FOOD PRESERVATION QUARTERLY

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C.S.I.R.O.

Food Preservation Quarterly

PUBLICATION of the "Food Preservation Quarterly" began thirteen years ago and has continued without a break. The C.S.I.R. Division of Food Preservation and Transport commenced publishing the Quarterly to circulate information on some of the problems arising from the extraordinary increase in the output of processed foodstuffs in Australia during the war. This rapid increase in production was accompanied by a growing need to overcome handicaps suffered by some sections of the food industries because of inadequate knowledge of current developments in food processing techniques. The original aims of the Quarterly were to present in non-technical language the results of the Division's research programme and to disseminate information of practical value to food processors, and these aims have been maintained since the war. Recent numbers have also laid some emphasis on material of general interest to food technologists.

With this issue the Quarterly assumes a new guise. Its format has been redesigned and its presentation made more attractive. The scope of the contents remains unchanged, but the Division of Food Preservation and Transport will be glad to consider any suggestions made by readers for articles of special interest in future numbers.

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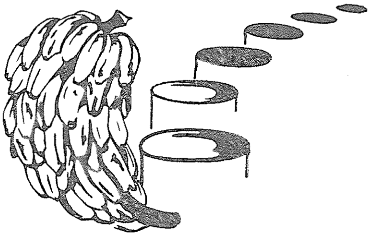
Canned bananas are now an established commercial pack with a ready overseas market. These notes concern canning procedure and the avoidance of discoloration



CANNING

UNTIL RECENTLY THE VIEW WAS WIDELY HELD in the canning industry that bananas could not be canned successfully. In 1949, however, the C.O.D. Cannery began experiments in banana canning and succeeded in obtaining a satisfactory product. Subsequently the C.S.I.R.O. Division of Food Preservation was requested to carry out more detailed investigations with a view to developing the best possible canning technique.

Successful banana canning followed recognition of the fact that bananas are a low-acid fruit (pH 4.6-5.4). If they are to be processed like other fruit it is necessary to lower the pH of the pack to 4.2-4.3. By acidification of the syrup it is possible to reach this pH without adversely affecting the palatability of the product. The acidification imparts a faint sourness to the bananas but this is partly balanced by the sweetness of the syrup. The canned bananas are, of course, "cooked" bananas but they retain the colour and texture of the fresh fruit to a considerable extent and are particularly suitable for use in fruit salads, custards, and ice-cream dishes.

Canned bananas are now an established commercial pack and have found a ready market overseas in countries such as Britain and Canada where fresh bananas are not readily available. The canned pack provides a useful outlet for bananas during the peak production of the fruit in November-December, when pineapple canneries are slack. It has been reported recently that banana purée has been successfully canned in America as a baby food.*

* GUYER, R. B., and ERICKSON, F. B. (1954).—Canning of acidified banana purée. *Food Tech. Champaign* **8**: 165-7.

Notes on Canning Procedure

The following notes are based on the results of investigations and commercial experience.

Variety and Maturity.—Cavendish bananas, the common commercial variety, are the most satisfactory for canning. The Mons Marie variety has also been canned successfully, but the Ladies' Finger variety is entirely unsuitable.

As with many other canned fruits, the maturity of the fresh fruit largely determines the quality of the final product. The best quality is attained by using bananas at the early stage of eating ripeness when brown flecks are beginning to appear on the yellow skins. Less mature bananas develop a hard texture and astringent flavour when canned.

Acidification. — In commercial practice citric acid is used to lower the pH of bananas, but lactic, tartaric, acetic, and aconitic acids have been used experimentally in the C.S.I.R.O. laboratory at Homebush. The following concentrations in 25° Brix syrup were found to be adequate to reduce the pH of the pack to about 4.2 or 4.3:

Citric acid	0.5 per cent.
Lactic acid	0.5 per cent.
Tartaric acid	0.25 per cent.
Aconitic acid	0.25 per cent.

Acetic acid imparted a disagreeable flavour to the product at all concentrations tried. Aconitic acid, it should be added, is not as yet a permitted additive to foods in Australia. Ascorbic acid and pineapple juice were also tried, but it was found that ascorbic acid did not produce a better pack than citric acid and that pineapple juice masked the banana flavour.

By P. W. Board

Division of Food Preservation and Transport, C.S.I.R.O., Homebush, N.S.W.

and P. E. Seale

Queensland Tropical Fruit Products, a Division of the Committee of Direction of Fruit Marketing, Northgate, Q.

BANANAS

Syrup Composition and Cloudiness.—Organoleptic tests on bananas canned in various concentrations of syrup containing 0.5 per cent. citric acid indicated that the optimum syrup concentration was about 25° Brix.

The addition of 0.2 per cent. anhydrous calcium chloride to the syrup improved the texture of the fruit and reduced the cloudiness which often appears in the syrup during processing.

Style of the Pack.—Bananas may be packed as chunks three-quarters of an inch long, or small fruit may be packed whole (after peeling).

Fill-in Weight.—The following weights are recommended:

16-oz. can: 9 oz.

30-oz. can: 18 oz.

Cans.—Cans lacquered internally with an acid-resisting lacquer are recommended since considerable corrosion has been encountered in plain cans.

Exhausting.—A satisfactory vacuum is produced in the chunk pack by filling boiling syrup onto the fruit and closing with steam flow. However, if this method is used with the whole-banana pack a large quantity of air is trapped in the seed cavities. Hot filling should, therefore, be followed by a short exhaust and steam-flow closure.

Processing and Cooling.—The following conditions have been found adequate for stationary processing: 16-oz tall can (301 × 411): 10 min in boiling water, 30-oz can (No. 2½, 401 × 411): 12½ min in boiling water.

The Problem of Discoloration

Three distinct forms of brown discoloration have been encountered in canned bananas:

Enzymic Browning.—Oxidizing enzymes in cut and peeled tissue quickly produce a brown discoloration when the tissue is exposed to the air. To minimize this deterioration delays on the processing line after peeling must be avoided.

Oxidative Browning.—In packs which contain excessive amounts of residual oxygen, because of excessive headspace or inadequate exhaust, banana tissue exposed in the headspace may show a grey to black discoloration.

"Tannin Browning".—In early commercial production a serious quality defect was a discoloration which appeared as fine pink to brown lines concentrated mainly in the carpel walls of the banana. These fine lines are formed by rows of mucilaginous cells which contain tannin-like substances.

After extensive investigations covering both raw material and processing variables this discoloration was found to be due to the interaction of substances in the acidified syrup with the tannins in the mucilaginous cells. It is known that carbonyl compounds, for example hydroxymethylfurfural, can be formed when sugars are heated under acid conditions. It was possible to reproduce the discoloration exactly by adding furfural in small amounts to processed bananas. Laboratory studies have indicated, however, that carbonyl compounds are formed in significant amounts only when acidified sugar syrups are heated too long. These studies are being continued in an attempt to define more closely the conditions for formation of compounds which may cause discoloration.

Food Technology Research

THE PRESERVATION OF FRUITS IN HONEY, THE pickling and drying of fruits and vegetables, the preparation of syrups from fruits, flowers, and herbs, and other indigenous methods of processing foods have been practised in India from time immemorial. Modern food technology, however, is of recent origin and is still in its infancy. A vigorous policy of scientific research on food and the development of many food industries dates from World War II, when India became an important supply base for the Allied Forces in many parts of Asia. Researches for the Army Supply Department were then begun at a number of centres throughout the country under the auspices of the Board for Scientific and Industrial Research and the Council of Scientific and Industrial Research (C.S.I.R.), which were established by the Government of India in 1940 and 1942 respectively. Investigations were also undertaken by industries and by Central and Provincial Government organizations such as the Indian (formerly Imperial) Council of Agricultural Research (I.C.A.R.) and Provincial Departments of Agriculture. Among these were the fruit and vegetable preservation schemes of the I.C.A.R. at Lyallpur and Quetta. A limited number of stations had been engaged in technological research before this development, but their activities were very limited.

