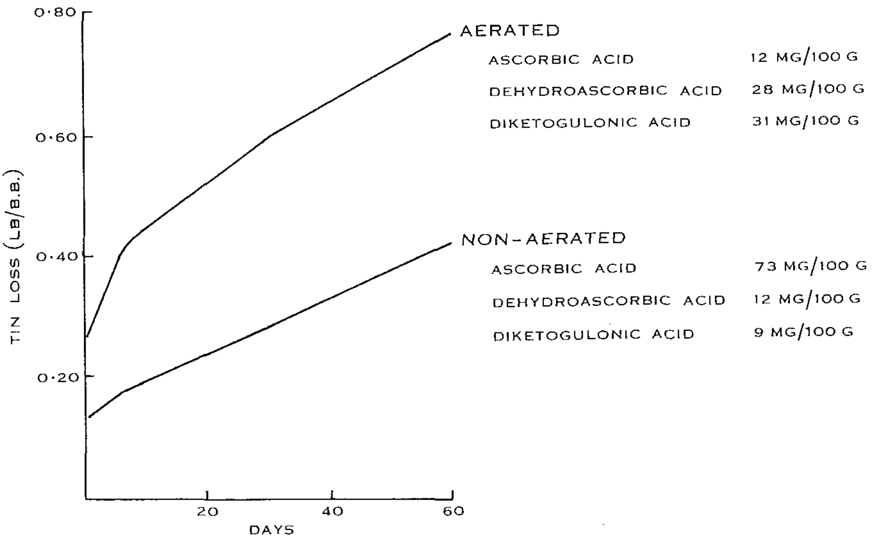

*Fig. 4.—Effect of aeration on detinning.*

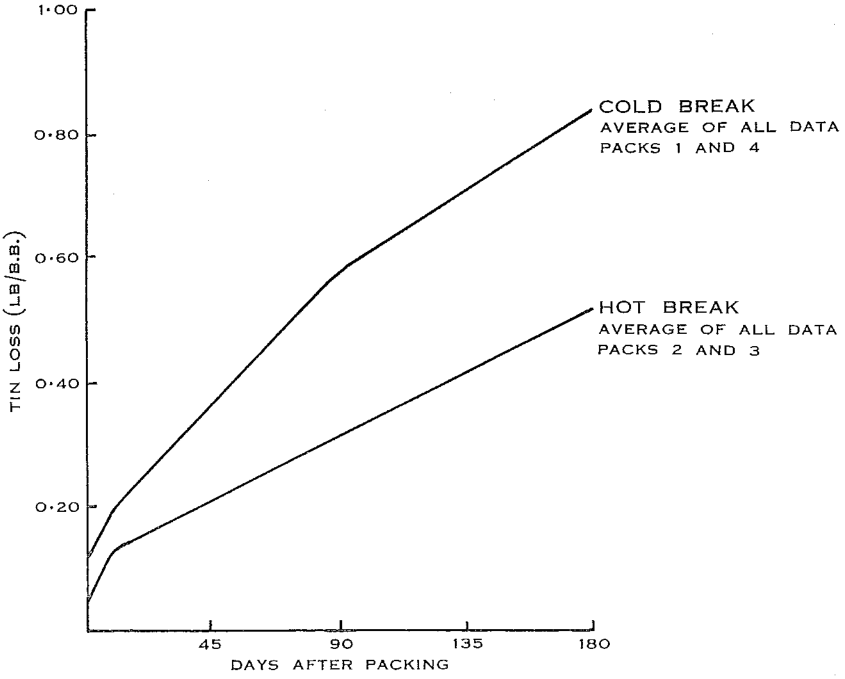

*Fig. 5.—Effect of break on detinning.*

known. A set of experiments was conducted with hot-break juice and a second set with cold-break juice. The effect of cold break, of course, should be to increase pectin breakdown products.

As "heat damage" also was known to affect the storage life of tomato products the effect of cooling should be a factor in corrosivity. In one series of experiments 603 × 700 cans were air-cooled in stacks, and a similar set was cooled in water which was kept agitated.

The addition of dehydroascorbic acid to the paste accelerated the de-tinning of containers and significantly reduced their storage life. Aeration which would contribute naturally to the oxidation of ascorbic acid had the same effect, but the contribution of a single compound in a complex organic system undergoing oxidation is difficult to assess. Processed food stored in containers represents such a dynamic chemical system that the contribution of ascorbic acid to corrosivity in tomato paste can be described only in a general way. It is shown in Figure 4 that over a 60-day period the aerated paste caused a tin loss which was almost three times that of the non-aerated.

## Cold Break Products Inferior

A summary of a number of experiments involving various commercial samples showed that the cold break product had significantly less storage life than the hot break product (Fig. 5). In experiments where pectin breakdown products were added to paste, the same effect was noted. Analysis of the pectin products in the hot and cold breaks would in general indicate that cold-break paste could be expected to have a higher level of low methoxy pectin and galacturonic acid and thus a markedly shorter shelf life.

The inadequate or slow cooling of high concentration tomato products could lead to quite a number of chemical changes within the paste. It might be expected that the breakdown of pectin materials would be enhanced but probably the most significant reaction is the production of the typical browning reaction products. The overall effect can be split into two phases. Slow cooling enhances chemical reactions taking place at the surface of the container. It was

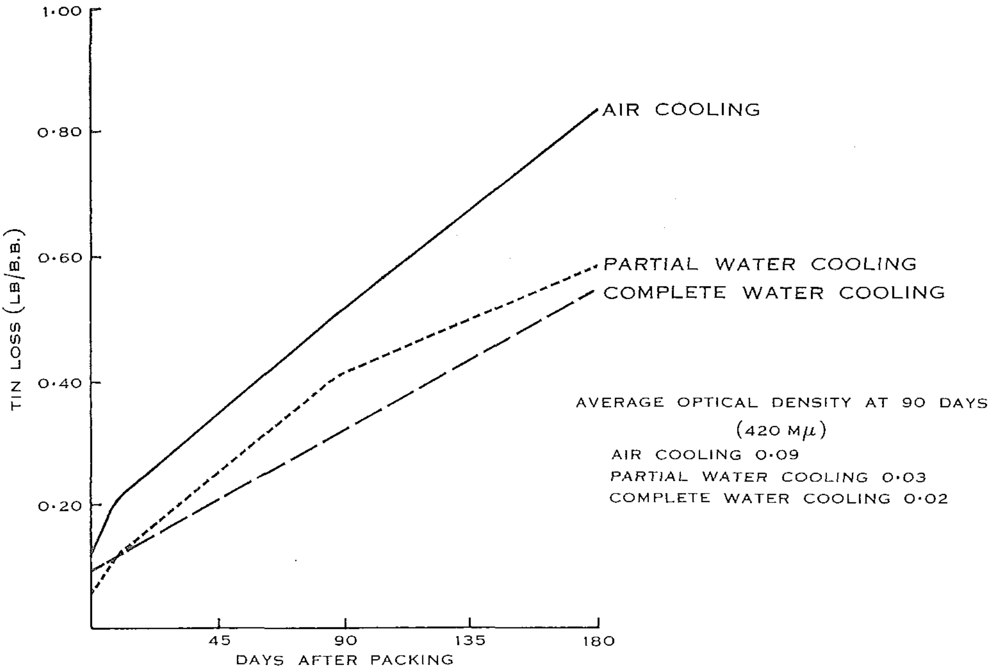

*Fig. 6.—Effect of cooling on detinning.*

found that the initial de-tinning which took place in one day after packing was significantly higher for the air-cooled, than for the water-cooled, paste. Secondly the slow-cooled tomato concentrates displayed a rate of de-tinning, for the rest of the storage periods investigated, significantly higher than that found in the rapidly cooled paste. Thus, rapid cooling would reduce the initial de-tinning by lowering surface temperatures as well as reducing the general chemical reactions the paste undergoes at high temperatures, which in turn lead to a high continued rate of tin loss from the container. These effects are shown in Figure 6.

## NEED FOR FURTHER RESEARCH

From this series of experiments concerned with the chemical aspects of food processing it is clear that a significant area of investigation is opened by each new study. Food processing deals with biological systems and the complex interactions during processing require a great deal more scrutiny. Even from a practical point of view there exist apparently simple problems which have not yet been explored but whose solution would make processed food more wholesome, nutritious, and attractive to the consumer.

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# Control of Freezer Burn

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## Introduction

Changes in bloom are invariably the first noticeable effects resulting from frozen storage of unprotected animal tissues. They result from moisture losses caused by sublimation of ice crystals on the surface of the tissue. The changes may appear as a dark discoloration, if the pigments in the surface layer are concentrated and oxidized, and/or as conspicuous blemishes, known as freezer burn. Moran (1934) showed that tissue affected with freezer burn is of a spongy, cork-like nature with numerous micro-cavities which scatter the incident light and so produce the typical pale greyish discoloration. Freezer burn blemishes and dark discoloration are often found side by side on tissue of apparently the same composition (see Fig. 1).

It is known that the desiccation and consequent discoloration of the surface of stored frozen animal tissue can be avoided, or at least minimized, if the evaporative power of the atmosphere in the store is reduced by maintaining a high relative humidity with low temperature and a low rate of air movement. Probably the simplest method of controlling weight losses, if cost could be disregarded, would be the use, prior to freezing, of vapour-proof packaging. It must be stressed, however, that punctures or other damage to even the best grade of packaging material would permit the formation of freezer burn.

*Fig. 1.—The two outside livers show advanced freezer burn; the central one shows normal slight dark discoloration.*

## Experimental Method

The two forms of discoloration resulting from surface desiccation of frozen animal tissue were reproduced under laboratory conditions at the C.S.I.R.O. Meat Research Laboratory. Since it had been observed that freezer burn rarely penetrates more than $\frac{3}{16}$ in. into the tissue, it was considered that slices about $\frac{1}{8}$ in. thick taken from the surface of liver should prove satisfactory for experimental purposes.

So as to simulate a range of commercial storage conditions such slices were frozen, under controlled conditions at various rates, and then stored at 14°F and 78, 88, or 97% relative humidity, in air moving slowly at a constant rate.

## Mechanism of Freezer Burn

The authors (Kaess and Weidemann 1961) covered liver slices with polyethylene film, to avoid weight loss, and froze them rapidly. When the slices were stored without protective film at 14°F a thin layer of compactly arranged cells (known as "a condensed layer") formed on the surface, where ice crystals had sublimed under desiccation. When more moisture was drawn from the ice-free surface layer, typical freezer burn blemishes appeared on the tissue surface. As storage continued, first the condensed layer and then the freezer burn blemishes penetrated towards the interior of the tissue, leading to the condition illustrated in Figure 2.

