FOOD PRESERVATION QUARTERLY

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Editor:
W. A. EMPEY

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THE DIVISION OF FOOD PRESERVATION AND TRANSPORT
COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH
HOMEBUSH, NEW SOUTH WALES, AUSTRALIA

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Canning Research at Homebush

By

L. J. Lynch.

The activities of the Canning Section of the Division of Food Preservation are briefly reviewed in the Annual Reports of C.S.I.R., and from time to time a particular study is given publicity in Food Preservation Quarterly. Investigations being carried on within the section are of more than passing interest to the canning industry in Australia, and a short record of work recently undertaken is therefore presented herewith.

A project relating to improvement in quality of canned foods provides scope for extensive and long term laboratory investigations. The raising of quality standards may be effected by a process of selection of fruit and vegetable varieties already within Australia, by the introduction of new varieties from other countries, and by plant breeding to certain specified requirements. As an example, the importation from America of five varieties of beetroot seed may be quoted. The object of the work was to confirm reports that beetroot varieties that do not exhibit the tendency to white rings shown by the popular Detroit Dark Red are available to canners. The seed was grown at Hawkesbury College, N.S.W., and canning tests to date show that at least one variety, viz. Asgrow Canner, was free of the defect quoted, and at the same time possessed the requisite flavour, texture and colour for canning purposes. Further confirmation of the general excellence of Asgrow Canner will be needed before a recommendation can be made to substitute it for varieties at present being used.

The selection of an existing variety is well exemplified in the clingstone peach trials recently concluded at Leeton, N.S.W. The superiority of Transvaal Yellow over Pullar was clearly demonstrated. Both varieties approximate in time of maturity. The Transvaal is better both in texture and flavour, and closely approaches the ideal colour for a canning peach.

The breeding of fruit and vegetable varieties specifically for canning has seldom been attempted in Australia. The need exists for a tomato that fulfils all the requirements of an ideal canner. A large number of tomato varieties from the M.I.A., Bathurst and elsewhere have been tested for suitability, and in general have given satisfaction if picked in a full ripe, though firm, condition. Practically all of them are inconveniently large or lack size uniformity. The need arises for a canning type rich in colour and flavour, globular in shape, and of a diameter uniformly approximating one and three-quarter inches. Such a tomato must possess desirable agronomic features such as disease resistance, economic yield and uniform maturity of the fruit. Preliminary discussions have been made with the object of initiating plant breeding trials.

In addition to the work already mentioned, varietal investigation of green beans, carrots, peas, rock melons and freestone peaches has been a major laboratory activity during the past twelve months. Briefly this work has given confirmation of the value of introduced varieties of beans, peas and rock melons ; it has indicated the need for a carrot more globular in form than the Chantenay such that trimming losses can be minimized. It has also shown that J. H. Hale, Dripstone and several other freestone peach varieties possess canning quality equal to that of commercial American packs examined at Homebush.

The maturity factor in quality has been studied together with the variety in all cases in an endeavour to locate a readily recognizable index of correct stage for picking. Over the last four seasons pea maturity work has been closely followed, and has culminated in the development of a portable instrument designed for the physical measurement of tenderness, an attribute that is more or less synonymous with maturity. A detailed report of this investigation will shortly appear as a C.S.I.R. publication. A similar study has been undertaken with sweet corn over the same period, and results confirm that recommended American moisture levels for picking are valid under local conditions, and that, for practical purposes, the refractometric reading of the expressed juice provides a rapid assessment of the moisture level. An account of the sweet corn work is at present being prepared for publication for the guidance of Australian canners.

The rapid gain in popularity of the freestone peach pack in U.S.A. has prompted a study of the reactions of this fruit to processing procedures in order that first-hand information should be available to the industry, if and when required. As a generalization it was found that white-fleshed varieties lack flavour and are unattractive in appearance. All varieties are softer in texture and do not show the clear-cut appearance of the conventional clingstone pack. They are superior in flavour to the clings and on the bases of tests carried out at Homebush they have substantial consumer-acceptance. Reduction in the length of the heat process by the adoption of thermo-rotation minimized loss of shape and resulted in appreciable improvement in texture. Continuation of freestone peach studies is proposed.

As a result of numerous enquiries relating to discoloration of canned cauliflower, an investigation of the factors involved has been conducted over the last two seasons. Careful selection of raw material was found to be essential, and a short dip in extremely dilute sulphurous acid solution proved to be useful as a preliminary to blanching. During the course of this work cauliflower immersed in various warm solutions as a pre-treatment was observed to be crisp in texture after canning and markedly superior to the soft texture of untreated material. Similar results were obtained with broccoli, beans, peas, cabbage and silver beet. It was later found that immersion in distilled water for 30 minutes at a temperature between 100° F. and 140° F. represented optimal conditions for tissue hardening. More recent work suggests that the phenomenon is a function of time and temperature. Firming treatment has distinct possibilities in the matter of quality improvement of canned vegetables and further exploratory work will be undertaken.