Following the independence of India in 1947, its Government recognized the paramount importance of scientific and industrial research to the nation by establishing 11 national research laboratories, one of which was given over to the study of modern food technology. This was set up at Mysore as the Central Food Technological Research Institute, and started functioning in October 1950. The Indian Institute of Fruit Technology, which was established at Lyallpur (now in West Pakistan) in 1945 under the I.C.A.R. and transferred to Delhi after partition of the country in 1947, was merged with the new Institute.

The Central Food Technological Research Institute

The Central Food Technological Research Institute at Mysore aims at the most efficient and economic utilization of the food resources of India by applying the methods of modern science and technology. It sets out to help food industries to develop on sound scientific lines.

The scientific staff of the Institute, numbering 75, is organized into nine divisions and sections, namely, Food Processing, Fruit Technology, Storage, Biochemistry and Nutrition, Dietetics, Microbiology and Sanitation, Quality Control, Engineering, and Information and Statistics. Most of the research work in food technology in India is carried out in this Institute, which is also responsible for coordinating allied work carried out by the C.S.I.R. at other centres in the country. It should be explained that investigations on problems of local importance, for example on canning and preservation of local varieties of fruits and vegetables, are carried out by Provincial Government Departments. Practically no research in food technology is carried out by private organizations or manufacturing concerns.

Occasionally the Central Food Technological Research Institute arranges symposia on scientific subjects. At other times representatives of the food industries are brought together to discuss problems and plan research likely to assist industrial development. The Institute also provides a one-year diploma course in fruit technology. The Government of India has recently set up at Khargpur, in Bengal, the Indian Institute of Technology to

Extracts from an address delivered by N. L. Jain, Central Food Technological Research Institute, Mysore, India, to the staff of the Division of Food Preservation and Transport, C.S.I.R.O., in June 1953

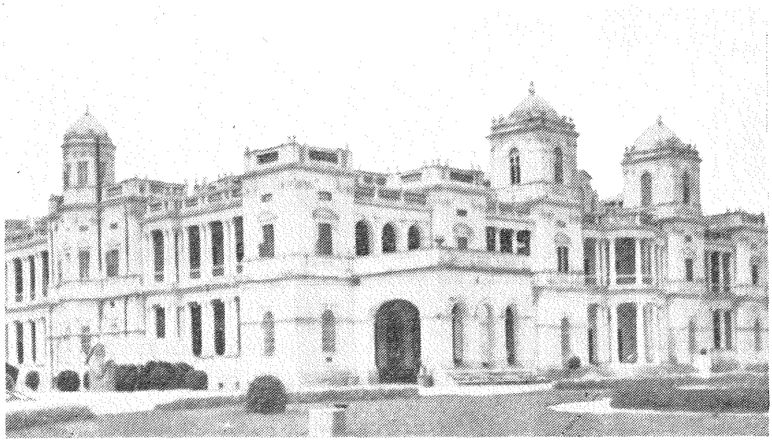
in India

meet the needs of research laboratories and industry for trained technologists. It will give post-graduate training in refrigeration and in food technology among other subjects related to the food industries.

The account which follows deals briefly with some of the food problems which have been investigated in India, particularly at the Central Food Technological Research Institute, Mysore, during the past few years.

Shortage of Food

One of the greatest problems facing India today is the shortage of food for its 360 million people. As the result of an annual increase in population of about four million, an additional 500,000 tons of grain foods are needed each year. Production has not, however, kept pace with demand. The two most important cereals are wheat and rice. The wheat position is not serious, but a rather alarming situation exists with rice. Firstly, there is a world shortage of rice, and secondly, people in India who are used to eating rice do not like to eat any other cereal. A need has, therefore, long been felt for a substitute for rice, possessing all or most of its characteristics. Such a product has now been made successfully from a mixture of tapioca flour (prepared from the root of the tropical shrub *Manihot utilissima*) and defatted ground-nut flour. It resembles rice, is acceptable to the taste of rice-eaters, and is as nutritious as rice itself. It has a protein content of eight to nine per cent. and cooks in about half the time required for natural rice. It has another advantage over rice in that it can be more readily fortified with the vitamins, protein, and calcium in which natural rice is deficient. The storage behaviour of this substitute grain is also satisfactory. Investigations having proved encouraging up to the pilot-plant stage, large-scale production is now being attempted. Methods have also been devised for using tapioca flour, sweet potato flour, and



The Central Food Technological Research Institute, Mysore.

*Colocasia** flour as partial substitutes for wheat flour.

Storage losses of cereals and other grain foods, which in India are estimated to be about 10 per cent. yearly, worsen the food shortage considerably. In the course of investigations to minimize these losses, optimum moisture limits have been determined and methods of fumigation standardized. Mercury and inert earths such as limestone have also been found effective against insect attacks. A method practised in India for ages, namely the hermetic storage of grain, has been found to be most efficient. The insects are killed by the high concentration of carbon dioxide which builds up. Impregnation of jute bags with pyrethrum in combination with nicotine sulphate has given encouraging results in the storage of flour.

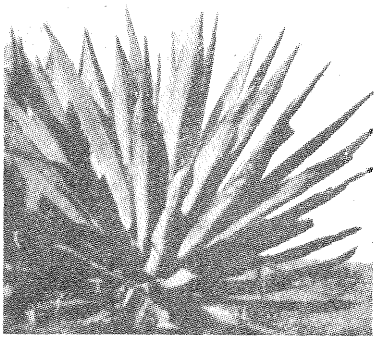
Another important problem facing India is the acute shortage of milk. A substitute milk prepared from ground-nuts has the same composition and nutritive value as cow's milk and is superior to soya-bean milk, which has been known in India for some years. It may be used in the preparation of curds, buttermilk, and a number of other products. One pound of ground-nut kernels yields 8-9 lb milk.

Preservation of Fruit and Vegetables

In the field of fruit and vegetable canning and preservation some of the important new canned products are: canned jack fruit,* banana, guava (yellow, pear-shaped or round fruit of *Psidium guajava*), cashew-apple (a fleshy adjunct to the cashew-nut, the fruit of *Anacardium occidentale*), musk melon, orange segments ready to serve, and curried vegetables. Beverages and candy have been made from cashew-apple; vitamin C concentrates and syrups from amla;† guava jelly powder; pectins from papaya (papaw), wood-apple,‡ and jack-fruit wastes; and pickles and chutneys from tender bamboo shoots. Various fruit juice concentrates and powders have also been made. Amla contains 600-900 mg ascorbic acid per 100 g pulp. Cashew-apple is a by-product of the cashew-nut industry. Its juice has a fine aroma and contains about 180 mg ascorbic acid per 100 c.c. It is not, however, palatable, because of some astringent and acrid principles present in the fruit. The amla is also rather astringent in taste. The undesirable principles of both these fruits and the cyanogen glucoside of bamboo have been successfully removed in the preparation of various products. Investigations are in progress to overcome the development of bitterness and off-flavours in canned juice made from loose-jacket oranges (mandarins). Studies are also under way to improve the nutritional values and general quality of indigenous products. Investigations on the following were carried out during the 1939-45 war: canning of important varieties of plums,

* A genus of tuberous shrubs. The flour is made from tubers of a cultivated species, *C. antiquorum*.