When liver, left without a surface covering, was frozen slowly it lost weight and a condensed layer formed while freezing was still in progress. This condensed layer, which appeared to be more rigid than that produced on surface-covered, rapidly frozen liver, thickened during storage. Moreover, in contrast with quick freezing, the freezer burn blemishes formed beneath the condensed layer, through which they were clearly visible (Kaess and Weidemann 1962*a*). The extensive areas of ice free tissue found between a comparatively few large ice crystals, which are characteristic of slow freezing with weight loss, appeared to transform readily into the condensed layer. With increasing weight loss the condensed layer increased in thickness and the freezer burn blemishes next to the surface shrank into it. New blemishes formed and penetrated to a greater depth in the tissue (see Fig. 3). Changes brought about by desiccation were found to be almost completely reversible when the moisture loss in the surface layer did not exceed about 0·5 oz per 100 sq. in. With a higher moisture loss, however, irreversible changes occurred. For example with a weight loss of 2 oz per 100 sq. in. or more, the freezer burn blemishes remained after thawing and on occasion were noticeable after cooking.

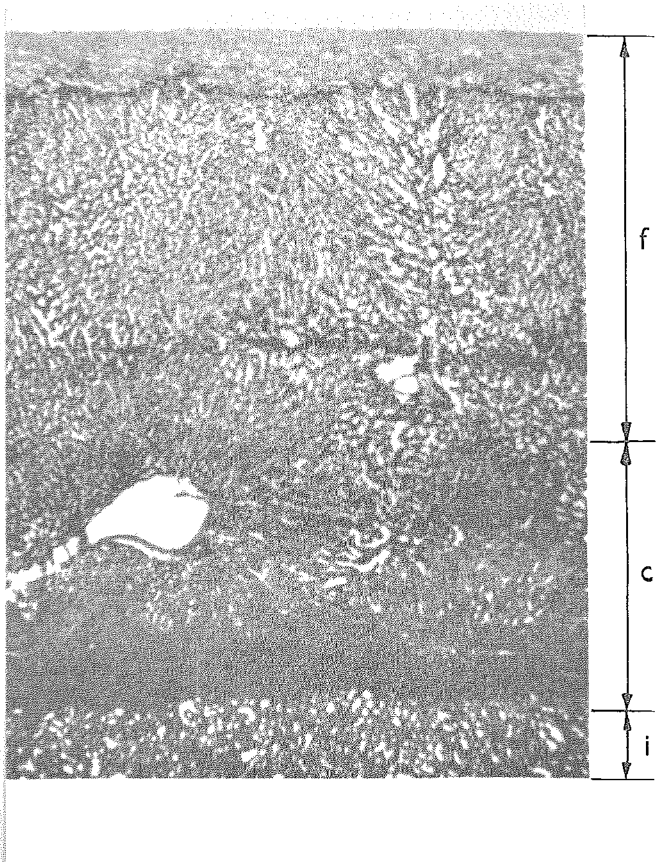

*Fig. 2.—Freeze-fixed section from liver rapidly frozen without weight loss. Severe freezer burn took place during storage at 14°F and 78% relative humidity.* f, *layer with freezer-burn;* c, *condensed layer;* i, *unchanged frozen tissue with ice crystals.*

## Effect of Freezing Conditions

Cooling, intermediate storage before freezing, rate of freezing, and weight losses within these steps are factors which may vary to a large extent in commercial refrigeration. A study of these factors revealed that the mode of freezing can have a great influence on the development of freezer burn. Quite unexpectedly it was found that freezing livers from mature animals rapidly with no weight loss resulted in the maximum formation of freezer burn with a small weight loss during storage (0·06 oz per 100 sq. in.). The weight loss was found to be independent of the rate of evaporation during storage and of the composition of liver (Kaess 1961). The age of the animal from which the liver was taken, however, proved of importance. When the same conditions of freezing as for mature livers were used, the onset of freezer burn was delayed in livers from young animals and was virtually impossible to produce in foetal livers.

The prestorage of liver at 36°F for one week retarded significantly the appearance of freezer burn but the noticeable loss in quality which occurred appears to preclude the commercial adoption of this practice.

Desiccation of the liver surface, at a temperature a little above the freezing point, delayed freezer burn slightly, though significantly, but only excessive moisture removal could prevent freezer burn in storage. However, if freezing was delayed after desiccation, the latter effect was partly or wholly counteracted by moisture diffusion from the interior to the surface of the liver.

Loss of weight during the actual process of freezing had an appreciable effect in suppressing the onset and development of freezer burn. The effect became more marked with increase in weight loss during freezing, as a consequence of desiccation of the surface layer of the tissue, and as a result of the crystal pattern of few large crystals, formed at the reduced rate of freezing. The weight loss during freezing proved almost directly proportional to the time required for freezing.

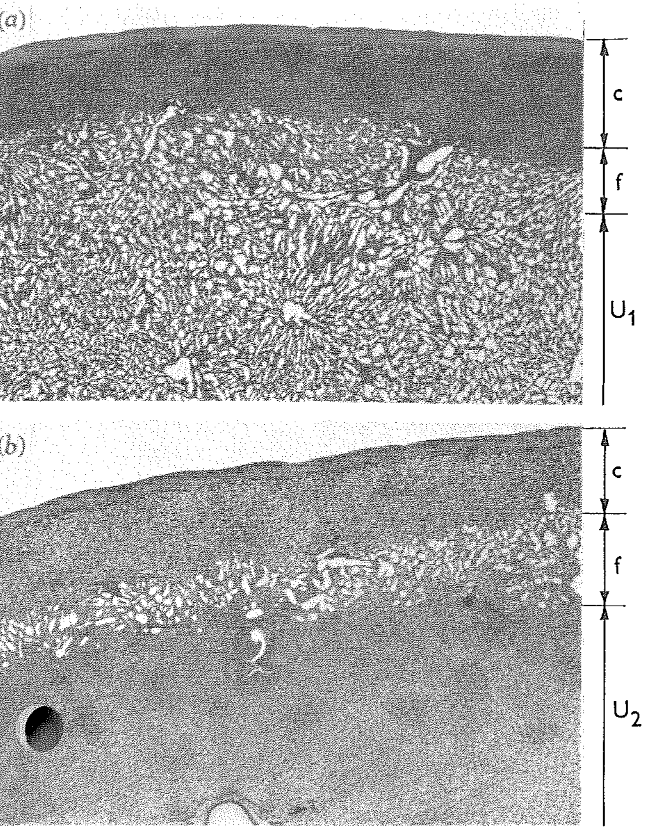

*Fig. 3.—Section from liver with an advanced stage of freezer-burn. Liver slowly frozen with weight loss and stored at 14°F and 78% relative humidity.* (a) *Tissue freeze-fixed;* (b) *tissue fixed at room temperature.* c, *Condensed layer;* f, *zone with freezer-burn;* $U_{1,2}$, *zone of unchanged tissue;* $U_1$, *with ice crystals;* $U_2$, *defrosted. Freezer-burn cavities are not easy to distinguish from ice crystals in* (a) *but can be seen clearly in* (b).

Slow freezing with weight loss appears to offer the best protection from freezer burn. With a weight loss of 0·23 oz per 100 sq. in. during freezing, and a fat content of less than 10%, freezer burn was prevented and only a dark discoloration of the surface took place. When, however, the fat content of the liver was high, desiccation during storage still produced freezer burn. Again, a reduced rate of moisture loss, induced by storing the frozen liver at high relative humidity, caused freezer burn to appear at a reduced weight loss.

## Effect of Dipping Treatments

The results of the experiments suggest it is the increased viscidity of the tissue fluids, after the sublimation of the ice crystals, which stabilizes the position of the cells in the newly formed condensed layer and prevents the formation of freezer burn. It was therefore to be expected that solutes which can readily penetrate into the surface of the tissue and increase the viscidity of the tissue fluids would reduce or prevent the formation of freezer burn. The dipping of livers for 10 min, prior to freezing, in solutions of 20% (w/w) glycerol, 25% sorbitol, 20% urea, 15% sodium chloride, or 10% sodium chloride containing 0·5% tetrasodium pyrophosphate and 0·1% magnesium chloride was found to prevent freezer burn on livers of all fat contents. A similar treatment with 25% fructose or 30% glucose eliminated the condition on livers with fat contents up to 25% and substantially reduced it on those of higher fat content. The success of these treatments was found to be independent of the rate of freezing (Kaess and Weidemann 1962*b*).

Experiments still in progress are showing that, in principle, the development of freezer burn on other beef tissue follows the same pattern as with livers.

## Control of Freezer Burn

As a result of the experiments two treatments are suggested for the prevention of freezer burn: (i) the elimination of moisture loss in storage, or its restriction below the limit necessary for the onset of freezer burn; (ii) the formation of a condensed layer by application of a slow freezing process with weight loss or, more effectively, by treating with one of several solutions before freezing.

### (i) *Restriction of Moisture Loss*

High relative humidities are needed to restrict weight loss sufficiently to prevent freezer burn over an extended storage period. Cook (1940) recommended a relative humidity of 96% at a temperature of —6°F to prevent the condition developing on dressed poultry stored for up to 10 months. The maintenance of such a high humidity in ordinary stores necessitates a refrigeration system with a large cooling surface. Jacketed cold stores would be the most suitable. In many instances, cold stores with sufficiently high humidities are not, at present, available. Barriers to water-vapour movement, applied as wrappers or as part of the packaging, offer good protection against moisture loss but the packages must be carefully handled because freezer burn will appear at the site of any defects in the wrapper. Since freezer burn has been observed in air pockets within sealed containers, resulting from sublimation–condensation effects caused by temperature fluctuations, flexible packaging materials should be tightly fitted to the surface of the frozen product. If rigid containers are used, they must be filled to capacity.

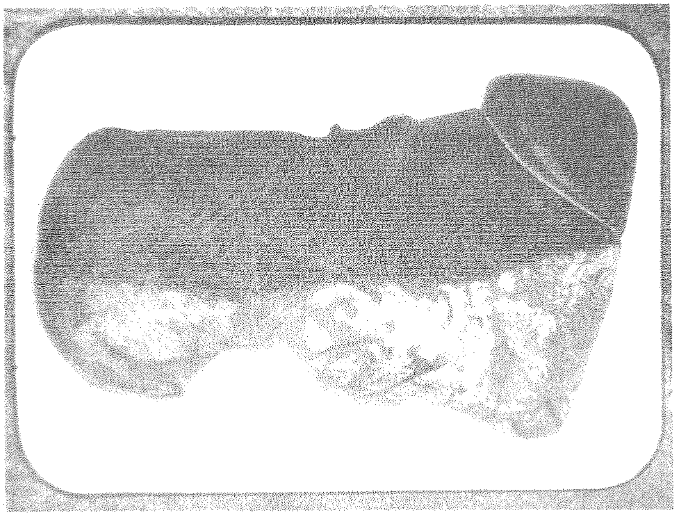

*Fig. 4.—High-fat liver slowly frozen without loss. The lower half, untreated, developed severe freezer burn, the upper half, dipped 10 min in 15% salt solution, remained free of freezer burn during storage at 7°F and 85% relative humidity.*

It is an accepted fact with many commodities that a rapidly frozen product maintains its quality better than one slowly frozen. From experience with liver, however, it appears that it is the rapidly frozen product, especially when frozen without weight loss, which is the most sensitive to freezer burn. It would appear, therefore, that where rapid freezing is practised, there is no satisfactory alternative to the use of packaging materials of low permeability. Lean livers frozen slowly, with weight loss, need no protection against development of freezer burn in storage, and if it is necessary to prevent darkening, low to medium grade barriers should prove adequate. With livers of high fat content, frozen slowly with weight loss, only the earliest stages of freezer burn are likely to appear, and medium grade barriers should be sufficient to prevent both this condition and excessive dark discoloration.