The long-standing problem of bitterness in orange juice has been continuously investigated at Homebush since 1938. During this time it has been shown that a product free from bitterness can be made from mature Valencia and Parramatta oranges and that Washington navels are unsuitable for juice processing purposes. Early recommendations based on American practice advocated deaeration followed by flash pasteurization, and this procedure was established in Australia for wartime production. In 1944 experimental investigations indicated an alteration in technique and subsequently deaeration was discontinued while in-the-can pasteurization has been substituted for the flash process.

In 1945 experimental evidence suggested that bitterness in processed juice was accentuated by the use of Bordeaux spray on the growing fruit, and this deduction was confirmed during the 1946 and 1947 seasons. In association with officers of the N.S.W. Department of Agriculture, an extensive spray experiment planned statistically will be commenced at Gosford during the forthcoming season.

A fundamental study of the bitterness problem has resulted in the isolation of bitter principle from rind and juice and it has proved to be identical with limonin, which is the bitter principle of Californian oranges. A chemical investigation of the isolated substance may provide the basic knowledge for a solution of the problem.

Some years ago the Canning Section in association with an Australian industrial organization developed an acid-resisting can lacquer which was used exclusively for processed citrus juices for the Defence Services during the war. From time to time other lacquers for specialized needs have been produced by similar cooperation. At present, and in response to requests from the canning industry, an extensive investigation of sulphur-resisting lacquers has been commenced, with the object of obtaining a formulation that combines consistent performance with an attractive appearance. During the course of the work it is hoped that some fundamental knowledge of the mechanism of staining and of the nature of the protection conferred by zinc oxide may be gained.

Observations made from time to time during the experimental processing of a variety of products have shown that the practice of heating food materials in open vessels often results in the loss of some of the volatile constituents which contribute to the intangible quality known as flavour. The process whereby vacuum is obtained in cans by their passage through a steam exhaust box comes within this category. The alternative use of automatic vacuum can-closers is costly and beyond the reach of all but the largest canners in this country. For this reason an investigation of the potentialities of steam flow closure as a means of vacuumizing was undertaken. Steam jets were designed and constructed in association with a local industrial firm. They were fitted to a commercial automatic can closer and connected to a permanent supply of steam at reduced pressure. Commercial vacua were obtained initially with six types of canned vegetable pack and further extended trials indicate that steam flow may be successfully applied to most canned products.

The maintenance of flavour by the avoidance of unnecessary heating in contact with the atmosphere stimulated work on in-the-can pasteurization as the logical alternative to flash pasteurization of orange juice. Flavour conservation was demonstrated by relatively makeshift equipment, and during the early part of 1948 a continuous rotocooker was designed and constructed. Experiment showed that juice in No. 1 Tall cans is brought to pasteurizing temperature in $1\frac{3}{4}$ minutes and reduced to 100° F. under cold water sprays in a further time interval of $1\frac{1}{2}$ minutes. In principle the speed with which the operation is carried out depends upon the substitution of convective heat transfer by the establishment of a definite circulation of the contents within the can. Lower and upper speeds of rotation are critical and an investigation of this aspect has been commenced by the application of cinephotography to rotating transparent cans.

Empirical tests have shown that the time required for an adequate thermal process for canned fruits in a standard fruit cooker may be reduced with safety by the adoption of thermorotation. This result has an important bearing on the processing of freestone peaches and nectarines, and theoretically it will permit an improvement in flavour in a number of fruits by the use of material of more advanced maturity without impairment of texture.

An important aspect of policy in all canning investigations has been that results obtained under laboratory conditions should be tested on a commercial scale before recommendations are made to industry. In this connexion the cooperation extended by canners, can-makers and allied industries has without exception been spontaneous ; this Division is confident that cordial relations with industry will be maintained and expresses herewith a note of appreciation for services rendered.

BIBLIOGRAPHIES AND SUMMARIES OF INFORMATION.

The following bibliographies, summaries of information and special reports have been prepared by the C.S.I.R. Information Service. Copies may be obtained on application to the Officer-in-Charge, C.S.I.R. Information Service, 314 Albert Street, Melbourne. The bibliographies are, in the majority of cases, selective only. Applications should state clearly the reason why the bibliography is requested, because the number of copies available is limited.