Cashew-apple and its processed products.



Agave plant.

* The fruit of *Artocarpus integrifolia.* The skin is prickly and the flesh has a texture like coarse bread.

† Prepared from the round yellowish fruit of the amla tree, *Phyllanthus emblica.*

‡ The fruit of *Feronia elephantum.* The tough, woody pericarp encloses numerous seeds set in pulp.

peaches, apricots, and pears, dehydration of fruits and vegetables, and reprocessing of poor-quality sun-dried fruits.

Some glut fruits like mango, monsoon season oranges, and wild plums have been used in the preparation of good-quality wines. A cheap vinegar generator has been designed for preparation of vinegar on a cottage scale. It has been successfully used for preparing vinegar from cane-juice molasses and jaggery (a coarse brown sugar made from palm-sap). Tamarind is under investigation for the preparation of tartaric and citric acids and pectin. Studies on spoilage in Indian pickles are in progress. Some enzyme preparations have been made for clarification of juices.

Other Investigations

A good-quality starch has for the first time been prepared from a waste material, the banana pseudostem, and an application for a patent is pending. *Agave vera cruz** has been found to be a rich source of fructosans. A patent for the preparation of fructose from this has been taken out by the C.S.I.R.

With regard to cold storage of fruits and vegetables, optimum conditions for temperature, humidity, and pre-storage have been determined for the more important Indian fruits and vegetables, and also the associated changes in quality under different conditions. The optimum conditions for ripening mangoes have been determined. Loss in weight of potatoes during storage has been reduced by pre-storage heat treatment at 100.4°F for 16 hours.

Little work has been done on freezing fruit and vegetables apart from some preliminary investigations on peas, cauliflower, cashew-apple, and orange segments.

Husk of coffee beans, formerly regarded as a non-edible waste material, has been found to be a suitable substitute for chicory in the preparation of French coffee.

It has been shown that the grain of *Amaranthus paniculatus,* a widespread species, the grain from which is used as a cereal, is a rich source of protein and calcium, and grains of *Sesbania grandiflora*† have been found to contain about 70 per cent. protein. The possibility is being investigated of converting both of these into breakfast foods and of using them in other nutritious forms. Ragi (*Eleusine coracana,* a millet 2-4 feet high cultivated for its grain, which is used as a cheap cereal) has been used for the preparation of malt. High-class tonic wines have been prepared from indigenous herbs.

* A short-stemmed plant bearing a rosette of long, pointed, erect, fleshy leaves. Sisal hemp is obtained from a related species.

† A legume growing to a height of 20-30 ft. The tender leaves are used as greens and the large white flower petals are made into curry or fried with butter.

Ragi.

Improvements have been made in the extraction of oil from ground-nuts. In the mechanical crushing method 8-10 per cent. of oil is left in the cake, which is likely to become rancid. Solvents extract the oil more completely, but the common hydrocarbon solvents such as petroleum ether confer strong odours on the cake. In a new process, for which an extractor has been successfully designed and operated, alcohol is used as a solvent. The residual cake is free from objectionable odours, and forms a high-class food. Investigations have also been made of the relative nutritive value of vegetable oils (hydrogenated and non-hydrogenated) and butter.

THE LABORATORY EXAMINATION OF CANNED FOODS

The third article in the series on the above topic. The earlier articles, by J. F. Kefford and W. J. Scott, appeared in the Food Preservation Quarterly, *Volume 13 (1953), pages 3 to 8 and pages 21 to 31.*

INTERNAL

SIGNIFICANCE OF VACUUM

THE FIRST OPERATION PERFORMED ON A CAN being opened for general inspection is customarily a determination of the internal vacuum (Boyd and Bock 1952; Anon. 1953). The pressure within a normal food can is less than atmospheric pressure, i.e. there is a vacuum in the can, because it has been hermetically sealed at a high temperature or in a vacuum chamber.

Can vacuums are expressed as the difference, in inches of mercury, between the internal pressure in the can and atmospheric pressure. Thus vacuums in the range 15-25 in. Hg are good vacuums and 1 in. Hg is a low vacuum. In commercial canning practice 7 in. Hg is commonly accepted as the minimum satisfactory vacuum. The South African Bureau of Standards (1951) has incorporated in its specifications for most canned foods a requirement that the minimum vacuum shall be 5 in. Hg at 75°F.

When Nicholas Appert invented the art of canning in about 1795, he thought it was the vacuum inside his jars that prevented the foods from spoiling. It was Louis Pasteur, many years later, who first showed that food spoilage was caused by microbes and that the secret of Appert's process was the long cooking in boiling water which destroyed the microorganisms. Canners have, however, retained the practice of creating a vacuum within food cans in order to collapse the can, to minimize strains in processing, and to control internal chemical activity.

To Collapse the Can.—The main practical purpose of a good vacuum is to hold the ends of the can (and in rectangular and tapered cans the sides also) in a collapsed, concave position. A well-collapsed condition is a useful external indication that the pack is probably sound and wholesome. In practically all cases of microbial spoilage except those due to flat-sour organisms, gas production and eventually swelling occur. Swelling may be due to causes other than microbial spoilage but in most instances it is accompanied by some deterioration in the acceptability of the product. Consumers are customarily suspicious of swelled or springy cans and are well advised to reject any can which shows evidence of swelling. As a precaution, therefore, the canner endeavours to produce cans with internal vacuums capable of maintaining a well-collapsed condition under all circumstances during storage and transport.

A number of external agencies may operate to produce springiness in cans with inadequate vacuums, for instance *mechanical damage*. A blow on the body of the can may reduce its internal volume so that a positive pressure is set up and the ends spring out. Again, since the vacuum in a can is the difference between the internal pressure and atmospheric pressure, this vacuum will be lower at *high altitudes*. The drop in vacuum which occurs is about 1 in. Hg per 1000 ft rise in altitude. This is seldom a practical hazard for Australian canners but South African canners shipping from the coast to Johannesburg (6000 ft) must provide for a

Critical comments on the procedures described, and suggestions for modified or alternative methods found to be useful in practice, will be welcomed.

By J. F. Kefford

C.S.I.R.O. Division of Food Preservation and Transport, Homebush, N.S.W.

VACUUM IN CANS

drop in vacuum of approximately 6 in. Hg (Knock 1951). *A rise in storage temperature* also reduces can vacuums by expanding the contents and the headspace gases and by increasing the pressure of water vapour. Cans returned from northern Australia (80-90°F) as springers have been found to be flat when examined in Sydney (60-70°F).

To Minimize Strains in Processing.—The effects of temperature are greatly accentuated at the temperatures (212-250°F) at which canned foods are processed. At these temperatures the positive pressures developed within cans strain the seams and may cause permanent distortion. The presence of an adequate internal vacuum reduces the internal pressure developed during processing.

To Control Internal Chemical Activity.—In general, the presence of oxygen in canned foods is detrimental both to the quality of the product and to the performance of the container. The higher the vacuum in a can, the less the amount of oxygen present. In addition, if corrosion occurs, with evolution of hydrogen, a good vacuum delays the appearance of swelling, since more hydrogen must be evolved to develop an internal pressure great enough to force the can end outwards.