As yet it is not possible to specify the exact value of water-vapour permeability necessary to prevent freezer burn in the various instances mentioned.

(ii) *Introduction of a Condensed Layer*

When several livers are packed and frozen in one cardboard carton having a polyethylene liner, they generally reach overseas markets in good condition. When, however, the wholesaler has to distribute individual livers he prefers them frozen in single units and packed in bags, generally without protective wraps of low moisture-vapour permeability. Under these conditions there will tend to be, depending on the fat content and rate of freezing, a certain amount of freezer burn.

Where the use of barriers to water vapour is precluded by high cost, as is the case with carcass meat, the application of the slow freezing process with weight loss or the use of dipping solutions before freezing recommend themselves. The meat industry has increasingly adopted rapid freezing which results in products particularly sensitive to the onset of freezer burn. In the absence of moisture-proof wrapping, the condition can be prevented by the use of the solutions which have been mentioned. Their application either as a spray or dip is simple and should not appreciably interfere with cooling and freezing. Figure 4 shows a liver, the lower half of which was dipped in a 15% solution of sodium chloride before freezing. During storage at 7°F and 85% relative humidity (without wraps) the untreated half developed severe freezer burn while the treated (lower half) surface remained entirely free.

## Application of Dipping Solutions

Care would have to be taken to have the solutions used at the specified concentrations for their effect is noticeably reduced if they are diluted below about three-quarters of the prescribed strength. On the other hand, the use of concentrations higher than those specified would not have any practical advantage and would tend to produce a surface gloss. Applications of solutions of glycerol, sorbitol, and urea at the recommended concentrations do not result in any appreciable colour changes. When the concentration of hexose solutions is kept below 30% colour changes on the surface, due to desiccation during storage, are not excessive but with higher concentrations the changes become more marked. On the other hand dipping in a 15% sodium chloride solution, for reasons not understood, noticeably enhances darkening during the desiccation in storage. It is, however, possible to take advantage of the efficacy of sodium chloride in preventing freezer burn, by reducing its concentration to 10% and adding 0·5% pyrophosphate. The latter has a pronounced solubilizing effect on proteins in the presence of sodium chloride of sufficient ionic strength and of a small concentration of magnesium chloride, and in livers with a fat content of up to 20% the onset of freezer burn may be retarded until after darkening.

The quantities of solutes penetrating the surface of liver during a 10-min treatment are very small and in any case sodium chloride, urea, and the hexoses are normally present in small amounts in animal tissue. In the U.S.A. there is no statutory objection to the incorporation of urea into packaging materials which are in direct contact with food (Anon. 1960) and glycerol and sorbitol are allowed as additives to certain foods (Anon. 1956); in Australia they are permitted in certain foods but not in meats.

## Summary

A study of the mechanism of formation of freezer-burn was made, using beef liver as test material, with a view to recommending methods for its prevention. Livers frozen rapidly, with little or no weight loss, are most sensitive to freezer burn and must be packed in wraps with low permeability to water vapour, otherwise this condition will appear at a low level of weight loss during storage. Livers frozen slowly, with appreciable weight loss, develop no freezer burn if lean, or only a moderate amount if fat. The requirement of low permeability in the wrapping material is also less stringent when livers are frozen slowly.

If the use of moisture-proof packaging material has to be excluded for economic reasons freezer burn can be eliminated or minimized by causing a condensed layer to form on the surface of the product. Slow freezing, with weight loss, produces an adequate condensed layer only with livers of low fat content. By the use of dipping treatments, prior to freezing, with solutions of higher alcohols, hexoses, sodium chloride, or urea, freezer burn can be prevented on livers, irrespective of the method of freezing and of their fat content.

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# Electrotinplate for Food Containers

## PART II. THE CORROSION PERFORMANCE OF TINPLATE

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IN the earlier part of this article (Davis 1962) some of the properties of hot-dipped and electrolytic tinplate which affect corrosion behaviour were discussed. This part, dealing with the internal corrosion performance of electrotinplate cans, summarizes results of investigations made in the Division of Food Preservation and also the experience of overseas laboratories.

## SELECTION OF TINPLATE

Electro-depositing tin on steel strip enables coating weights to be varied over a wide range, and electrotinplates of 0·25, 0·50, 0·75, and 1·00 lb/base box are available. In selecting the correct grade of tinplate for a particular food, both the tin coating weight and the corrosiveness of the food have to be considered.

### 0·50 lb/b.b. Electrotinplate

The commercial electrotinplate first produced in the United States had a tin coating weight of 0·50 lb/b.b. Experience prior to 1948 showed cans made entirely from this plate to be satisfactory for a limited number of foods. With dry foods, such as coffee and dried milk, the material was satisfactory, but with wet foods it was not. (Stevenson 1951; Meneilly 1951). Suitably coated with sulphur-resisting (S.R.) lacquers, cans made from 0·50 lb/b.b. plate proved suitable for a range of low-acid, high-protein foods from which the main corrosion reaction is sulphur-staining. Lacquered cans made entirely from 0·50 lb/b.b. electrotinplate were not suitable for either mildly or highly corrosive foods.

"Combination" cans which consisted of plain hot-dipped tinplate bodies and acid-resisting lacquered 0·50 lb/b.b. electrotinplate ends proved satisfactory with a wide range of mildly corrosive fruit and vegetable products normally packed in plain cans. This application greatly increased the amount of electrotinplate used by the canning industry overseas.

### 0·25 lb/b.b. Electrotinplate

The successful introduction of 0·50 lb/b.b. electrotinplate for a range of canned foods prompted research on still lighter coatings. It was soon realized that with sulphur-staining and mildly corrosive foods, for which lacquered 0·50 lb/b.b. plate was used, 0·25 lb/b.b. coatings of tin gave equally satisfactory results (Hartwell 1951; Mutschler 1953). By 1950, 50% of the electrotinplate produced in the U.S.A. had a coating weight of only 0·25 lb/b.b. (Meneilly 1951). Combination cans with 1·25 lb/b.b. hot-dipped bodies and lacquered 0·25 lb/b.b. electrotinplate ends frequently gave a longer shelf life than cans made entirely from hot-dipped tinplate (Hartwell 1956).

### 1·00 lb/b.b. Electrotinplate

Electrotinplate with a coating weight of 1·00 lb/b.b. was developed as a substitute for the conventional 1·25 lb/b.b. hot-dipped tinplate used with foods which could not be packed satisfactorily in cans made from 0·50 or 0·25 lb/b.b. plate. Although early trials with this new coating weight were disappointing, by 1952 development of quality control tests and modifications to manufacturing processes enabled plain 1·00 lb/b.b. electrotinplate cans to be used for commercial packs of tomato juice. Since then, the range of products packed in both plain and acid-resisting (A.R.) lacquered cans made from 1·00 lb/b.b. plate has been greatly extended (Sampson 1953; Jenison 1957; McKirahan, Connell, and Hotchner 1959).

A large proportion of 1·00 lb/b.b. electrotinplate now produced overseas is "differential tinplate" with a coating weight of 1·00 lb/b.b. on one side and 0·25 or 0·50 lb/b.b. on the other. Cans fabricated from this plate have the heavier coating on the inside, and the lighter coating on the outside, surface.

### 0·75 lb/b.b. Electrotinplate

Electrotinplate with a coating weight of 0·75 lb/b.b. has been in use overseas for a number of years for evaporated milk products. It is possible that 0·75 lb/b.b. electrotinplate may find applications with products which are at present packed in cans made from 1·25 lb/b.b. hot-dipped or 1·00 lb/b.b. electrotinplate, but it would be necessary to make test packs with the products concerned.

## TESTS WITH AUSTRALIAN CANNED FOODS

Workers in the Division of Food Preservation have completed two major investigations on the performance of cans made from electrotinplates with Australian canned foods (Davis 1954, 1961).

The first investigation, commenced towards the end of 1949, was made on 0·50 lb/b.b. electrotinplate.

Test cans were made up in accordance with American practice at that time and duplicate packs of the test products were made in commercial canneries.

Results of the tests showed that cans from lacquered 0·50 lb/b.b. electrotinplate and packed with the products mentioned in Table 1 gave a satisfactory performance compared with that of control cans made entirely from 1·25 lb/b.b. hot-dipped tinplate. Later work overseas showed cans with plain bodies having 1·25 lb/b.b. of tin to be satisfactory for peaches and pears, and that lacquered 0·25 lb/b.b. electrotinplate could be used instead of 0·50 lb/b.b. plate for sweet corn, and for the ends of cans for tomato juice, peaches, and pears.

**TABLE 1**

**Programme of Test Packs with 0·50 lb/b.b. Electrotinplate**

P, plain; A.R., acid-resisting lacquer; S.R., sulphur-resisting lacquer; h, hot-dipped; e, electrotinplate.

| Product | Test Cans | | Control Cans, Bodies and Ends |
|---|---|---|---|
| | Bodies | Ends | |
| Peaches and pears | P 1·50h | A.R. 0·50e | P 1·25h |
| Tomato juice | P 1·25h | A.R. 0·50e | P 1·25h |
| Sweet corn | S.R. 0·50e | S.R. 0·50e | S.R. 1·25h |

The second investigation made in the Division of Food Preservation on the performance of electrotinplate containers was designed to assess the suitability of 1·00 lb/b.b. electrotinplate as a substitute for 1·25 lb/b.b. hot-dipped tinplate. The programme of the tests which were made with a wide range of food is shown in Table 2.

The 11 foods chosen covered broadly the mildly corrosive foods normally packed in plain cans, the high-acid, pigmented foods which require A.R. lacquered cans, and the sulphur-staining foods normally packed in either plain or S.R. lacquered cans. Several lacquers and batches of tinplate were included in the tests. The majority of the test

**TABLE 2**

**Programme of Test Packs with 1·00 lb/b.b. Electrotinplate**

P, plain; Oa, oleoresinous A.R.; Ea, Epoxide (Batch A); Eb, Epoxide (Batch B); Os, oleoresinous S.R.

| Product | No. of Electro-tin-plates | Initial Vacuum Level | | Lac-quers |
|---|---|---|---|---|
| | | Low | High | |
| Peaches | 1 | + | + | P |
| Tomato pulp | 1 | + | + | P |
| Plum jam | 1 | + | + | P |
| Green beans | 1 | + | + | P |
| Grapefruit juice | | | | |
| First pack | 1 | + | + | P |
| Second pack | 5 | + | | P |
| Meat loaf | 1 | + | + | P |
| Green peas | 1 | + | + | P |
| Meat-in-gravy | 1 | | + | Eb, Os |
| Processed cheese | 1 | | + | P, Eb |
| Boysenberries | 1 | + | + | Oa, Eb |
| Beetroot (acidified) | | | | |
| First pack | 1 | + | + | Oa, Eb |
| Second pack | 5 | | + | Ea, Eb |
| Third pack | 5 | | + | Ea, Eb |

packs were prepared with high (approx. 15 in. Hg) and low (approx. 5 in. Hg) levels of initial vacuum in the cans.