Number.	Date Prepared.	Title.	No. of Refs.
B286	September, 1947.	The Preparation of Commercial Stearic Acid—Selected References.	8
B290	October, 1947.	Synthetic Detergents—Selected Review Articles.	5
B298	November, 1947.	The Manufacture of Pure Glucose (Dextrose)—Selected References.	13
B300	October, 1947.	Manufacture of Terpene-free Essential Oils—Selected References.	5
B320	February, 1948.	The Dehydration of Bananas—Data and Selected Literature References.	15
B322	January, 1948.	Vegetable Canning—Bibliography.	103
B323	March, 1948.	Quick-freezing of Food — Selected References.	65

The Pressures Developed in Containers During Heat Processing

By

P. C. O. THOMPSON.

Recently this laboratory has been interested in the relative magnitude of pressures developed in cans during processing, and after surveying the published literature it was thought that food processors in general might also be interested in the factors involved.

The question of internal pressures was originally studied by Magoon and Culpepper,[1] of the United States Department of Agriculture, who published their work as a bulletin in 1922. Theirs was an exhaustive study embracing heat penetration as well as the pressures developing under a range of closing and processing temperatures with a variety of products (beans, peas, tomatoes, spinach, sweet corn and sweet potato).

Munro[2] in 1931 published the results of his work, in which he claimed more accurate measurement of the pressures developed during processing. His initial work was done with gas-free distilled water and subsequently included canned soups, peas and other products.

Workers at the Campden Research Station[3, 4, 5, 7] carried the work a stage further when they studied the relative effect of headspace and closing temperature and also measured the volume changes produced in different sized cans by increasing internal pressures.

Internal pressures developed in cans during processing are significant because, together with other factors, they may easily lead to buckled cans. In presenting a paper on " Methods of Cooling Processed Cans of Meat " in 1938, Hallman[8] pointed out that with increasing diameter the pressure necessary to cause buckling decreased, and presented the following experimental figures.

Diameter of Can. Inches.	Can Designation.	Pressure Causing Buckling. Lb./sq. in.
$2\frac{1}{2}$	208	65
$2\frac{11}{16}$	No. 1	56
3	300	45
$3\frac{3}{16}$	303	$43\frac{1}{2}$
$3\frac{7}{16}$	No. 2	40
$4\frac{1}{4}$	No. 3	26
$6\frac{3}{16}$	No. 10	15

These figures are in agreement with values given for the same sized cans by other writers and indicate the necessity of proper canning technique, particularly with cans of $3\frac{7}{16}$ inches and larger diameters, to ensure that pressures capable of causing permanent distortion of the cans are not attained during processing.

Such pressures when found in cans are the result of several factors which are, in order of importance:

(*a*) Pressure due to water-vapour.
(*b*) Pressure due to expansion of air included in headspace.
(*c*) Pressure due to expansion of can contents.
(*d*) Pressure due to liberation and expansion of gases in the product.

However, pressures theoretically possible from this combination of factors are seldom attained, largely due to the careful design of the tin can which allows expansion so that a relatively large increase in volume gives a corresponding reduction in pressure.

In a paper published in 1931, Adam[3] pointed out that a significant proportion of the pressure at processing temperatures was due to water-vapour pressure.

Temperature. ° F.	Water-vapour Pressure. Lb./sq. in. Absolute.
0	0·08
60	0·25
130	2·2
180	7·5
212	14·7
240	25·0
250	29·8

The table given illustrates that at low temperatures the absolute pressure due to water-vapour is very small but increases rapidly with temperature.

As a generalization atmospheric pressure at sea-level is equivalent to 14·7 lb./sq. in. absolute, so that cans sealed at this atmospheric pressure contain at the instant of sealing a headspace pressure of 14·7 lb./sq. in. This pressure is made up of two components—pressure of the water-vapour at the temperature of sealing, and pressure due to residual air. For example if a can was sealed at a uniform temperature of 130° F., the pressure due to water-vapour would be 2·2 lb./sq. in. absolute, while the remaining pressure due to the enclosed air would equal (14·7—2·2) or 12·5 lb./sq. in.

A hypothetical can sealed at 212° F. would therefore contain only water-vapour in the headspace, and if heated to 240° F. the pressure developed will be due to the water-vapour entirely and will equal (25—14·7) or 10·3 lb. in excess of atmospheric pressure.

At whatever temperature a can is sealed there will be at 240° F. a pressure of 10·3 lb. due to the water-vapour present and the pressure due to the air enclosed at sealing will be superimposed upon this. Thus, with a sealing temperature of 130° F., the theoretical pressure in the can at 240° F. would be 10·3+12·5, i.e. 22·8 lb. per sq. inch (no allowance is made here for expansion of the air with heating).

In processing under pressure, however, there would be a counter-balancing pressure external to the can equivalent to the water-vapour pressure of the steam in the retort, e.g. 10·3 lb. at 240° F., so that the actual strain pressure would be due to the air enclosed, that is 12·5 lb./sq. in., if the sealing temperature was 130° F., plus, of course, the additional pressure due to expansion.