MEASUREMENT OF VACUUM

The Campden Manometer

For the accurate measurement of internal vacuums in cans, a mercury manometer is used. A convenient form of manometer was developed by Adam and Stanworth (1932-33) working at the Fruit and Vegetable Preservation Research Station, Campden, England, and this instrument is commonly referred to as the Campden manometer. A somewhat similar instrument was later described by Blatt and Tarassuk (1950).

The Campden manometer consists of an open mercury manometer connected, through a capillary tube and a three-way tap, to a hollow needle which enters the can under test. When the can is punctured the manometer registers a vacuum which is not, however, the true vacuum because the connecting capillary contained air at atmospheric pressure. Therefore the connecting system is restored to atmospheric pressure, by opening the three-way tap, and then a second reading is taken of the vacuum in the can. From the two manometer readings, the true vacuum is calculated by applying a formula derived as follows:

Let P = atmospheric pressure,
v = volume of the connecting system,
H = true vacuum in the can,
V = headspace volume in the can,
h_1 = first manometer reading,
h_2 = second manometer reading.

Initially, the connecting system (volume v) is at a pressure P, and the can (volume V) is at a pressure $P - H$. After puncturing, the whole system (volume $V + v$) is at a pressure $P - h_1$.

Then

$$(P - h_1)(V + v) = Pv + (P - H)V.$$

Simplifying,

$$h_1 v = V(H - h_1) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

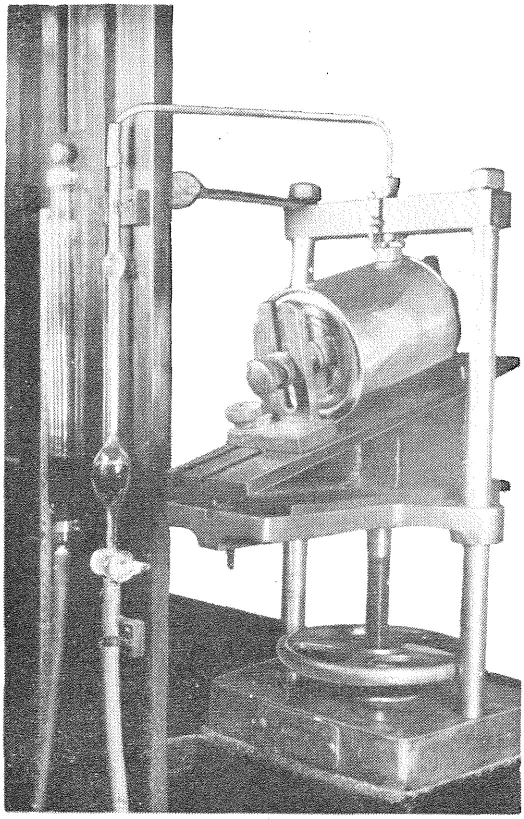


Fig. 1.—The Campden manometer.

Now the connecting system is restored to a pressure P while the can remains at a pressure $P - h_1$. When the second reading is taken, again introducing a volume v of air, the whole system has a pressure $P - h_2$.

Then

$$(P - h_2)(V + v) = Pv + (P - h_1)V.$$

Simplifying,

$$h_2 v = V(h_1 - h_2) \quad \ldots\ldots\ldots \quad (2)$$

From equations (1) and (2), the true vacuum is derived:

$$H = (h_1)^2/h_2.$$

The Campden manometer* in use in this Laboratory is illustrated in Figure 1 and sketched diagrammatically in Figure 2. One arm of the mercury manometer is fixed and the other arm (S) may be moved up and down a millimetre scale. The fixed arm is marked at three points: the uppermost mark, M_1, is at the zero of the scale, the mark M_2 indicates a known volume (about 2 ml) in bulb B_1, and the mark M_3 indicates a further known volume (15-20 ml) in bulb B_2. This portion of the manometer could consist of a graduated burette tube. The sliding arm (S) has a capillary side arm of the same bore as the fixed arm at the points M_1, M_2, and M_3, in order to avoid errors due to capillarity.

The manometer is connected by a capillary tube to a capillary three-way tap T_1. The volume (v) of the capillary from the mark M_1 to the tap T_1 is known. In Figure 1 the three-way tap is machined into a brass bar and immediately below is mounted a hollow needle, surrounded by a soft rubber gasket to prevent leakage at the point of puncture. The needle is a veterinary hypodermic needle clamped in position in such a way that it is readily removed for sharpening, cleaning, or replacement. The needle should be sharp enough to pierce tinplate without distorting the can.

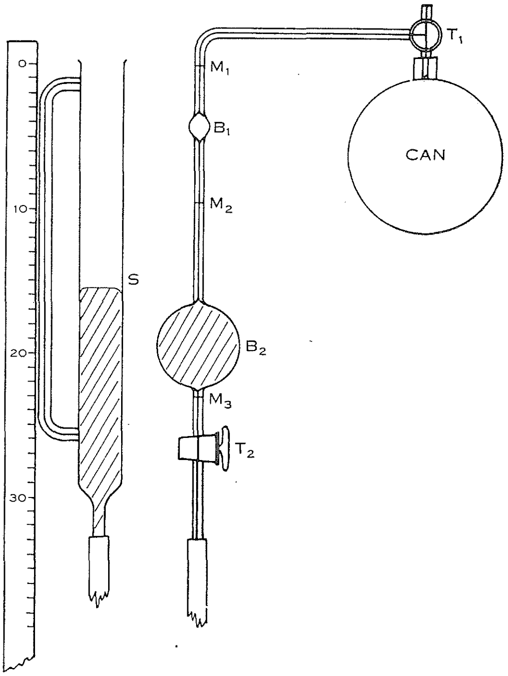


Fig. 2.—Diagrammatic sketch of the Campden manometer.

* This instrument was designed, made, and presented to C.S.I.R.O. by John Heine & Son Pty. Ltd., Leichhardt, N.S.W.

The can is brought up to the needle on a platform elevated by means of a threaded shaft and a wheel. A number of other devices have been used for performing the operation of forcing the needle into the can (cf. Blatt and Tarassuk 1950; Humphriss 1952). In the device* shown in Figure 3, the can is clamped against the rubber gasket by turning the lower handle, then the needle within the gasket is forced into the can by turning the screw at the top. A small hydraulic motor-car jack can also be readily adapted to bring the can up to the puncturing needle.

When the can is punctured it is obviously important that the needle should enter the headspace. For this reason, cans containing liquid foods or foods in liquid media are customarily mounted on an inclined frame so that the headspace is brought into the top "corner" of the can.

The inclined frame is provided with adjustable screw clamps which hold the ends of the can in their original position throughout a determination. An ordinary G-clamp could be adapted to perform this function. When the internal vacuum is released the ends of a can tend to move outwards and this movement could lead to error in the estimation of original vacuum and headspace volume.

When solid or semi-solid packs are being examined, the inclined frame is removed. The cans are placed on the flat platform and punctured through one end. It is generally possible to identify the headspace end by tapping.

Vacuum Determination

To determine the vacuum in a can with the Campden manometer the following sequence of operations is performed:

1. Place the can on the inclined frame and clamp the ends.
2. Moisten the rubber gasket around the needle and raise the can so that the gasket presses on the can body just below the end seam.
3. Turn the three-way tap T_1 so as to connect the manometer with the air and close off the can.
4. Puncture the can.
5. Open the tap T_2 and bring the mercury in the fixed arm to the zero mark M_1.