Results showed that plain cans made from 1·00 lb/b.b. electrotinplate were satisfactory with peaches, green peas, tomato pulp, grapefruit juice, and plum jam, but not with meat loaf, green beans, and processed cheese. Lacquered cans, made from 1·00 lb/b.b. electrotinplate, were satisfactory with processed cheese, meat-in-gravy, and boysenberries. With acidified beetroot, the performance was generally inferior to that of cans made from 1·25 lb/b.b. hot-dipped tinplate and epoxide type lacquers gave a better performance than an oleoresinous lacquer.

## CURRENT TEST PACKS

The suitability of particular grades of tinplate for specific foods is a problem likely to arise when electrotinplate, with a range of tin coating weights, becomes readily available to the Australian industry. It will be necessary to prepare test packs and observe their performance over a period of storage.

Four test packs are being studied in this Laboratory to clarify some uncertainties in the performance of plain cans made from 1·00 lb/b.b. electrotinplate. Test products are luncheon meat, stewed steak, baked beans in tomato sauce, and spaghetti in tomato sauce. The test packs, stored at 100°F and 68°F, are being examined at regular intervals.

Luncheon meat after 30 weeks, and the stewed steak after 24 weeks, of storage show very severe sulphur-staining in the cans of hot-dipped plate used as controls whereas the electrotinplate cans show only minor sulphur-staining. Some evidence of isolated detinning apparent in the electrotinplate cans with both meat products is not considered serious. Isolated detinning which appears as objectionable black spots over the can interiors was found previously with a test pack of meat loaf in plain 1·00 lb/b.b. electrotinplate cans (Davis 1961).

No difference could be discerned in the performance of 1·00 lb/b.b. electrotinplate and 1·25 lb/b.b. hot-dipped tinplate when judged from the general appearance of opened cans, and from the tin and iron contents of baked beans and spaghetti in tomato sauce after storage for 36 weeks. With both products, however, the electrotinplate cans showed a higher vacuum loss than the controls.

The results reported are not conclusive, and it will be necessary to continue examinations over longer storage periods.

## DISCUSSION

It is obviously impractical to test a new container material, particularly a material such as electrotinplate with a range of tin coating weights, with all products for which it is likely to be used. The results obtained in this Laboratory, together with those reported from overseas, may be used as a guide for the choice of container materials for a wider range of foods than those specifically tested.

Plain cans made from 0·25 or 0·50 lb/b.b. electrotinplates should be suitable for dry products, but should not be used for wet foods. When treated with a S.R. lacquer, cans made from 0·25 or 0·50 lb./b.b. electrotinplates should be satisfactory with a wide range of meat and vegetable products where the main corrosion reaction is sulphur-staining, but should not be used when these products have been acidified or packed in an acid sauce. When coated with an A.R. lacquer, 0·25 or 0·50 lb/b.b. electrotinplate should be satisfactory as ends for cans with plain 1·25 lb/b.b. hot-dipped tinplate bodies, for a range of mildly corrosive products normally packed in plain cans. Cans made entirely from plain 1·00 lb/b.b. electrotinplate, or from 1·00 lb/b.b. bodies with A.R. lacquered 0·25 or 0·50 lb/b.b. ends, should be satisfactory for those fruits, vegetables, fruit and vegetable juices, and jams, normally packed in plain cans, but they would be unsuitable for green beans, asparagus, spinach, cherries, processed cheese, solid meat packs, and products such as baked beans and spaghetti packed in tomato sauce. When coated with an A.R. lacquer, cans made entirely from 1·00 lb/b.b. electrotinplate should be satisfactory for pigmented fruits such as berries and cherries and jams made from these fruits but not for acidified beetroot. On present information, acidified beetroot should continue to be packed in 1·25 lb/b.b. hot-dipped tinplate cans lacquered with two coats of an epoxide-type lacquer.

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# Accelerated Freeze-Drying of Foodstuffs

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**Based on an address given by the author to the Commonwealth Cold Storage Association Conference, Melbourne, September 1961.**

## INTRODUCTION

Of all the methods of preserving foods none is more ancient than drying which is known to have been practised by the ancient Egyptians and Babylonians who found that water in food could be changed to vapour on heating. The change of state from ice to vapour without melting is sublimation, which is known as "freeze-drying" when ice is sublimed from frozen foods and biological materials. The process occurs in nature and during frozen storage. It is believed the early Incas of South America may have practised a crude form of freeze-drying over a thousand years ago. Today, their descendants in Bolivia and Peru make a snow-white potato flour called chuño by exposing mashed tubers to the icy winds of the High Andes. Under such conditions fairly high rates of freeze-drying must occur, as they do in the laboratory when histological specimens are subjected to a stream of cold dry air.

Freeze-drying in vacuum, instead of in air, is applicable to any material that can be frozen without damage and has been used for many years for the preparation of blood plasma, vaccines, and antibiotics. Wollaston in the early nineteenth century demonstrated for the first time the principle of sublimation in an evacuated cryophorus, or frost producer. Later, Shackell (1909) used the technique to obtain freeze-dried biological materials, but at the time this was regarded as a laboratory curiosity. When freeze-dried blood plasma was produced by Greaves (1942) for the Armed Services of World War II the potential of the process was fully realized, and a number of patents followed. One of these was a British patent for freeze-drying foods using the heat pump principle. Meanwhile, a large freeze-dryer with refrigerated and scraper condenser was built in Florida for drying fruit juices; it proved uneconomic because the formation of gummy substances on the surfaces of the product restricted further drying. This difficulty has since been overcome in the C.S.I.R.O. Division of Food Preservation by surface-wetting the frozen juice prior to

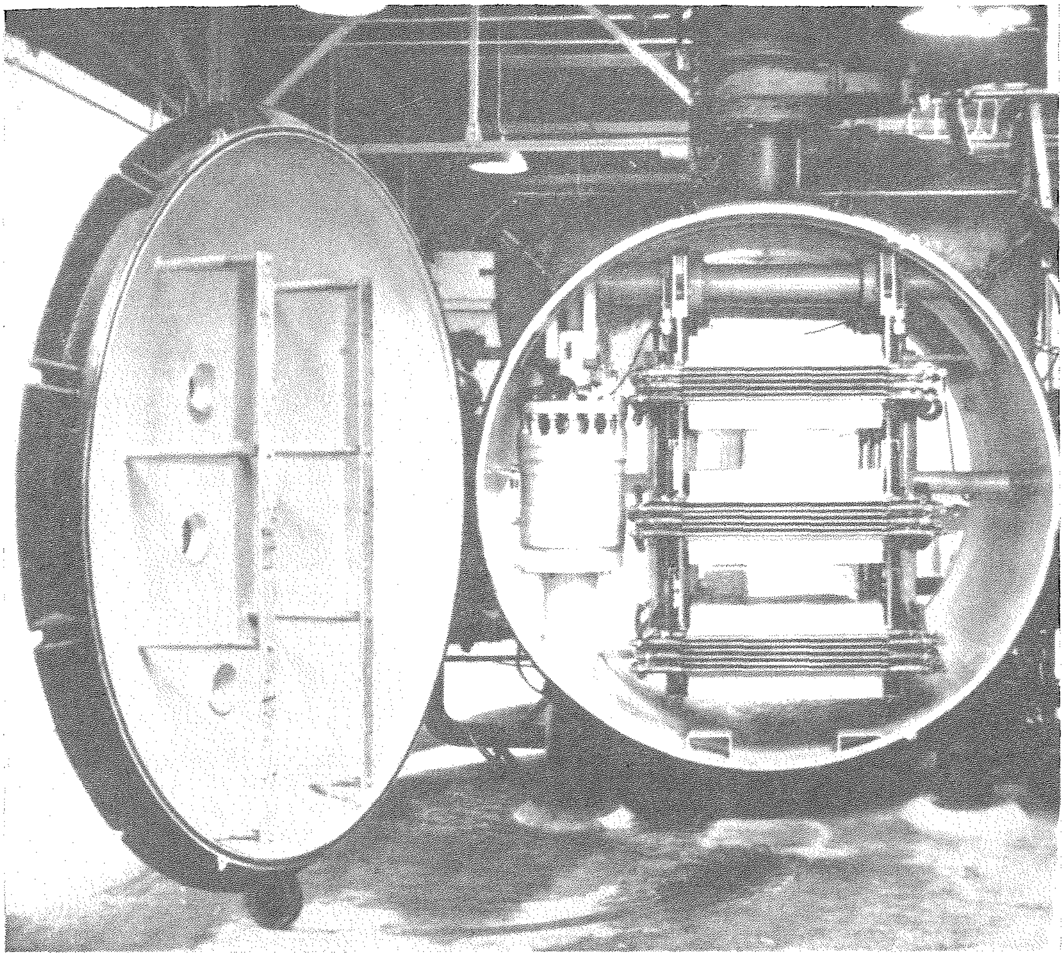


*Fig. 1.—General view of Mark I Accelerated Freeze-Drying Cabinet. (By courtesy of the British Ministry of Agriculture, Fisheries, and Food.)*

drying (Mellor 1954). In addition, aromatic compounds essential for the flavour were lost during vacuum distillation, and these had to be prepared separately and added to the freeze-dried product.

After World War II, work commenced on the dehydration of foodstuffs at the experimental factory of the British Ministry of Agriculture, Fisheries, and Food at Aberdeen, Scotland. Vacuum contact plate drying equipment was used, and, in 1954, trials in initial freeze-drying followed by ordinary vacuum drying of fish fillets were carried out. By 1956 a novel idea for improving drying rate of freeze-dried steaks by impaling them on spiked heater plates was put forward by Brynko and Smithies (1956) of Canada. The Ministry of Food (Gooding and Rolfe 1957) adapted the idea to their existing plant (which had by that time been equipped with more efficient steam ejectors to complete the freeze-drying process) by interposing sheets of expanded metal, instead of spikes, between the drying surfaces of the frozen food and heating platens. Because of the substantially higher rates of freeze-drying achieved the process was named "accelerated freeze-drying". The type of equipment developed is shown in Figure 1. In 1960 details of the new process were released to industry for commercial exploitation.

## PRINCIPLES OF FREEZE-DRYING

The process involves the sublimation of ice from frozen food under vacuum by the application of heat, and the removal of the water vapour from the drying layer and vapour space surrounding it. Within this layer and space, thermal and vapour pressure gradients exist, as well as resistance to the flow of heat and vapour, which are the limiting factors affecting drying rate. There are thus three main considerations involved: heat supply, vapour transfer, and removal of vapour.