The pressure due to included air is dependent on the temperature of the headspace within the can, and this is not necessarily the same as the temperature of the contents. It is essential to seal the cans immediately in order to minimize cooling of the headspace since as soon as the can is sealed the headspace will come to the same temperature as the contents and, if there is an appreciable difference between the two, expansion of the air will cause swelling of the can before entering the retort.

Magoon and Culpepper[1] found in their work that there is an initial rapid rise in pressure (the extent depending on the sealing temperature) during the first few minutes of heat processing, which can only be due to expansion of the air. Subsequently the pressure increases slowly, never reaching a constant value during the entire heat process.

Appreciable quantities of air and respiratory gases are included in the tissues of many foods and if not removed will cause additional pressure in the sealed cans.

Blanching of vegetables and certain fruits is therefore practised as a means of removing these gases and thereby reducing the quantity introduced into the cans. Horner[6] of the Campden Research Station has published the following figures, which illustrate the value of blanching for removing included gases.

Vegetable.	Gas in Vegetable Tissue.	
	Raw. Quantity ml./100 g.	Blanched. Quantity ml./100 g.
Peas..	18·0	2·7
Beans	12·8	2·0
Carrots	10·0	1·7
Peas (dried)	38·0	1·2
Beans (dried)	13·0	1·2

Another possible, though uncommon source of additional pressure mentioned by Adam[4] is brought about by an excessive lapse of time between filling and sealing, through the fermentation of the product and consequent production of carbon dioxide which would be liberated and expanded during the heat process.

With cured meat packs an additional cause of excess pressure is possible with an over-liberal addition of nitrite to the pickle. This decomposes during retorting with the liberation of gaseous oxides of nitrogen and subjects the cans to pressures additional to those normally present.

Expansion of the can contents is of special importance in containers with small headspaces, because reduction of the latter by half would necessarily double the effective pressure of the headspace gases.

Overfilling, especially of rigid containers, must also be avoided with liquid products. Expansion of the relatively incompressible liquid could quite conceivably rupture such a container during processing.

In effect all these factors acting together would mean the development of large pressures inside cans during processing, but as has already been mentioned, such pressures are not attained in practice due largely to the expansibility of the can.

Adam and Stanworth[5, 7] made careful measurements and discovered that the ends of a No. $2\frac{1}{2}$ can (401×411) normally "flip" at an internal pressure as low as $3\frac{1}{2}$ lb. with a resultant increase in volume of 21 cubic centimetres (1·28 cu. in.) and subsequent expansion increased the volume uniformly at the rate of 1·9 c.c. (0·116 cu. in.) for each additional pound of pressure.

Expansibility of cans is largely a factor of diameter (and design of ends). Small diameter cans require high pressures to cause expansion, while very slight pressure causes marked volume changes in large diameter cans. This is reflected in the buckling pressures previously quoted.

During pressure processing the theoretical pressures possible in cans are further reduced by the partial neutralization by the retort pressure. However, should the external pressure be released suddenly the danger of buckling or possibly rupture is very real. It is for this reason that gradual reduction of pressure before cooling, or cooling under pressure is a necessity in modern cannery practice.

All that has been said regarding pressures is equally applicable to glass-packing; in fact it is more critical, because of the rigid nature and comparative fragility of the containers. In the majority of commercial concerns, however, the danger is avoided by carrying out a large part of the heat treatment with the containers loosely covered, so that the air and included gases can escape, thus eliminating the main causes of excessive pressures.

Summarizing the important factors influencing pressure in containers during processing, we have:

(*a*) The temperature when closed.
(*b*) Initial headspace.
(*c*) Presence of occluded gases.
(*d*) Flexibility of containers.
(*e*) Method of cooling.

In order to minimize the possibility of these factors causing distortion in processed cans the procedure suggested is:

(1) Close when at a high temperature, taking care that cooling of the headspace does not occur.
(2) Make sure that blanching is efficient.
(3) Do not overfill cans and thus eliminate doming before processing.
(4) Do not allow cans to stand too long before processing.
(5) Check up on cooling methods and eliminate any sudden drops in pressure.

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Notes on some Aspects of the Design of Fruit Cool Stores

By

G. M. Rostos.

General information for the design of a fruit cool store can be found in technical publications.[1] Special requirements regarding storage capacity, kind and variety of fruits to be stored and the best storage practices may be specified readily in consultation with the prospective users and local advisers of the State Departments of Agriculture.

There are, however, certain problems connected with the selection of the refrigerating and control system for fruit cool rooms which are difficult to approach without a fairly detailed knowledge of the physical conditions in existing fruit cool stores of various designs.

A survey of physical conditions in representative types of Australian fruit cool stores has been conducted by this Division since late 1946. The main object has been the measurement of temperature variations, relative humidity and weight losses, but necessarily other information of a physical and engineering nature has been collected as well.