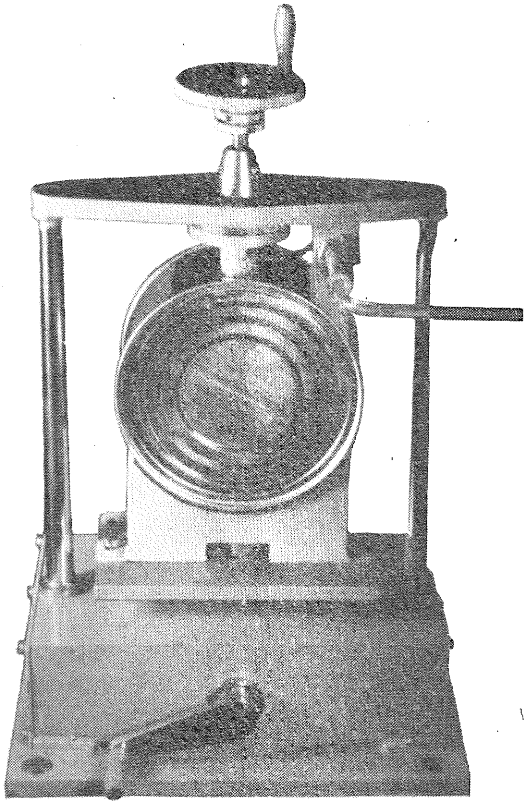


Fig. 3.—Can puncturing device.

6. Close the tap T_2 and lower the sliding arm to prevent mercury from being sucked over.
7. Turn the three-way tap T_1 to connect the can to the manometer.
8. Open the tap T_2 and bring the mercury back to zero (M_1).
9. Read the mercury level in the sliding arm. *This reading is* h_1.

Now the connecting capillary is restored to atmospheric pressure and a second reading of the vacuum is taken:

10. Close the tap T_2.
11. Turn the three-way tap T_1 to connect the manometer to the air and close off the can. This admits air at atmospheric pressure to the capillary.
12. Turn the three-way tap T_1 to connect the can with the manometer.
13. Open tap T_2 and bring the mercury to zero (M_1).
14. Again read the mercury level in the sliding arm. *This reading is* h_2.

* Designed and made in the workshops of the National Standards Laboratory, C.S.I.R.O., Sydney.

Then the true vacuum (H) is calculated from the formula derived above:

$$H = (h_1)^2/h_2.$$

Headspace Volume

In addition to the vacuum, it is also possible to determine the headspace volume (V) in a can by means of the Campden manometer. From equation (**2**) above:

$$V = vh_2/(h_1 - h_2).$$

The capillary volume (v) is known and this simple formula gives a satisfactory estimate of the volume of small headspaces. But when the headspace is large, the difference $(h_1 - h_2)$ is very small and the determination is subject to large errors. For accurate determinations of headspace volumes it is necessary to make further observations. The can and the connecting system (total volume $V + v$) are brought to atmospheric pressure P. The mercury is dropped to one of the marks (M_2 or M_3) on the fixed arm of the manometer, representing a known increase (d) in volume, and the mercury level in the sliding arm is read; let this reading be h_3.

The system with total volume $V + v + d$ is then at a pressure $P - h_3$.

Therefore

$$P(V + v) = (P - h_3)(V + v + d),$$

from which

$$V = [d(P - h_3)]/h_3 - v.$$

In the instrument illustrated in Figure 1 the capillary volume v is approximately 0.5 ml and the volume d in the small bulb B_1 is about 2 ml. When examining large cans a supplementary bulb B_2 having a capacity of approximately 20 ml is used. The greater increase in volume is necessary to give an h_3 reading of reasonable magnitude when measuring headspace volumes of the order of 50-100 ml.

Continuing the sequence of operations from above:

15. Turn the three-way tap T_1 to connect both the can and the manometer with the air.
16. Bring the mercury to zero (M_1).
17. Turn the three-way tap T_1 to connect the can with the manometer.
18. Drop the sliding arm so that the mercury in the fixed arm is at the mark M_2 for small headspaces or the mark M_3 for large headspaces.
19. Read the mercury level in the sliding arm. *This reading is* h_3. For accurate results h_3 should not exceed h_1. Then the headspace volume (V) is given by the equation derived above:

$$V = [d(P - h_3)]/h_3 - v.$$

It is convenient to mount a Fortin barometer immediately beside the Campden manometer so that atmospheric pressure (P) can be read for the purpose of this calculation. But in most cases it is sufficiently accurate to assume that P is normal (760 mm Hg at sea-level) and to plot V for various values of h_3. The headspace volume in cans under test may then be read off from the curve according to the value of h_3 observed.

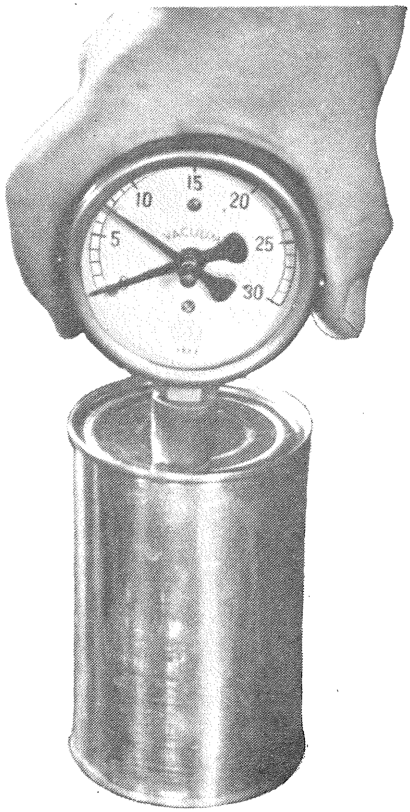


Fig. 4.—Can vacuum gauge with jockey needle.

Vacuum Gauges

Routine measurements of can vacuums in the control laboratory or in the cannery require instruments more robust and portable than the Campden manometer. For this purpose use is made of small dial gauges of the Bourdon type, fitted with a puncturing needle surrounded by a soft rubber gasket (Boyd and Bock 1952). A gauge of this type is illustrated in Figure 4.

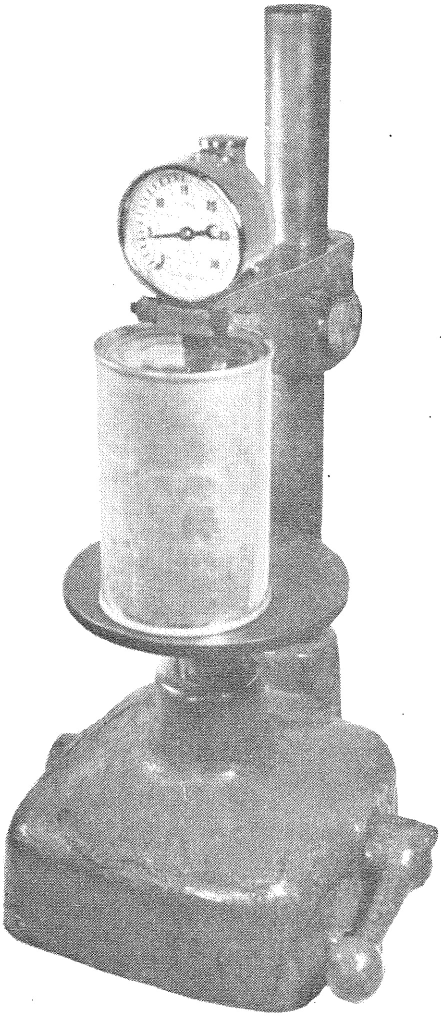


Fig. 5.—Can vacuum tester incorporating F.I.R.A. gauge.