(i) Heat for sublimation, of about 1200 b.t.u./lb of ice, can only be supplied to the frozen food at a fixed rate if it is to bring about continuous sublimation. The temperature of the drying boundary will, in such a case, be determined by this rate and will reach a level at which the rates of sublimation and heating are exactly balanced. This is true only if all the subliming vapour can be promptly removed from the dry layer and space, for otherwise its presence retards the escape of vapour from the drying layer.

(ii) Transfer of water vapour takes place by diffusion through the drying layer, which is increasing in thickness, and through the vapour space. It must be recognized that the only force driving water vapour from the drying boundary to this outer region is a vapour pressure gradient.

(iii) Removal of water vapour which reaches the surface of the product and the surrounding space depends on the type of pumping system. The ideal would be to have a very low vapour pressure by locating the throat of the pump or refrigerated condenser in this area. Since this is impossible in practice, it is necessary to increase the vapour pressure gradient by raising the temperature of the drying boundary. However, there is a limit above which the vapour pressure cannot be increased without raising the temperature too high.

### Heat Input

In the usual method of freeze-drying, heat is conducted to the drying boundary from a single surface through the frozen or dry layer. There are, however, technical difficulties involved in maintaining a desired temperature gradient through the frozen layer with constant sublimation and surface heating temperatures. There is also a tendency for drying to take place from the edges of the frozen layer, and at surfaces in contact with the heater plate. The first difficulty has been solved by controlling the temperatures of the heater and drying boundary automatically, and the second can generally be overcome by drying foods at lower temperatures in metal trays.

Heat is introduced as shown in Figure 2 but the boundary and surface temperatures are limited by the maximum safe temperature for the frozen material in question. In some cases this will be its melting point; in others it may be necessary to maintain lower temperatures to prevent denaturation.

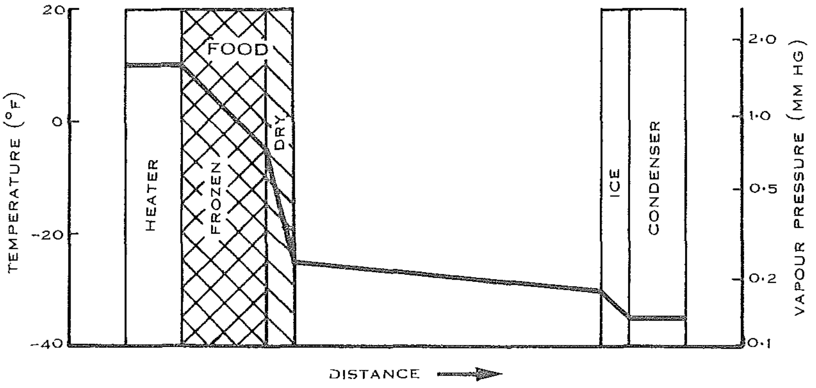


*Fig. 2.—Temperature and vapour pressure gradients in freeze-drying food heated through the frozen layer.*

A second approach to the heat input problem is the use of radiant heat or by the accelerated freeze-drying technique in which a sheet of expanded metal, in close contact with a heater and drying surface, serves as a spacer to allow water vapour to escape. One important advantage of these methods is that drying can be induced from all sides instead of from a single face. Both these methods of heating, however, are far from ideal since it is necessary for the heat to traverse a thermal gradient. Furthermore, the thermal insulation effect provided by the dry layer in a vacuum is considerable (about 0·02 b.t.u./ft hr °F for dry beef). The gradient must be quite steep in order to deliver heat through an appreciable thickness of dry material, but its steepness will be limited by the maximum permissible temperature at the surface. Work in the Division of Food Preservation (Mellor 1962) is directed toward freeze-drying at faster rates without an accompanying rise in the temperature of the surface of the product.

Temperature gradients for heating by radiant heat and by accelerated freeze-drying are shown in Figure 3. It should be noted that radiant heat can only be applied to surfaces of the frozen food in direct line of sight from the heating source.

A third method of heating, shown in Figure 4, has been frequently proposed and occasionally tried. This is high-frequency radiation at wavelengths of about 12 cm (high-energy commercial equipment is available in this range). The rationale of the method is that the drying layer is not heated, only the frozen layer.

There are several disadvantages with this method; feed-back of energy occurs, causing melting, and since water absorbs 4000 times more energy than ice pockets of steam appear with explosive effects. At low frequencies there is a skin effect to a depth of a few microns causing little penetration of heat, and at operating pressures of several millimetres of mercury and less there is maximum corona discharge.

## Vapour Transfer

Resistance to vapour flow may be reduced by punching holes in the drying layer, reducing the thickness of the frozen slab, or by slow freezing—which produces large ice crystals, giving low resistance pathways. It appears some resistance is unavoidable, and efforts must be directed towards increasing the vapour pressure gradient across the barrier by raising the vapour pressure at the drying boundary, or reducing it at the surface. An ingenious method of reducing resistance, demonstrated by Greaves (1960), when liquid foods are freeze-dried involves continuous scraping of the dry layer away from the frozen layer during its formation.

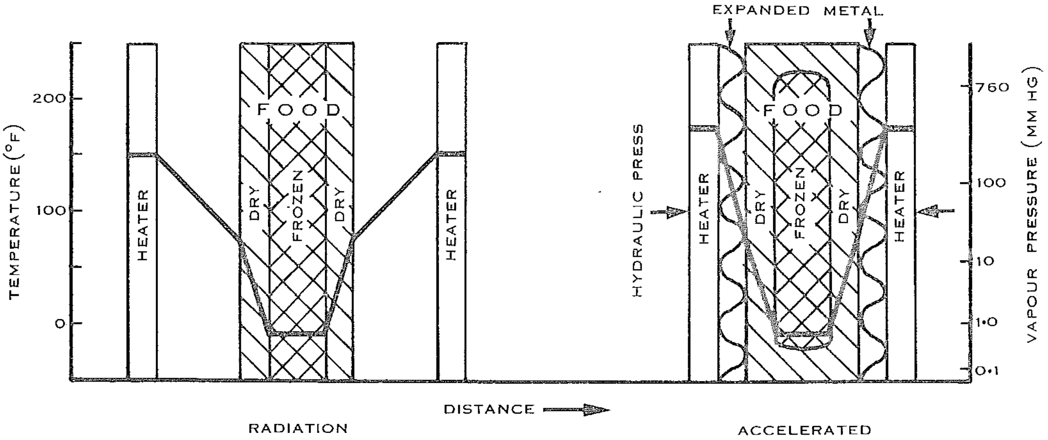


*Fig. 3.—Temperature and vapour pressure gradients in freeze-drying food heated through the drying layers.*

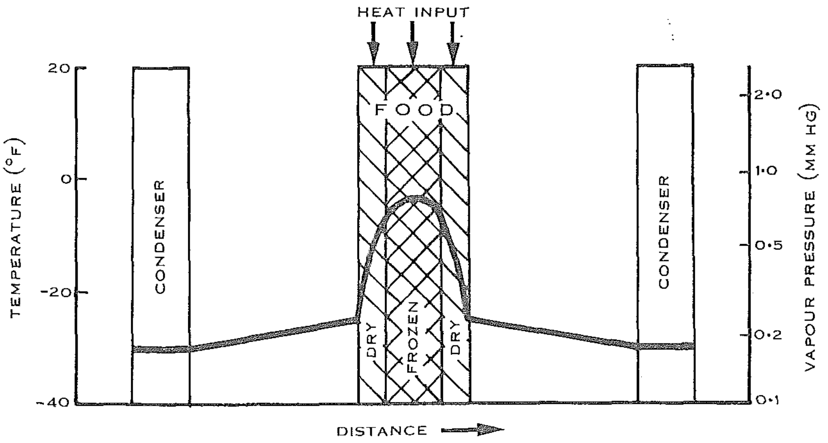


*Fig. 4.—Temperature and vapour pressure gradients in freeze-drying food heated by high-frequency radiation.*

## EQUIPMENT

### Accelerated Freeze-Drying Plant

In Britian, single-cabinet plant for accelerated freeze-drying of meat and certain prepared fruits and vegetables is built commercially to process 1¼ ton a day of fresh food to a moisture content of 2% (dry basis) in three equal batches. The type of unit, and its associated equipment, is constructed to comply with the general processes recommended by the Ministry of Food. It does not include the plant to generate steam, provide electrical power, or pump water, neither does it include any preparation or packaging plant.

Each cabinet is 6 ft square by 6½ ft long internally, with doors which seal the ends. It holds 30 trays having a total area of 350 sq. ft. The space between the heating platens can be varied from 1⅝ in. to ⅜ in. by hydraulic pressure (0·8 lb/sq. in. maximum).

The heating system consists of a vertical bank of 16 platens which can be heated or cooled with water. Hot water for heating is supplied at a maximum flow rate of 80 gal/min from a heat exchanger operated by dry-saturated steam at a pressure of 140 p.s.i.g.; and is sufficient to raise the temperature at a rate of 13°F/min. Another heat exchanger in the line serves to lower the temperature at about the same rate, with water at 65°F.

Instrumentation is provided in the form of vacuum gauges, and there is a thermocouple recorder for measurement of temperature of the food, trays, and platens.

One firm has installed these units as a multi-cabinet plant to dry about 5 ton of input per day. Larger plants are in the planning stage. In one model intended for processing 34,000 lb of frozen food per day by semi-continuous operation, the frozen food will enter through a vacuum lock at one end of the tunnel and be taken out through a similar lock at the other end. A small secondary vacuum system will be required to operate these locks.

### Operating Conditions

Slices of food up to ¾ in. thick are prepared and quick-frozen in the normal way and loaded in the cabinet from an adjoining frozen store. They are spread on single sheets of expanded metal in shallow metal trays, and other single sheets placed on top, before finally being placed between the platens. Four-stage steam ejectors, which can deliver up to 350 lb/hr of vapour, are then used to pump the sealed cabinet down to a pressure of 1 mm Hg. This takes about 6 min, after which the ejectors are used to pump water vapour directly. They work on dry-saturated steam at 140 p.s.i.g. and consume on the average 1100 lb/hr. Water at a temperature of 65°F and at a rate of 11,500 gal/hr is required for condensing. A total electrical load of 27 kW is involved.

Temperatures of platens and drying food for a typical process are shown in Figure 5, and reflect the high surface temperatures employed after a dry layer of sufficient thickness has been formed. Drying times are of the order of 7 hr in this type of plant and,

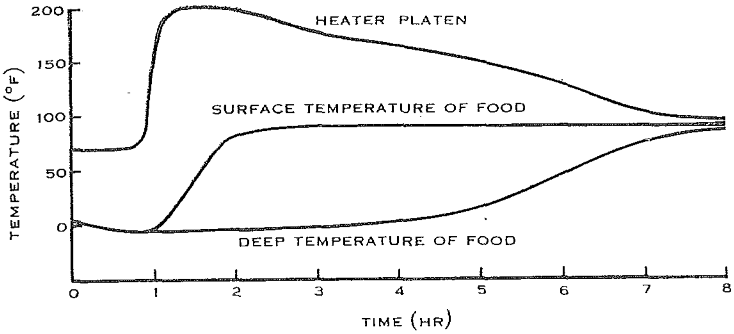


*Fig. 5.—Typical temperatures during drying of food by the accelerated freeze-drying technique.*

allowing an hour for loading and unloading operations, it is possible to process three batches per day.