The purpose of these notes is to discuss some aspects of the design of fruit cool stores in the light of this recent survey.

Requirements for Temperature Control.

In general, the lower the temperature the longer the storage life of the fruit, so long as the temperature is not low enough to cause freezing or cold injury disorders. With some fruit, e.g. certain varieties of apples, such disorders may become serious well above their freezing point. Pears[2] are not harmed by low temperatures above their freezing point but are amongst the most sensitive of fruits to small differences in storage temperature. The main Australian varieties have about 20 per cent. longer storage life at 30° F. than at 32° F.

If, therefore, it is of commercial importance to store pears for the greatest possible length of time it is reasonable to aim at a storage temperature within 1° F. above the freezing point of the fruit. In order to achieve this without a serious risk of freezing, the fluctuations of temperatures in time as well as the consistent differences in the average temperature between different parts of the stack must be small. Some Australian pear stores almost reach the ideal of uniformity to within 1° F. but others fall far short of it.

Another objection to temperature variations arises from the fact that the relative humidity changes with temperature. At certain high humidity conditions condensation of water may occur on the fruit and increase the danger of wastage by mould.

Fruit has a large thermal capacity, so that the fluctuations in time of fruit temperatures are much less than those of the surrounding air. With good manual control, or automatic control with sensitive thermostats, it is fairly easy to keep the fluctuations in fruit temperature in any particular part of a store below ¼° F. If, however, refrigeration is applied to a store for only one short period each day, the daily fluctuations in some parts of the stack may be much greater than $\frac{1}{4}$° F.

The reduction of differences in temperature between the various parts of the room is more difficult. The best results can be obtained if efficient insulation is used ; paths are left for the free flow of air around the stack and to every case inside the stack ; the distribution of air flow or the cooling coils is uniform ; the temperature of cooling medium (ammonia, brine or air) varies little in time and rises little whilst passing through the room.

Requirement for Humidity Control.

If the relative humidity in the room is too low, excessive weight loss from the fruit will occur. With pears this may lead to shrivelling, which reduces the market value of the fruit. If the humidity is too high mould wastage may be increased.[5]

It is desirable to design stores so that the humidity in a passageway in a fairly well loaded room, should approach 90 per cent. The actual " drying power " of the cooling system depends largely on the temperature difference which must be maintained between cooling surface and goods in store (to hold the storage temperature).

The more heat that is transmitted through the insulation, or the smaller the cooler-surface, the lower the temperature of this surface must be below that of the fruit and the more moisture is removed from the fruit. Air movement tends to increase the drying power, but this effect is not large enough to be, as often believed, the main cause of some bad cases of shrivelling in certain older " battery " stores. More likely causes are: inadequate cooling surface ; too little air circulation ; poor air distribution and temperature control ; too high brine concentration ; long, exposed main air ducts.

If the temperature of the brine is higher its salt concentration can be lower, without freezing on the coils, and its drying power be smaller.

In the better Australian fruit cool stores 80-85 per cent. in spring and near 90 per cent. in winter are typical relative humidity readings.

Design Features of Fruit Cool Stores.

Arrangement. The arrangement of the cool rooms depends largely on the site and the proposed handling of the fruit. In Australia, older stores are mostly single floor buildings except for some stores on hillsides which have two stories. Recently two-story buildings have been more frequently chosen.

There are reasons in favour of a multi-story building besides the obvious advantages of the reduction of roof area. One is that floor heat can be a prominent cause of bad temperature distribution and rooms above a refrigerated space are almost free from this cause of trouble ; thus at least a section of the store will be suitable for keeping sensitive fruit. A further advantage is that the conduits of air, brine or ammonia can be much shorter.

Insulation. The insulation of the best stores in Australia is at least as efficient as six inches of cork board, often much better, and American practice is similar. This high standard is adopted not only for the saving of refrigeration and reduction of temperature variations but also for obtaining higher humidity in the rooms.

The sealing of insulation against water-vapour has received deserved attention during recent years. In a number of recently built stores the rooms have a gas-proof enclosure,[4] making them suitable for controlled atmosphere storage ("gas storage").

Stowage. A great variety of stacking systems are used in Australia, according to the type of package and cooling system. In the best pear rooms (natural circulation, roof-grids), a distance of at least ½ in. between columns of cases and 3 in. from the wall is satisfactory for 9 to 10 ft. high stacks. No floor dunnage is used with unwrapped pears, loose in open kerosene cases. Most stores use floor dunnage and more liberal gaps with wrapped pears in lidded Canadian bushel cases; dump bushel cases of apples are either stacked flat with ½ in. dunnage between layers or on ends with 1 in. or more distance between vertical tiers.