In using a can vacuum gauge, the gasket is moistened and applied to one end of the can under test, preferably the headspace end —located by tapping. The can is punctured by gentle pressure and the vacuum read on the gauge. The gauge* shown in Figure 4 has

* Manufactured by Sydney Instrument Co., Parramatta Rd., Annandale, N.S.W.

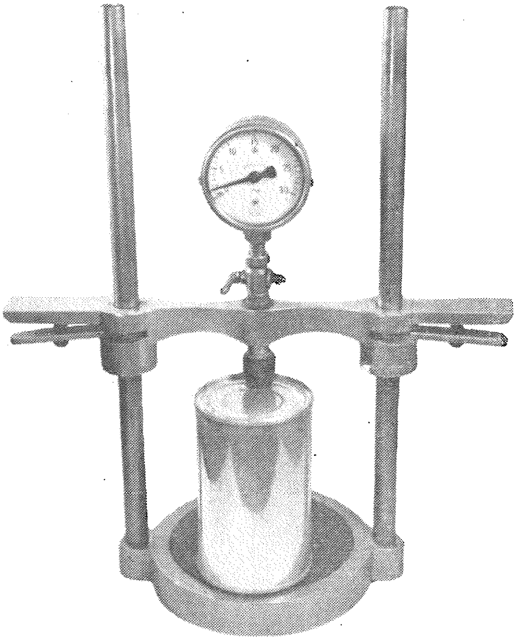


Fig. 6.—Vacuum tester for cans and bottles.

a jockey needle which permits the vacuum to be read after the gauge is lifted off the can. To avoid altering the internal volume of the can while taking the vacuum reading, it is desirable to puncture the can end away from the centre and it is important to keep the needle sufficiently sharp to pierce tinplate readily.

When a considerable number of vacuum determinations are being made it is convenient to mount the vacuum gauge on a stand. In one form of mounting (Anon. 1944),* shown in Figure 5, the can is brought up to the gauge on a table raised by a lever and cam. The set-up† shown in Figure 6 is designed more particularly for measuring vacuums and pressures in bottles.

Vacuum determinations with Bourdon gauges are subject to errors from several sources. Some of these are errors in reading due to the design and method of graduation of the gauge. In selecting a gauge the characteristics to look for are: graduations extending round the full circle of the dial at intervals of $\frac{1}{2}$ in. Hg, intervals marked with fine

* Manufactured by J. W. Earnshaw Pty. Ltd., Pacific Highway, North Sydney, N.S.W.

† Manufactured by Sydney Instrument Co., Parramatta Rd., Annandale, N.S.W.

lines, and a stable pointer with a tip in the form of a knife-edge turned edgewise to the scale. Errors in calibration of the order of 1-2 inches of mercury are common and it is advisable to calibrate gauges periodically against a mercury manometer.

The source of the most serious errors in can vacuums measured with a Bourdon gauge is, however, the internal volume of the Bourdon tube and connexions, which is usually about 3-5 ml. When this volume, at atmospheric pressure, is connected with the headspace of a can the recorded vacuum is less than the true original vacuum. The smaller the headspace in the can and the higher the vacuum, the greater the error. Theoretical considerations (British Food Manufacturers' Research Association 1943) show that with a gauge volume of 5 ml, the error in vacuums of 15-20 in. Hg is 33 per cent., 25 per cent., 9 per cent., and 6 per cent. when the headspace volume is 10 ml, 15 ml, 50 ml, and 75 ml respectively. One practical example of this effect, encountered in this Laboratory, related to 2-oz cans of a fruit spread which had headspace volumes 3-8 ml. Twelve cans tested with a Bourdon gauge showed vacuums 8.3-10 in. Hg, mean 9.3 in. Hg; whereas 12 cans tested on the Campden manometer had vacuums 12.5-15.1 in. Hg, mean 13.8 in. Hg.

The F.I.R.A. Vacuum Gauge

In the Campden manometer, the error due to headspace is eliminated by calculating the true vacuum from two readings taken after the admission of known volumes of air. A similar principle has been applied to the Bourdon gauge in a can vacuum gauge patented by the British Food Manufacturers' Research Association (1943 and 1946) (now the British Food Manufacturing Industries Research Association). The commercial form of this gauge, known as the F.I.R.A. gauge,* is illustrated in Figures 5 and 7. The gauge incorporates an air reservoir equal in volume to the Bourdon tube and connexions. This reservoir is connected with the gauge through a Schrader tyre valve actuated by a push-button at the back of the gauge. When the gauge is about to be used this button is pressed to ensure that the air reservoir is at atmospheric pressure. The rubber ferrule is moistened, the can punctured, and a first vacuum reading taken. With the gauge still in position on the can, the valve-button is again pressed, admitting to the system the air in the reservoir. The gauge is again read, giving a second reading lower than the first.

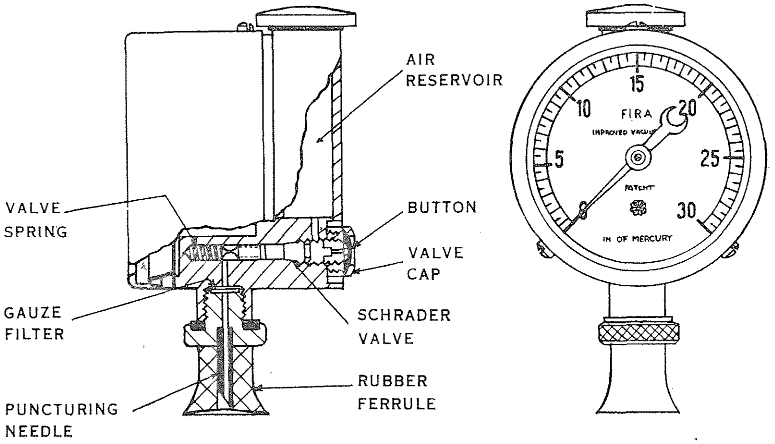


Fig. 7.—F.I.R.A. can vacuum gauge.

* Manufactured by Budenberg Gauge Co. Ltd., Broadheath, England. N.S.W. agents: H. G. Thornthwaite Pty. Ltd., 43 Margaret Street, Sydney, N.S.W.

Then, if P_1 is the first gauge reading and P_2 the second gauge reading, a simple derivation (Morpeth 1951) leads to the relation:

True vacuum $= (P_1 \times P_2)/(2P_2 - P_1)$.

A calculator supplied with the F.I.R.A. gauge performs this calculation. After setting according to the two gauge readings, the true vacuum is read on a scale. Experience has shown that vacuums determined with the F.I.R.A. vacuum gauge are generally within $\pm \frac{1}{2}$ in. Hg of the true vacuum.

Mounting the gauge on a suitable stand, such as the one shown in Figure 5, makes it more convenient to use and minimizes the likelihood of leakage round the rubber ferrule while the two readings are being taken.

Sterile Vacuum Tester

The Hyndman sterile vacuum tester (Anon. 1952) has been designed for taking vacuum readings on cans which are subsequently to be subjected to microbiological examination. The piercing unit of the tester is sterilized, then the gauge is screwed on. After the vacuum in a can is measured, air is admitted to the gauge and the can through a cotton-wool plug. A similar device is described by Baumgartner (1949).

ESTIMATING VACUUM IN UNOPENED CANS

In all the methods for determining can vacuums described so far, the can is destroyed in making the determination. It is often helpful, however, to be able to estimate the internal vacuum in a can without puncturing it, when a rough indication of the probable condition of the contents is required or when changes in the vacuum in an individual can during storage are being followed.