## Other Plant

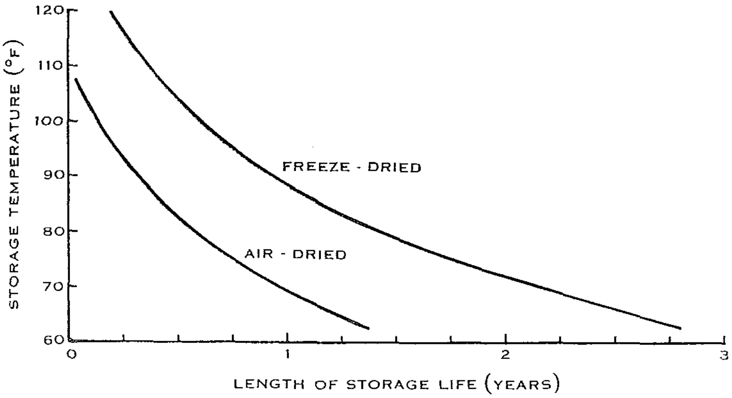
Parallel with British developments notable advances have been made in Germany (Neumann 1957). For instance, a new principle of temperature control and measurement without the use of measuring probes has been perfected. It is called the "temp-pneumatic" system of regulation, and depends on raising the water vapour pressure in the drying chamber at regular intervals. A large electromagnetic gate valve is located in a wide bore pipe connecting the drying and condensing chambers. When it is closed momentarily, a rapid rise in pressure in the drying chamber results, since the lower vapour pressure in this space tends to adjust itself to that of the ice in the frozen food. The pressure is a function of the temperature of the ice, hence it is monitored through an electrical controller to supply heat by hot water to the drying food, in accordance with the rise in pressure.

A larger freeze-dryer can be assembled from smaller tunnel sections, each section being capable of processing 4 ton of input per day. Vapour pumping is by means of refrigerated condensers running at a temperature from —5° to —15°F. Sublimation temperatures can be somewhat higher in this plant, although surface temperatures are lower and drying times are usually 50% longer than by "accelerated freeze-drying".

For some foodstuffs freezing *in situ* by self-cooling can be carried out in this equipment in about 45 min by gradual reduction of pressure, which is equivalent to a 20–30% saving in the total quantity of water to be removed. Another saving concerns "instant" foods. Their pre-cooking is essentially a pre-drying treatment, during which a certain amount of water is lost.

While fewer fundamental developments in freeze-drying have taken place in the U.S.A. than in other countries, it has a greater range of industrial plant available.

*Fig. 6.—Storage life of freeze-dried products compared with air-dried products at high temperatures.*



## PROPERTIES OF FREEZE-DRIED FOODS

During the freeze-drying process, the food does not undergo serious shrinkage, nor is there much migration of soluble constituents to the surface, as with other forms of dehydration. The finished product is rigid with a porous cellular structure. When immersed in water it reconstitutes in a short time. Perhaps the most important characteristic of many freeze-dried foods is that, when the rehydrated product is cooked, it is difficult to distinguish from the fresh counterpart.

All dehydrated foods, irrespective of the method of drying, deteriorate during storage. Microbial attack does not occur because most dried foods have equilibrium relative humidities in the 5–30% region where micro-organisms cannot flourish. The most serious deterioration is due to chemical reactions within the material or with its surrounding atmosphere.

Oxidative rancidity occurs where fat or oil is present in the dried product; it is most likely to be found in animal products. It can be reduced by the use of antioxidants, and by packing in an atmosphere which contains no oxygen.

The most serious deterioration of dried foods arises from a Maillard type reaction in which carbohydrates react with amino acids to produce brown pigments. This "browning" also gives rise to odours and off-flavours which may be such as to render a product inedible. Browning is most serious in fruit and vegetable products. It can be minimized by using a food additive such as sulphur dioxide, and by packaging in an inert atmosphere.

Both of the above types of chemical deterioration increase with storage temperature and, in general, they lessen with decreasing moisture level in the dried material. Freeze-drying results in moisture levels of 1–2% in the dried material while hot-air drying only reduces the level to 4–6%. This is the main reason why freeze-dried products have a longer storage life than conventionally dehydrated products; however, products can be over-dried. In this connection, a method of freeze-drying directly to a known optimum level of residual moisture has been developed in the Division of Food Preservation (Mellor 1961). It is being used in storage investigations of biological materials.

Properly packaged freeze-dried foods possess a shelf life of 2 years at moderate ambient temperatures and up to 10 years if stored at —14°F. Sunlight, however, has a detrimental effect on colour. Freeze-dried products have a longer storage life than air-dried foods at high temperatures (as in the tropics, or in the interior of continents) as shown in Figure 6. In general, it has been demonstrated that accelerated freeze-dried foods with 1–2% residual moisture have, in tropical areas, 3–4 times the storage life of air-dried foods.

Finally, it must be pointed out that there are many storage behaviour problems still requiring careful investigation.

## COST OF ACCELERATED FREEZE-DRYING

The only reliable costing of the process has been undertaken by Forrest (1960) of the British Ministry of Food, who assessed the average cost of 40 proving runs on a range of foodstuffs. The costs of processing quoted by equipment manufacturers when this article was being written can be regarded as speculative.

The costing for the Aberdeen plant (total capacity: 1¼ ton of input per day) was as follows (all amounts in £ stg.).

| | |
|---|---|
| *Capital Costs* | |
| Drying cabinet | 9000 |
| Steam ejectors (refrigeration condensing system £7000) | 4550 |
| Installation (including instrumentation) | 2000 |
| Total | 15550 |
| *Running Costs* (assuming 6000 hr p.a. operation) | |
| Depreciation (10 yr) | 1555 |
| Interest at 3½% | 544 |
| Electricity (19 kW at 1¾*d.*/unit) | 830 |
| Cooling water (11500 gal/hr and 7·5 kW for pumping water) | 328 |
| Steam (1100 lb/hr at 10*s.* per 1000 lb) | 3300 |
| Wages (7*s.* per hour, and assuming one man attends to four cabinets) | 525 |
| Maintenance (5%) | 778 |
| Total | 7860 |

Throughput: 650 lb per charge; i.e. 1950 lb/day or 487,500 lb p.a.

This is 4*d.*/lb of input which is higher than the cost of quick-freezing (about $\frac{1}{2}$*d.*/lb in Britain). The cost of preparing the food for freeze-drying is similar to that for freezing or canning, but packing costs are likely to be higher.

## CONCLUSIONS

The principal advantages of freeze-drying over more conventional drying processes are: the products are less subject to the detrimental effects of high temperature; the volatile constituents are not lost to any degree; the physical form of the dried product is essentially unchanged, and rehydration is readily accomplished. It should not be necessary, therefore, for the consumers to develop an acquired taste for freeze-dried foods. Prices of freeze-dried foods should prove competitive with those of frozen foods because they do not require special forms of transport such as insulated vans or refrigerated ships, nor special cold storage or deep-freezing facilities at the point of sale. An important point is that refrigerated storage is not needed.

Freeze-dried foods should be highly suitable for "instant" products. In this connection, a new approach, and one which has been adopted in Europe and U.S.A. for some time, is the freeze-drying of diced material which is normally difficult to reconstitute. The freeze-dried pieces are incorporated into instant mixes and soup powders, and the high cost of processing in a small plant is offset by the low cost of producing the bulk of the powder by conventional methods.

The packaging of freeze-dried foods is very important if the desirable properties of such foods are to be maintained subsequent to processing. A successful package should be one impermeable to water vapour and oxygen as well as opaque to light, and fairly rigid to sustain mechanical handling during transportation. Freeze-dried foods are often packed in plastic bags filled with nitrogen. In order to meet this and the other requirements, semi-automatic machines for packaging have been developed in Sweden. They are known as "Cekatainer" machines.

However, as with all new developments requiring universal application, there is still a need for more fundamental investigations by companies and affiliated research organizations into the packaging, storage, and product evaluation of freeze-dried foods.

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# Bulk Bins for Fruit Storage

By E. G. Hall and J. D. Mellor*

Division of Food Preservation, C.S.I.R.O., North Ryde, N.S.W.

THE use of bulk containers for fresh fruit, and of associated mechanical handling equipment, substantially reduces costs and, provided the loading of the containers does not exceed about 70 lb/sq. ft, little damage need occur to apples, pears, or citrus fruit.

Bulk bins now widely used in Australia for harvesting and transport to the packing shed, and for cool storage, have also been adopted for export. With the exception of the export apple bin there has been little standardization of size or design since bulk handling of apples was introduced from New Zealand, where it was first successfully demonstrated in 1953.

Early model bins were not ventilated and, while satisfactory for harvesting, did not allow the quick cooling of fruit required in cool storage. In an attempt to overcome this disadvantage later types were constructed with vents left between all boards on the bottom and sides. Bin design has been studied in the United States, where bulk handling of fresh fruit is now general practice, in relation to strength, ease of handling, and freedom from fruit bruising (Anon. 1959) and to fruit injury and cooling (O'Brien 1960).

The cooling of fruit in orchard bins came under investigation by the C.S.I.R.O. Division of Food Preservation in 1960 and 1961. Martin (unpublished data) working in Tasmania, in collaboration with the authors, investigated the cooling of apples in export bins.

## Cooling

Fast cooling of the fruit in the cool store is necessary to ensure a long storage life, particularly for pears and Delicious apples. Recent research work and also commercial experience have shown that apples and pears can be cooled faster in bulk bins than in conventional boxes if proper provision is made to ensure a good flow of air through the bins. Unless very high rates of air flow are used an initial cooling rate of 1 °F/hr is as much as can be expected with loose fruit in stacked wooden boxes. If the fruit is individually wrapped the cooling rate will be considerably lower. While the cooling rate of fruit in unvented, open top, pallet-base bins of the usual size (approximately 4 ft by 4 ft by 2 ft deep) is about the same as for loose fruit in stacked boxes, suitable venting of the bins has been found to increase the rate considerably. If the bottom of the bin is vented and no gaps are left in the sides a beneficial "chimney effect" is produced. The warm air leaving the top of the bin is replaced by cooler air entering from the bottom and a good flow of cool air is established around individual fruits. Tests under commercial conditions have shown an initial cooling rate as high as 4 °F/hr with 10% of the bin bottom suitably ventilated, and the whole bin freely exposed.

Rates of cooling of better than 2·5 °F/hr have been obtained with bins stacked three deep. With deeper stacking, however, the cooling rates progressively decrease as the stack height is increased since the air reaching the higher bins has been warmed by contact with fruit below. To overcome this difficulty it has been recommended that bins of warm fruit should be stacked no more than two deep on the floor of the cool store, or placed on top of bins of previously cooled fruit. After 24 hours, when the greater part of the desired cooling has been achieved, the bins may be stacked with safety to the full height of the store.