Natural Circulation Rooms. The most successful pear stores in this country are "natural circulation" rooms with brine-in-coil or direct expansion type roof grids. A typical room with a maximum holding capacity of 6,000 cases and 1,800 sq. ft. floor area has 3,000 ft. of 1¼ in. piping and this appears to be ample without being excessive. In these natural circulation rooms the pipes are arranged in one to three horizontal banks ("grids") above the stacks. These grids may either cover the entire ceiling area evenly or only certain sections. For evenly distributed grids mostly narrow drip trays are used—shielding only two pipe runs. For sectional grids, trays shielding as many as six runs are used in at least one store. The uniformity of temperatures measured in the stack below such drip trays has been found satisfactory. There is a variety of designs using special pipe grouping and wide drip trays (up to half room width) as baffles to encourage air flow in particular ways. Data obtained so far provide no clear indication of outstanding virtues or defects of any of these.

In fruit stores, as a rule, room coils are not defrosted after the rooms have settled down. If the storage temperature is above 32° F. some melting occurs when refrigeration is interrupted; if under 32° F. the frost gradually accumulates. In both cases a "smoothing out" of temperature fluctuations occurs—quite significant with melting and desirable, particularly with direct expansion coils which have much smaller heat capacity than brine-filled ones.

Central Air Cooler Systems. A number of large fruit cool stores in Australia have a central air cooler (or "battery") system. These stores are mostly fairly old and their equipment does not measure up to present-day requirements. The air cooling surface consists of a battery of (ammonia) pipes which are wetted by trickling brine and, in some instances, only about 3,000 sq. ft. of 1¼ in. pipe is provided for a store holding 20,000 cases. The use of such small cooler surfaces requires low brine temperatures (perhaps 15° F. below fruit temperature), leading to low room humidities and excessive weight losses).

In many modern American "battery" stores a brine spray cooler is used. This consists of a spray chamber, brine sump with a refrigerating coil, pump and a centrifugal fan. It may be used as a central cooler or each room can have its own unit. It is less expensive to instal than pipe grids or batteries of the same performance. This may not always be true in Australia, particularly with small units. The mean temperature difference between air and brine can be made less than 5° F. without using sprays so fine that they are too difficult to trap in a simple eliminator. The drying power of a well designed spray cooler may be made very small, certainly comparable with good natural circulation systems.

It is quite feasible to use "dry", i.e. unwetted pipes, in an air cooler and keep the humidity in the rooms reasonably high if a large enough surface is used. Finned pipe batteries may be less expensive than bare ones of the same performance (i.e. rate of heat and moisture removal) but still substantially above the price of a spray cooler. Finned steel pipes are used in other countries for air coolers as well as for room grids; however, there is no early prospect of the manufacture of these in Australia.

With dry batteries, periodical defrosting is essential. It is common practice to use hot ammonia vapours for defrosting direct expansion coils; hot brine is the obvious method for a brine-in-coil system (e.g. on shipboard); hot water sprays are often used in other countries as a supplement or alternative to hot ammonia.

Air Flow. In order to maintain a small temperature difference between delivery and return air, a fairly high rate of air circulation is needed. For pears, 2° F. difference should not be exceeded after the initial cooling is completed unless the air circulation is reversed frequently. The simple sheet steel blade propellor fans, used in many of the old battery stores, are of poor design and are not suitable for providing high rates of circulation. In modern stores centrifugal fans or streamlined propellor fans have to be used. This latter type can be adapted for reversible operation and is widely used in this form on refrigerated ships. Many modern American stores use centrifugal fans but have the circulation automatically reversed at short intervals (15 minutes to three hours) by mechanically operated shutters in the duct system.[3] Air circulation rates of 20 to 30 changes per hour are common in modern stores, whilst in old ones often less than half of this is achieved.

Air Distribution. It is very difficult to design a good air distribution system because unless the room is quite full and large gaps, such as a central passageway, are blocked, the main air stream will by-pass the stack and the air movement inside the stack will be largely due to secondary air currents—hardly more effective than thermal air currents. However, the amount of air movement required over each case of fruit is not large and there are many duct and diffuser systems in use which provide adequate air movement.

Choice of Cooling System and Controls.

In designing a store choice has to be made between room grid and battery on the one hand and between direct expansion and brine on the other. In general the *brine system* is favoured where electric power at reduced night rates is available and the brine tank can be used as cold accumulator for the day runs during an appreciable part of the season. Other reasons such as the need for brine reserve for rapid initial cooling of the fruit or the ease of temperature control may justify the choice of brine. However, these reasons are usually more carefully weighed against the advantages of a direct expansion.

A *direct expansion system* is always cheaper to instal and operate than a brine-in-coil system but not necessarily cheaper than a central battery system. The theoretical advantages of higher suction pressures compared with a brine system may not be significant. Real advantages are, firstly, those common to all room grids; the comparative ease of *individual* temperature control in each room and cooling without mixing the air of the various rooms; secondly, the absence of brine pumps and corrosion.