Several ingenious methods have been developed which permit a more or less reliable guess to be made at the level of vacuum in an unopened can. Some of these tests are literally "rule of thumb" tests; for instance, on cans with moderately high vacuums the beads on the ends can be depressed with the thumb, and the walls can be dented inwards readily. Such tests have little real value except perhaps in the case of tapered meat cans on which springy sides, caused by loss of vacuum, are most readily detected by handling (Savage 1920, 1922).

The Tapping Test

When filled sealed cans are tapped with a wooden or metal rod, the character of the sound emitted varies with the internal vacuum (Savage 1920, 1922). The nature of the variation in the sounds made by tapping high- and low-vacuum cans is difficult to describe in terms of pitch or timbre, but it is a fact that a tapper trained in the art is able to use these sounds to grade cans for vacuum with considerable success. The tapping method is widely used in Australian canneries for checking stacks prior to casing and shipment. The Commonwealth Department of Commerce requires for many canned foods a holding period of 10 days between processing and shipment. After this 10-day period it is customary to work over the stacks, tapping all cans and rejecting swelled or springy cans and "tap-outs", that is, low-vacuum cans, which are regarded as incipient or potential swells.

Two examples may be quoted to illustrate successful application of the tapping method:

(i) Cans of tomato juice sorted by the tapping test into "good vacuums" and "tap-outs" were tested for puncture vacuum with the results shown in the table below.

Vacuum in Cans of Tomato Juice

Group	No. of Cans	Vacuum (in. Hg)	
		Range	Mean
"Good"	34	18-21	20
"Tap-outs"	23	0- 4	2

(ii) In a batch of meat and vegetable ration, 100 "tap-outs" had vacuums less than 4 in. Hg, while 50 "good" cans from the same consignment had vacuums 8-16 in. Hg.

The Flip Test

Several methods for estimating the vacuum in unopened cans depend on the fact that the ends of a can move in diaphragm fashion under the influence of differences between the internal and external pressure.

In the method known as the flip test, one end of a can is subjected to a gradually increasing external vacuum until a point is reached when the internal pressure is greater than the external and the can end moves from a concave to a convex position. This movement is usually sudden and the can end is said to "flip". When the external vacuum is released the can end flips back into the concave position. The external vacuum level at which the flip occurs is largely determined by the internal vacuum in the can, but it is also influenced by other factors such as the diameter of the can end, the stiffness of the tinplate, and the pattern of the expansion rings. The flip vacuum is usually 6-10 in. Hg higher than the internal vacuum in cans with 401 ends, and 9-14 in. Hg higher in cans with 301 ends. When the internal vacuum exceeds 20 in. Hg it is usually not possible to cause the ends to flip.

Thus the flip vacuum does not give an accurate direct measure of the internal vacuum in a can (Adam and Stanworth 1933-34). However, changes in the internal vacuum in an individual can may be followed closely by making periodic measurements of the flip vacuum. This technique has been widely used in metal container research for estimating the rate of loss of vacuum, which represents the rate of hydrogen formation in corrosion reactions (Anon. 1946; Davis 1954).

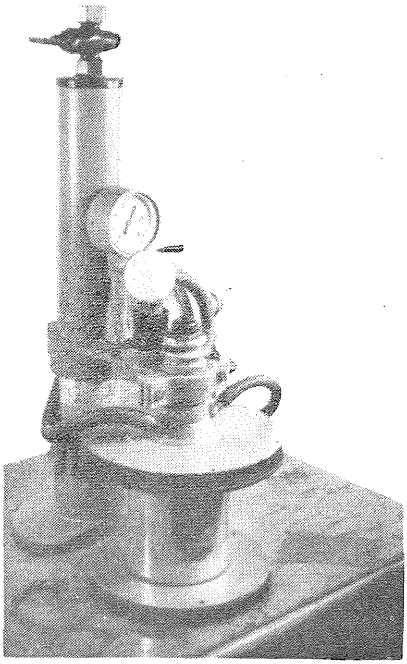


Fig. 8.—Flip vacuum tester.

A simple way to perform a flip test is to place a can in a glass bell jar and observe the flipping of the end when a vacuum is applied. A number of instruments have been devised for the measurement of flip vacuums (Hicks 1934; Lueck and Brighton 1944, 1951; American Can Co. 1946; Kraft Foods Ltd. 1953), some depending on visual observation of the flip and others on detection of the sound of the flip.

The instrument* in use in this Laboratory is illustrated in Figure 8. The can under test is placed on a metal plate which is raised by a vacuum piston so that the can approaches an upper fixed plate and the raised portion of the end seam of the can is held tightly against a rubber gasket. In the small chamber so formed above the can end, a vacuum is applied and the vacuum level is indicated on a Bourdon gauge. When the can end flips out it contacts an adjustable pin in the centre of the upper plate and completes a low-voltage electrical circuit from the lower plate through the can and the pin to an indicator lamp. When the lamp glows the vacuum gauge is read. Then the vacuum is slowly released until the lamp goes out, indicating that the can end has flipped in. At this point the vacuum gauge is again read. There is usually a difference of a few inches of mercury between the external vacuum levels at which the flip-out and the flip-in occur. The mean of the two vacuum readings is customarily recorded as the flip vacuum.

When flip vacuums are being determined on individual cans at intervals during storage, the measurements should always be made on the same end of each can to avoid variability due to the factors mentioned above.

The Spherometer Test

In this method the internal vacuum in a can is estimated by measuring the depth of the concavity in the can end by means of a spherometer (Adam and Stanworth 1933-34; Adam 1943).

A spherometer† designed specifically for measurements on can ends is illustrated in

* Designed and manufactured by J. W. Earnshaw Pty. Ltd., Pacific Highway, North Sydney, N.S.W.

† Designed and fabricated in the workshops of the National Standards Laboratory, C.S.I.R.O., Sydney, N.S.W.

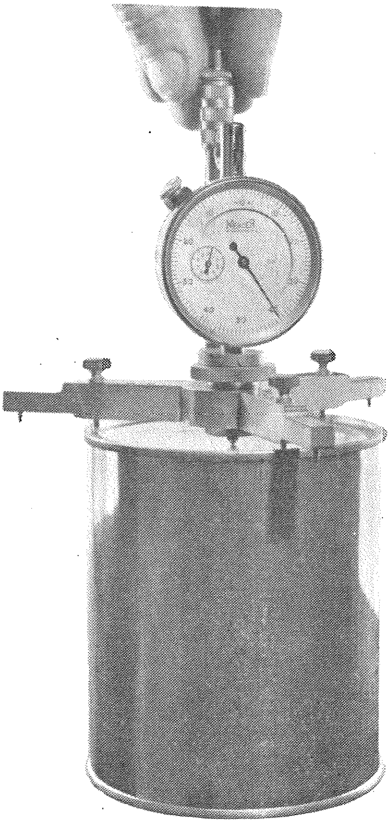


Fig. 9.—Spherometer for can ends.

Figure 9. It consists of an engineer's depth gauge mounted on a tripod. The legs of the tripod rest in the countersink of the can end and they are adjustable horizontally so as to fit cans of different diameters. The level of the countersink is thus the reference level from which the depth of the centre of the end is measured on the depth gauge. It is assumed that there is negligible movement of the tin-plate of the end in the countersink close to the end seam. In placing the spherometer on a can end, the side seam position should be avoided since the countersink depth is slightly less at this point.