Unfortunately this procedure, involving double handling, increases costs. This might be avoided by the adoption of the sloping bin covers used experimentally to divert warm air rising from the lower bins to one side and away from the bin above. The sloping cover also serves on its upper side, to divert cooler air, from outside the stacked bins, up through the bin above.

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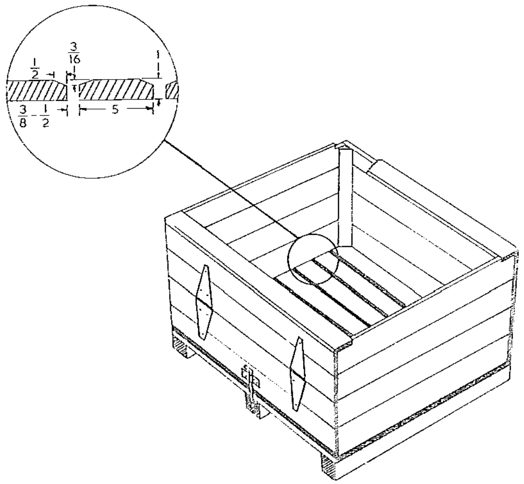
* Mr. J. D. Mellor reported on investigations made by C.S.I.R.O. on the cooling of fruit in bulk bins at the Annual Conference of the Victorian Orchardists' and Cool Stores Association, held at Orange, N.S.W., on June 6 and 7, 1961. This article is based on that report.

## Design of Bins

The strongest all-timber bins have sides of boards, preferably jointed together, fixed vertically on 3 by 1 in. upright timbers with a 2 by 1 in. diagonal brace. Corner posts, which should be triangular, can be made from 3 by 3 in. timber cut diagonally. To provide a good stacking surface, and to increase the strength of the structure, it is recommended that a piece of 3 by 3 in. timber be secured horizontally along the top of the back and front, preferably half lapped into the corner posts and sides. The pallet base runners, preferably made of hardwood, should consist of three pieces of 3 by 2 in. timber placed on edge so as to provide sufficient space for fork entry as well as for good air flow. By careful design provision can be made for four-way fork entry into the pallet base without significant reduction in the strength of the bin. All timber used should be well seasoned and dressed on the inner face. The inner edges of the gapped boards should be bevelled to a 20° angle ($\frac{1}{2}$ by $\frac{3}{16}$ in. deep) so as to minimize damage to the fruit. This is illustrated in the diagram.

To ensure satisfactory cooling of fruit on placing in cool storage, the bin bottom should be vented with half-inch gaps between boards, so as to leave 7–10% of the total area open. Ventilation in excess of that necessary for a satisfactory rate of cooling should be avoided, since on long storage it may cause undue shrinkage of the fruit. Since slatted sides to the bins add little to the speed of cooling, and are structurally much weaker than solid sides, their use is no longer recommended. Sides of horizontally fixed boards are weaker than when placed vertically since the bin is rendered less resistant to twisting stresses.

To permit the free flow of fruit from the bin when tilted, the top-hinged door placed at the bottom of one of the sides should be made the full width of the bin and 8–10 in. high. A gap of $\frac{3}{4}$ in. under the door makes for easier opening, and provides useful ventilation (see Figure). The length and breadth of bins may vary according to particular requirements. They are often made square. One dimension should not exceed 4 ft so as to enable the placing of two bins across the body of a lorry for which the maximum loading width is 8 ft. The internal depth of the bin should not exceed 2 ft since the optimum depth of fruit is about 20 in. for both apples and pears. A greater depth of fruit will greatly increase the risk of bruising. Satisfactory bins can also be constructed with pressed-wood sheet sides nailed on a 3 by 1 in. diagonally-braced frame. To increase bin life the use of light angle iron corner braces may prove worthwhile. Another strengthening device sometimes used is a tension wire strap around each end with the wire recessed into the pallet runners. All nails used should be of the square shank twisted pallet type and be cleated.



*Typical orchard and storage bin for apples and pears, showing method of construction, bottom venting, and side door for removal of fruit. Measurements in inches.*

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# Canning of Water for Emergency Use

By D. J. Casimir

Division of Food Preservation, C.S.I.R.O., North Ryde, N.S.W.

CANNED potable water is an important component of survival rations carried by ships and aircraft. It may even become an essential item in emergency supplies, held for civil defence, in anticipation of the danger of contamination of water supplies by radioactive fallout. The canning of water was investigated by the Division of Food Preservation, at the request of the Commonwealth Departments of Navy and Air, since Australian canners had been unable to supply a satisfactory product under existing specifications. Some recent investigations in India, along similar lines, have been described by Siddappa and Nanjundaswamy (1960).

At first thought water would appear to be an easy product to can, but in fact it has been difficult to produce canned water free from discoloration or taint. Discoloration is usually due to rusting of the can, which causes the water to appear brown and to deposit a sediment of rust. Off-flavours picked up during processing or from the container are more readily detectable in water than in most canned foods, because it is neutral in taste. It is known that rusting may be minimized by removing oxygen from the water and the can, and by protecting the can internally with an organic coating. All commercially lacquered cans tested, however, imparted detectable taints to water; a procedure was therefore sought which would give satisfactory water in plain cans.

## Existing Procedures

The Australian Commonwealth Food Specifications lay down a procedure in which water is deaerated by boiling, filled into plain cans, closed at not less than 190° F, and retorted for 10 min at 240° F. The British Admiralty (Victualling Department) (1956) specify a similar procedure in which the water is processed for 10 min at 230° F, and the U.S. Department of Defence (1957) also require a retort process at a temperature of not less than 250° F for not less than 15 min.

Canners following the procedure of the Commonwealth Food Specifications (Department of Primary Industry 1952) found it impossible to prepare canned water which complied with the quality requirement that the water "shall be free from discoloration, off-flavours, and oiliness, and practically free from sediment and rust". Preliminary investigations in the Division of Food Preservation indicated that rusting occurred mainly during the retort process, and therefore the necessity for this step was questioned. Microbiologists in the Division expressed the view that the retort processes specified were excessive and that a procedure of hot filling at temperatures in excess of 190° F would suffice to destroy all vegetative organisms which might cause trouble. Heating to an extent that would ensure the destruction of heat-resistant bacterial spores was considered unnecessary since the chances of significant growth and toxin production by such spore-bearing organisms as *Clostridium botulinum* were negligible. No case of botulism arising from toxin production in potable waters has ever been reported.

## Adjustment of pH

Most of the waters available for canning in the United Kingdom are subject to temporary hardness and deposit salts on heating.

TABLE I
Typical Composition of Water Supplies in Australia*

| Location | pH | Total Dissolved Solids (p.p.m.) | Total Hardness (as $CaCO_3$) (p.p.m.) |
|---|---|---|---|
| Sydney | 6·0–7·8 | 49–113 | 7–50 |
| Melbourne | 6·4–7·3 | 34–68 | 12–15 |
| Adelaide | 7·8 | 373 | 158 |
| Perth | 6·6–7·0 | 197–566 | 35–64 |
| Brisbane | 7·4–7·6 | 90–350 | 75–284 |
| Tasmania | 6·5–7·7 | 25–190 | 9–106 |
| Admiralty specification | 5·0–5·8 | < 1500 | < 500 |

* Information supplied by the relevant authorities, September 1959.

For this reason the British Admiralty (Victualling Department) (1956) specifies that canned water must be acidified to pH 5·0–5·8 to prevent precipitation. This acidification appeared to be unnecessary in Australia since hardness is not a problem in the water supplied to the capital cities (see Table 1). However, some tests were made using waters in which the pH and hardness were adjusted by the addition of citric acid and calcium carbonate. The effect of adding ascorbic acid, which combines with residual oxygen in the can, was also investigated in view of its use in canned soft drinks to minimize iron pickup.

## Canning Trials

A series of test packs of canned water was prepared according to the experimental details set out in Table 2. Each batch of water, drawn from the Sydney Water Supply, was boiled for 15 min to remove dissolved air and to flocculate suspended material. The additives were then stirred in and the water was filled at 200–205°F into 301 × 411 plain cans which were immediately closed under steam flow and inverted. Treatments 1 to 4 received no further processing, but Treatments 5 and 6 were retorted for 10 min at 240°F. The canned water was placed in incubator storage at 100°F and samples were withdrawn for examination soon after processing, after 3 months, and after 6 months. At each examination the treatments from two replicate packs were evaluated by a trained panel of 10 persons who scored for appearance and flavour using tap water as a standard.

**TABLE 2**
**Experimental Procedure**

| Treatment | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Heat process | Hot fill and invert | | | | 10 min at 240°F | |
| Additives (g/gal) | | | | | | |
| Ascorbic acid | 0·25 | 0·25 | — | — | — | — |
| Citric acid | — | 0·625 | 0·625 | — | 0·625 | — |
| $CaCO_3$ | — | 0·375 | 0·375 | — | 0·375 | — |
| pH after processing | 6·3 | 5·1 | 5·3 | 6·6 | 5·4 | 7·1 |

No significant differences in appearance or flavour could be established between the treatments. It appeared reasonable, therefore, to recommend the simplest treatment, No. 4, as most suitable for commercial use. This treatment received a very satisfactory mean score above 4 (tap water = 5) for both appearance and flavour after 6 months at 100°F. Moreover, examination of further samples after holding 3 years at 100°F (see Table 3) revealed that Treatment 4 showed values within specified limits for vacuum and dissolved metals. No evidence of microbial growth was found in any of the treatments.

**TABLE 3**
**Examination of Canned Water after 3 Years Storage at 100°F**

| Treatment | Vacuum (in. Hg) | Headspace (in.) | pH | Tin Content (p.p.m.) | Iron Content (p.p.m.) | Appearance |
|---|---|---|---|---|---|---|
| 1 | 23·5 | $\frac{1}{2}$ | 6·8 | 2·0 | 8·8 | Colourless, white flocculent residue |
| 2 | 23·5 | $\frac{9}{16}$ | 5·4 | 32·8 | 6·6 | Yellowish, few rust particles |
| 3 | 25 | $\frac{9}{16}$ | 5·7 | 26·1 | 7·3 | Yellowish, slight cloudiness |
| 4 | 23·5 | $\frac{1}{2}$ | 6·9 | 5·8 | 2·2 | Colourless, slight cloudiness |
| 5 | 24 | $\frac{9}{16}$ | 5·7 | 28·2 | 6·8 | Yellowish, some rust particles |
| 6 | 23 | $\frac{9}{16}$ | 7·3 | 7·9 | 13·0 | Turbid, brownish sediment |
| Specifications: | | | | | | |
| Admiralty | >20 | | 5·0–5·8 | <75 | <2·5 | Clear, colourless, free from sediment |
| Commonwealth | >20 | $\frac{5}{16}$ – $\frac{7}{16}$ | 6·6–7·6 | | | Free from discoloration, practically free from sediment and rust |

## Conclusion

It is recommended that canned water for emergency use should be prepared according to the following procedure:

1. Use suitable tap water without additives (see Table 1).
2. Boil for 15 min to de-aerate.
3. Fill into plain cans at a temperature not lower than 200°F.
4. Close immediately under steam flow.
5. Invert.