The *manual temperature control of a direct expansion room* is very simple. However, it has the disadvantage that with light loads only the beginning of the coil may be effective. In order to overcome this, the room grid is usually subdivided into two to four sections which can be controlled by separate expansion valves and are carefully arranged to smooth out uneven temperatures below the coils. Flooded evaporating coils have been successfully used for grids in other countries but are generally too expensive.

With *automatic control,* if its cycle is short the subdivision of coils may not be so important. Automatic controls for a direct expansion system are fairly expensive and become unreasonably complicated when a large number of rooms has to be controlled or the compressors are too large to be started by simple switches.

One of the virtues of a *brine-in-coil* system is that both manual and automatic control of refrigeration is simple and effective even in the largest cool stores.

The temperature differences in space can be minimized by circulating enough brine to keep the difference between delivery and return less than 3° F. and to arrange the pipe runs in such a way that the effects of this difference are largely neutralized. The variations of temperatures in time can be kept small generally by regulating the flow of brine whenever deviation from the required room temperature occurs. This may be done much more easily with brine than with ammonia or air.

For *automatic operation,* room thermostats of a sensitivity of the order of $\frac{1}{4}$° F. are needed, otherwise too long—over 12 hours—cycles and "drifts" in the fruit temperatures may occur. The regulation of the brine flow is, as a rule, the "on" and "off" type, and this is quite satisfactory for fruit stores. The brine is either circulated by a master pump in the delivery main and admitted from this to the individual rooms by solenoid or motorized valves, or a pump is provided for each room. These pumps may draw brine from the tank only, but it is preferable to provide a by-pass so that a variable proportion of the return brine can be re-circulated into the coil. An advantage of this system is that when the heat load diminishes after the summer peaks and the *average* coil temperature has to be higher, this adjustment can be achieved without unduly reducing the brine flow and spoiling the uniformity of temperatures in space. Another effect is that the deviations from the average coil temperature (in time) can be small without the control cycle being unduly short.

Auxiliary fans—stationary or portable—are very useful, often essential, for equalizing temperatures in a grid room during the initial cooling of the fruit. However, they are not effective in improving the uniformity of temperatures where a difference of the order of 5° F. exists in the settled store owing to dense stacking or insufficient insulation. The same applies to some more elaborate duct systems designed for circulating the air in grid rooms.

The attraction of a modern *air cooling battery* is its low price on account of the small amount of piping used. Also, used as a "unit" battery serving one room only, there is no doubt it can be very satisfactory. However, the central battery system has inherent disadvantages which need to be discussed.

In central battery stores the *mixing of the air of the various rooms* may be undesirable because of possible tainting, but this is no serious concern in specialized fruit stores. The undue warming up of the fruit or condensation on its surface in some of the rooms whilst others are being freshly filled, may do some harm.

A more serious defect of the central system is the difficulty of close *temperature control in the rooms individually.* The performance of the battery can be regulated readily but in the rooms the only means of control is the restriction of the air-flow by shutters, and alteration of the flow in one room influences the others. Long and often costly experience is needed to gain enough judgment for close control. The restriction of air flow has in itself adverse effects on the uniformity of temperatures.

Automatic temperature control for a central battery store, though technically quite feasible, has not been used in Australia.

Remarks on Thermometers.

A number of cool stores in Australia have now electric distant reading thermometers. Usually there is one measuring element in each room permanently installed in a fixed position. In this form these instruments serve merely as a convenience for the attendants. However, if there are at least two measuring elements (possibly three or four) in a room and these have a flexible lead so that they can be placed where most needed (as on some ships), valuable information can be obtained for the achievement of good results. The air temperature measured at one or two places in the passageway in a cool room is not necessarily the same as the temperature of the bulk of the fruit. Hence it is advisable to place thermometer elements between the fruit cases, at least one in a location where the coldest, and one where the warmest temperatures, are likely to occur.

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FROZEN STORAGE OF POULTRY.

The beneficial effects of low storage temperatures on the retention of good quality in frozen poultry are clearly indicated in a recent paper, " Low Storage Temperatures Keep Dressed Poultry Good Longer ", published in *The U.S. Egg and Poultry Magazine*, Vol. 53 (1947) by C. H. Koonz, R. D. Trelease and H. E. Robinson. In a comparison of storage temperatures ranging from +28° F. to −20° F. the approximate storage life, as judged by acceptable aroma and flavour of the fat and meat in the cooked poultry, was as follows: +28° F. 1 month, +20° F. 3 months, +10° F. 5 months, 0° F. 9 months, −10° F. and −20° F. 12 months or longer. Storage temperatures above +20° F. are not to be recommended except for short periods because of the danger of microbial spoilage.