Before measurements on cans are commenced the instrument is placed on a plane glass surface and the dial gauge is set to zero. The zero setting is checked frequently when a number of cans are being examined. The can ends must be carefully dusted before readings are taken.

A spherometer reading of the concavity of a can end will not give a direct measure of the internal vacuum in a can because of the influence of the same factors which affect flip vacuums, but successive measurements on individual cans throughout a storage period permit changes in internal vacuum to be followed closely.

Light Reflection Methods

Differences in the concavity of can ends have also been applied in another technique for estimating internal vacuums, a technique which depends upon the reflection of light from the can end. Razek (1948, 1950) describes a vacuum tester for glass jars in which a photo-cell reacts differently to light reflected from the flat cap of a jar with low vacuum as compared with light focused by the concave cap of a jar with adequate vacuum. Shiga and Kimura (1953) photographed the circle of light reflected from can ends under standard conditions and found a logarithmic relation between the diameter of this circle and the can vacuum.

EFFECT OF ATMOSPHERIC TEMPERATURE AND PRESSURE ON VACUUM

As already pointed out, the vacuum in a can varies with the atmospheric pressure and temperature. Therefore in strictly accurate recordings of vacuum, the barometric pressure and room temperature should also be recorded. In routine laboratory inspections this is an unnecessary refinement but it is desirable in the case of determinations with the Campden manometer. In comparative vacuum studies, for example when applying the flip test or the spherometer, it is essential that observations at different times be made under similar conditions. When following storage tests at constant temperatures it is desirable to examine the cans for vacuum in the constant temperature room. A correction is applied for changes in barometric pressure assuming constant volume in the can, which is a reasonable assumption over small pressure changes.

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ANSWERS TO INQUIRIES

LOW-SODIUM CANNED FOODS

Diets low in salt are often prescribed by doctors in the treatment of high blood pressure and certain heart and kidney diseases. Is it possible to produce canned foods suitable for patients on such diets?

The production of such foods is now well established. In the United States of America, for example, there were in 1951 85 packers of canned dietetic foods turning out no less than 53 products, mostly low in sodium. Common salt must not be added to these packs, and the canner must make sure that sodium does not get into the food by other means, for example through the cannery water supply, which may be high in sodium especially if it is softened by the "Permutit" process. Peas cannot be graded by separation in brine, nor can salt solution be used to prevent discoloration in pears. Lye peeling must be replaced by steam peeling for tomatoes, but it is permissible in some cases, for example grapefruit segments and peaches, provided they are washed well.

It would be possible to use a salt substitute to season low-sodium canned foods, but medical opinion favours the omission of seasoning, which may be added at table to suit individual tastes. Salt substitutes may contain potassium chloride or amino-acid hydrochlorides. One formula on the market is: potassium chloride, ammonium chloride, potassium formate, calcium formate, magnesium citrate, and starch.

Cans of low-sodium foods should bear a distinctive label carrying the words "Packed without added salt", and a statement of the sodium content in milligrams per hundred grams of product.

CANNING STRAWBERRIES

What is the procedure for canning (or glass packing) strawberries?

Medium-size berries are preferred; they should possess a high colour and a firm texture. The berries are sorted, stemmed, capped by hand, and then size-graded, preferably by the same worker in order to reduce handling. Washing is carried out with gentle cold-water sprays.

Filling of the cans or bottles is complicated by the tendency of the berries to float in syrup. Fill-in weights to be aimed at are: 16-oz container — 8 oz, 30-oz container—17 oz. Larger fill-in weights can be obtained, however, by placing the berries and syrup in a steam-jacketed kettle and quickly bringing them to the boil, thus driving out much of the air trapped in the fruit. The syrup is drained from the berries, which are placed carefully in the can or glass. The syrup is added after being reheated to boiling point. The concentration of syrup will vary with the market being supplied, but the range 40-55° Brix is satisfactory. The syrup is always added boiling, which necessitates pre-heating the bottles to reduce the temperature shock to less than 60°F.

Exhaust for 10 minutes at 180-200°F and heat-process as follows: 16-oz container for 7 minutes in boiling water (212°F), 30-oz container for 10 minutes in boiling water (212°F).

The sterilizing process causes some deterioration in the colour of strawberries, but this may be overcome to some extent by cooling quickly. Artificial colours, a number of which are permitted under the Pure Foods Regulations in all States in Australia, may be used to mask this defect. It is suggested that $4\frac{1}{2}$ to $5\frac{1}{2}$ ounces of Ponceau 2R be added to each 50 gallons of syrup.

NEWS from the Division of Food Preservation and Transport

WORK OF THE PHYSICAL CHEMISTRY SECTION

The Physical Chemistry Section is housed for the most part in the Biochemistry Department at the University of Sydney, but its spectroscopy laboratory is located in the Division of Physics of the nearby National Standards Laboratory.

The staff of the Physical Chemistry Section consists of two research officers, one technical officer, one laboratory assistant, and two research students.

The Section is interested primarily in studies on the physical chemistry of proteins, the denaturation of which is of particular importance in food preservation and storage. The denaturation process itself and the behaviour of proteins in particular foods are being investigated. Research is also proceeding on the combination of metals with proteins. The Section works in close collaboration with other parts of the Division, and its highly specialized equipment is put to use in the solution of a variety of chemical problems.

Among the notable apparatus with which the laboratory is equipped is a Specialized Instruments Company quantitative refrigerated ultra centrifuge, a Perkin Elmer single-beam infra-red spectrophotometer, a moving boundary electrophoresis and diffusion apparatus built by C.S.I.R.O., and direct-current and derivative polarographs.

PERSONAL

Dr. J. R. Vickery, Chief of the Division, has been elected an honorary member of the South African Institute of Refrigeration. The constitution of the Institute allows it to confer honorary membership on "a person eminent by his work connected with refrigeration in foreign lands, whom the Institute desires to honour".

Dr. J. F. Turner returned to Sydney on December 24, 1953, after spending four years at the Botany School, Cambridge, England, where he was elected to the Broodbank Fellowship of the University of Cambridge. Overseas Dr. Turner carried out biochemical investigations into the synthesis of sucrose by plant enzyme systems. At Homebush he will rejoin the team of investigators engaged on problems in the storage of fruit and vegetables, with whom he will continue his biochemical work.

PUBLICATIONS BY STAFF

Effects of Skin Coatings on the Behaviour of Apples in Storage. III. Cool Storage Investigations. *E. G. Hall, S. M. Sykes, and S. A. Trout. Aust. J. Agric. Res. 4: 365-83 (1953).*

The effects of skin coatings on several varieties of apples during cool storage were studied in several seasons from 1941 to 1946. Most of the work was done with the Granny Smith and Jonathan varieties, and coatings tested included alcoholic solutions of castor oil and shellac (C.O.S.), oil emulsions, and wax emulsions. With most varieties the more successful coatings, under favourable conditions of fruit maturity and of temperature before and after storage, reduced wastage and retarded loss of condition.

The most successful coating, a 7-10 per cent. C.O.S. solution, increased commercial cold-storage life of a number of varieties by 25-30 per cent. C.O.S. and some oil coatings controlled superficial scald, but to a lesser degree than good oiled wraps. Most coatings controlled Jonathan spot and senescent disorders, but only the alcoholic solutions reduced mould wastage. Coatings at times caused direct injury to the fruit, but under favourable conditions this was usually not of commercial significance. Skin blemishes, internal disorders, and off-flavours were often severe in coated apples exposed to temperatures above 70°F either before or after cool storage.

Wrapping in either plain or oiled wraps improved the out-turn of coated fruit.