This procedure has been applied successfully to water packaged in polyethylene containers, but there are problems of tainting to be solved before such containers can be recommended.

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# NEWS FROM THE DIVISION OF FOOD PRESERVATION

## INTERNATIONAL AWARD FOR MR. L. J. LYNCH

Mr. Lawrence J. Lynch, of the C.S.I.R.O. Division of Food Preservation, has been selected for the International Award for 1962 of the Institute of Food Technologists, an international body with its headquarters in the U.S.A. and branches in many countries including Australia. This highly prized award is made annually to a member of the Institute "*who has made outstanding efforts to promote the international exchange of ideas, or whose work has led to such an exchange of ideas or to better understanding, in the field of food technology*".

Mr. Lynch is the second Australian to receive this award, Dr. J. R. Vickery, Chief of the Division of Food Preservation, having been honoured similarly in 1960.

Mr. Lynch, born in Maitland, N.S.W., is a graduate with first-class honours in Agriculture from Queensland University. He was appointed to the Section (now Division) of Food Preservation in 1935 and is at present in charge of its Canned Foods Section. In 1943 Mr. Lynch visited the U.S.A. to obtain the latest information on food canning so as to help in the development of the Australian food industry to meet the needs of the Allied Armed Forces. In this, he was singularly successful.

Ten years later he was again in the U.S.A. as a Visiting Professor of Vegetable Crops at Cornell University, New York State, where he demonstrated the techniques he had developed for the precise determination of the optimum maturity of vegetable crops for processing. In 1958 he was Visiting Food Technologist and Acting Head of the Department of Food Processing and Utilization at the University of Hawaii, Honolulu.

During his visits overseas Mr. Lynch has inspected many research centres and food plants in the U.S.A., the U.K., and in Europe where he has become respected as a versatile food technologist. Since 1960 he has been a Consultant to the Australian Colombo Plan Supplies Directorate and over the past 15 years he has supervised the postgraduate training of 20 Colombo Plan and F.A.O. Fellows from Asia and the Middle East.

In his own country Mr. Lynch is a foundation member of the Australian Northern Section of the Institute of Food Technologists; he is Australian Liaison Officer for the Comité International Permanent de la Conserve and a member of the Australian Canning Convention Secretariat.

Mr. Lynch is well known to Australian food processors to whom his fund of knowledge, and ability to impart it in a lucid manner, has proved a boon in the rapid development of the food industry which has taken place in postwar years.

### STAFF CHANGES

Two employees of the Division of Food Preservation, who joined it as Laboratory Assistants, have recently received professional appointments. Mr. G. G. Swenson, who holds the M.Sc. degree of the University of Queensland, has been appointed Experimental Officer and will take part in researches on the transfer of heat and moisture in meat during cooling and freezing, at the Division's Meat Research Laboratory at Cannon Hill, Queensland. Mr. R. G. P. Elbourne, a graduate of the University of New South Wales, also becomes an Experimental Officer and will serve at the North Ryde Laboratories where he will participate in the chemical investigations concerning corrosion of tinplate food cans.

### OVERSEAS TRAVEL

Dr. W. J. Scott, Assistant Chief of the Division, returned from a month's visit to the U.S.A. on the 10th December 1961. He was a guest speaker at a Symposium on Low Temperature Microbiology organized by the Campbell Soup Company at Camden, N.J., and also visited a number of American Universities and research institutions.

Dr. H. L. Evans, leader of the Physics Section, attended a conference on International Developments in Heat Transfer held in London, England, in early January. Before returning to Australia on February 10, 1962, he visited a number of British Universities and some research institutions in Germany and Switzerland.

# PUBLICATION NOTES

## Circular 6-P

DETAILED investigations of problems concerned with the dehydration of meat were made during World War II and in the immediate postwar period by research workers in the Division of Food Preservation.

Much of the work was concerned with the air-drying of mutton mince, but some work was carried out with other types of meat and other methods of dehydration. The results of these investigations have been published in a series of scientific papers. A list of these papers is given in a new publication (Circular 6-P) issued recently by the C.S.I.R.O. Division of Food Preservation.

The new Circular deals in a comprehensive manner, while omitting detailed descriptions of experimental procedure, with many aspects of meat dehydration, especially the use of air-drying. Sections on the production of mutton mince cover the influence of preprocessing factors including sex, age, grade, portion of carcass, and tenderization by holding; of processing factors such as precooking, mincing, concentration of cooking liquors, and drying procedures; and finally of packaging and storage factors such as gas packing, compression, control of browning changes, flavouring additives, and temperature and time of storage. Other sections deal with air-dried mutton slices, air-dried beef mince, and vacuum-dried beef chunks. Copies of the new Circular (6-P) may be obtained from the Division of Food Preservation, C.S.I.R.O., Box 43, Ryde, N.S.W.

## C.S.I.R.O. and the Food Industry

A PROFUSELY illustrated and well-produced booklet, with the above title, is the work of the C.S.I.R.O. Industrial Research Liaison Section. Written in non-technical language, it should prove a useful source of knowledge for those, including laymen, who may be interested in the Australian food industry and allied food science and technology research.

The description given of the research activities of the Division of Food Preservation, the Dairy Research Section, the Wheat Research Unit, and the Bread Research Institute of Australia covers a wide range of products — meat, fish, and eggs; dairy products; fresh, canned, frozen, and dehydrated fruits and vegetables; wheat, flour, and bread.

Copies of the booklet are obtainable through the Industrial Research Liaison Section, C.S.I.R.O., 314 Albert Street, East Melbourne, C.2.

## Second Census of Fruit Cool Stores

THE Fruit and Vegetable Storage Section of the C.S.I.R.O. Division of Food Preservation, working in collaboration with the State Departments of Agriculture, has brought up to date a census of fruit cool stores in Australia, first compiled in December 1958. (See *Food Pres. Quart.* **21**: 15.)

The census covers all cool stores, other than those attached to retail establishments, handling fresh fruits. Information has been collected on the age of premises, type of construction, varieties of fruit stored, method of refrigeration, and store capacity in terms of bushel cases. Although not listed in the census, small cool stores attached to retail shops are known to be playing a very important part in ensuring that fruits and vegetables reach the consumer in good condition.

The census shows an overall increase of 12·9% in cool store capacity over the past two years. New South Wales with 31·5% shows the greatest, and Victoria with 7·8% the lowest, increase, but Victoria still has the greatest total capacity (4,883,523 bushel cases). It is followed by New South Wales with a capacity of 1,512,640 bushel cases; South Australia 964,550; Tasmania 916,100; Western Australia 724,360; and Queensland 598,200. In Victoria three canneries in the Goulburn Valley have between them a capacity for almost 1,000,000 bushel cases. It is of interest to record that 62 cooperative fruit stores possess 43% of the total cool store capacity in Australia, while 486 growers' stores account for 28%.

In spite of the 1,000,000 bushel increase in total cool store capacity in the last two years the additional storage space is barely keeping up with the increased production of apples, pears, and canning peaches — which are the main fruits cool-stored.

E.G.H.

Copies of the new Census Report are available from the Divisions of Horticulture of the State Departments of Agriculture in the capital cities, or from the Division of Food Preservation, C.S.I.R.O., Box 43, Ryde, N.S.W.

## Special Australian Food Science Number

THE April 1962 issue of the British journal *Laboratory Practice*, which has a world-wide circulation, should be of especial interest to Australian food scientists and technologists, since it is entirely devoted to Australian food research and laboratory facilities.

There is a well-referenced article on "Some Australian Contributions to Food Science and Technology", a full description of the new laboratories of the C.S.I.R.O. Division of Food Preservation at North Ryde, N.S.W., an account of other laboratories and their research facilities, including the new Queensland Food Preservation Laboratory, the Australian Wine Research Institute, and the Bread Research Institute of Australia. An article on Dairy Manufacturing Research in Australia traces the activities of the C.S.I.R.O. Dairy Research Section from its early days when research groups worked on war-time problems. The articles are well illustrated and there are biographies of the senior authors who include Dr. J. R. Vickery, Dr. S. A. Trout, Mr. G. Loftus Hills, Mr. E. E. Bond, and Mr. J. C. M. Fornachon. The articles are supported by a pertinent Editorial.

*Laboratory Practice* is published at 9 Gough Square, Fleet Street, London, E.C.4.

# SELECTED PUBLICATIONS OF THE DIVISION

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Board, P. W. (1960).—Procedure for evaluating tomato varieties for processing. C.S.I.R.O. Aust. Div. Food Pres. Tech. Pap. No. 17.

Board, P. W., Cowell, N. D., and Hicks, E. W. (1960).—Studies in canning processes. III. The cooling phase of processes for products heating by conduction. *Food Res.* **25:** 449–59.

Christian, J. H. B., and Waltho, Judith, A. (1961).—Sodium and potassium content of non-halophilic bacteria in relation to salt tolerance. *J. Gen. Microbiol.* **25:** 97–102.

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Hicks, E. W., Stevenson, C. D.,* and Blake, J. D.* (1960).—Performance of a type of railway fan car cooled by ice. *Proc. 10th Int. Congr. Refrig.* **2:** 301–4.

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Howard, A., and Prater, A. R. (1960).—Influence of fat, moisture, and addition of concentrated cooking liquor on the initial quality and storage life of air-dried mutton mince. C.S.I.R.O. Aust. Div. Food Pres. Tech. Pap. No. 18.

Howard, A., Prater, A. R., and Coote, G. G.* (1960).—Effect of drying, mincing, and cooking on quality of dried mutton mince. C.S.I.R.O. Aust. Div. Food Pres. Tech. Pap. No. 20.

Ingles, D. L. (1960).—Chemistry of non-enzymic browning. XI. The reactions of bisulphite with reducing sugars. *Aust. J. Chem.* **13:** 404–10.

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Ingles, D. L. (1960).—Reactions of aldoses with bisulphite and hydrosulphite: the formation of sugar sulphates. *Chem. & Ind.* **1960:** 1159–60.

Kaess, G. (1961).—Freezer burn as a limiting factor in the storage of animal tissue. I. Experiments with livers frozen without weight loss. *Food Tech.* **15:** 122–8.

Kaess, G., and Weidemann, J. F. (1961).—Freezer burn as a limiting factor in the storage of animal tissue. II. Histological study of freezer burn of liver. *Food Tech.* **15:** 129–33.

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McKenzie, H. A., and Wake, R. G. (1961).—Improved method for the isolation of $\kappa$-casein. *Biochim. Biophys. Acta* **47:** 240–2.

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Prater, A. R., Vere-Jones, N. W.,* and Roberts, E. A.* (1960).—Storage trial on New Zealand beef and mutton vacuum-dried in fat. C.S.I.R.O. Aust. Div. Food Pres. Tech. Pap. No. 19.

* These co-authors are not officers of the Division of Food Preservation.

*Copies of most of the papers mentioned may be obtained from the Librarian, Division of Food Preservation, Box 43, P.O., Ryde, N.S.W. (Telephone 88-0233).*