Answers to Inquiries

PACKAGING OF PLUM PUDDINGS.

Owing to the shortage of tinplate a number of manufacturers are interested in the use of alternative packages to the tin can for plum puddings for the domestic market and for export to Britain.

Mould attack is likely to be the main cause of loss in puddings which are not canned. Theoretically there are three ways in which mould attack can be prevented, namely:

(1) By destroying all mould spores on the surface, either in cooking or by a subsequent heat processing, and using a container which will prevent recontamination of the surface with mould spores.

(2) By using preservatives.

(3) By making a pudding of low equilibrium humidity and keeping the surface dry enough to prevent mould growth within the likely storage period of the pudding.

The first method is the one generally used with canned puddings. If tinplate is not available it may be possible to use glass or perhaps aluminium containers, but there is little hope of keeping the surfaces sterile with puddings packed in any of the flexible packing materials or substitute containers available in Australia at present.

No preservative can be recommended and guaranteed to prevent mould attack in puddings, so the third method of preventing mould attack may often be the only one available.

It has been shown that with fruit cake the risk of mould attack decreases rapidly as the equilibrium humidity is decreased below about 80%, by changing the composition of the cake, and there is little risk of mould attack within six months in cakes of equilibrium humidity 75% or lower. The main factors affecting the equilibrium humidity of ordinary cakes are the water content and the fruit content, the higher the water content the higher the equilibrium humidity, but the higher the fruit content the lower the equilibrium humidity. Cakes with low fruit content need to be made too dry to be palatable to reduce the equilibrium humidity below 75%, but commercial rich fruit cakes (with high fruit content) commonly have equilibrium humidities of 73-75%. The reason for the effect of the fruit in reducing the equilibrium humidity of cakes is that most of the sugar in the fruit is in the form of monosaccharides which have roughly twice the effect of equal weights of cane sugar in reducing the equilibrium humidity. A similar effect to the addition of fruit could, therefore, be obtained by replacing part or all of the cane sugar in the mix by invert sugar or glucose.

Commercial plum puddings vary greatly in composition and equilibrium humidity but many have equilibrium humidities high enough to permit mould growth.

One pudding we have seen had an equilibrium humidity of 73%, a water content of 22·5%, a total sugar content of 36% and reducing sugars 34%. This reducing sugar content is unusually high and although some inversion of cane sugar may have occurred during cooking it is likely that most of the added sugar was in the form of invert sugar or glucose syrup. Substituting invert sugars for cane sugar, either wholly or in part, may alter the flavour of a pudding and affect the texture, but it might sometimes be the best way of achieving low enough equilibrium humidities.

A freshly cooked pudding has a moist surface which must be dried out to prevent mould attack if it cannot be kept sterile. If the pudding were stored, unwrapped or with a wrapper which did not restrict water vapour transfer greatly, the equilibrium humidity would vary with the humidity of the storage atmosphere. Under dry conditions, e.g. at humidities of 70% or lower, it would gradually dry out and if its initial equilibrium humidity were below 75% there would be very little risk of mould attack. If stored at a high humidity, e.g. 80%, the surface would absorb water and mould growth would soon occur however low the initial equilibrium humidity.

The average indoor humidities in most temperate regions are below 70%, but values of 80% and higher are common in the tropics. It is common practice for housewives in the temperate parts of Australia to store puddings, which have not particularly low equilibrium humidities, with only cloth coverings, and the success of this depends on evaporation keeping the equilibrium humidity of the pudding surface low enough to prevent mould growth. For storage at humidities of 70% and lower, wrapping in a material which restricts evaporation greatly would increase the risk of mould attack. For long storage at humidities above 75% a wrap or container of very low permeability to water vapour would be needed. There is not enough information available to calculate exactly how good the wrapping material would need to be, but rough calculations indicate that the better materials available locally might be good enough for individual wrapping of puddings initially of 73% equilibrium humidity which have to be held about three weeks at 80° F., 80% R.H.; and at humidities of 70% or lower before and after this period. This can only be a rough estimate, but it indicates

(1) The wrapping materials available are unlikely to be good enough for long storage in the tropics of individually wrapped puddings.

(2) They are probably good enough for puddings exported to Britain but the margin of safety may be small.

A wrap which restricts water uptake also restricts drying out when the storage humidity is reduced, so that it would be dangerous to use a wrap which seems barely good enough for the anticipated storage conditions.

For export puddings it would seem safest to use a wrapping of low resistance to water vapour for the individual puddings but put them in bulk containers lined with an efficient moisture vapour barrier. The efficiency required in this barrier will be much less than for protecting puddings individually because of the smaller wrap area per pound of pudding or square foot of pudding surface. For successful handling in this way it is, of course, essential to use puddings whose equilibrium humidities are below 75% and to dry out the surfaces thoroughly before packing.

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