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Use of Sulphur Dioxide in

THE USE OF SULPHUR DIOXIDE TO PRESERVE grapes in storage, mainly against grey mould (*Botrytis* sp.), was first proposed in America about 30 years ago (Winkler and Jacob 1925). It was recommended that the packed fruit be fumigated with 2-3 per cent. of sulphur dioxide prior to shipment or storage. Since then the use of sulphur dioxide gas and SO_2-releasing chemicals has been investigated by many workers, especially in South Africa but also in Australia. Some form of sulphur dioxide treatment is now normal practice, and there is no doubt that it effectively reduces mould wastage, preserves the freshness of the stalks, and retards shattering, i.e. dropping of the berries from the bunches.

FUMIGATION WITH SULPHUR DIOXIDE

Pre-shipment and in-storage fumigation with sulphur dioxide was discussed in detail by Jacob (1929). He considered that the desirable concentration of sulphur dioxide *in the grapes* was about 75 p.p.m., which could be achieved by exposure of warm grapes to 2-3 per cent. of the gas for 10-20 minutes, provided that granulated cork or other filler material was not used in the boxes.

More recent work in South Africa (Marais 1951; Malan 1954) has shown that under South African conditions about 10-15 p.p.m. of sulphur dioxide in the fruit are effective, less than 7 p.p.m. are ineffective at higher temperatures, and more than 20 p.p.m. may injure the grapes. Sulphur dioxide injury to grapes is readily detected as a bleaching of the skin, which first appears around the pedicel or berry stalk. Satisfactory results were obtained by fumigating the store room every week or fortnight with 0·25-0·5 per cent. of sulphur dioxide for about 20-25 minutes, and then ventilating.

Pentzer and Barger (1941), working in America, considered that a concentration of 10-20 p.p.m. of sulphur dioxide in the fruit was both safe and effective, and found that a preliminary fumigation with 1 per cent. sulphur dioxide at 70 °F for 20 minutes gave very good results with only negligible damage to the berries.

To avoid risk of injury by periodic exposure of the grapes to higher concentration of the gas and to maintain effective levels in the fruit, techniques have been developed for continuous exposure to low concentrations in the atmosphere or treatment of packing materials with SO_2-releasing chemicals.

Marais (1951) gives details of the automatic control of sulphur dioxide with a photo-electric cell in the long-term storage of grapes.* More recently Malan (1954) reported that the Waltham Cross variety kept very well for three months at a temperature of 31 °F in an atmosphere containing approximately 20 p.p.m. of sulphur dioxide. Other varieties have kept as long as six months. Boyes, of the Western Province Fruit Research Station, Capetown, in a private communication stated that for long storage 15-20 p.p.m. is maintained in the atmosphere, but that concentrations as low as 10 p.p.m. may be enough. Gaseous fumigation in a cold store involves a corrosion problem. The coils and other metal work require adequate protection; polyvinyl or polyethylene coatings have proved effective for this purpose.

USE OF CHEMICALS IN THE BOX

Investigations on the chemical treatment of packaging materials were commenced in South Africa after serious losses of grapes in the 1927-28 season (du Plessis 1936, 1939). Although both iodine and formaldehyde were found to be effective in reducing wastage, sodium or potassium metabisulphite or sodium bisulphite, which release sulphur dioxide, are now preferred. Similar investigations were carried out in Australia between 1938 and 1941 by Huelin and Tindale (unpublished data) and later by Manuel

* He states that to reach approximately 10 p.p.m. in grapes packed in boxes, an atmospheric concentration of approximately 30 p.p.m. must be maintained.

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Storing and Shipping Grapes

(unpublished data). Metabisulphites or bisulphites can be used as a powder distributed through the granulated cork or sawdust packing material, as a solution sprayed on to wood-wool, or as pellets, one being enclosed with each bunch in the wrapping paper.

Continuous fumigation is not very practicable for export, and preliminary fumigation with higher concentrations involves some risk of injury, hence treatment of packing materials has become the standard procedure.

In a report on the use of bisulphites in the control of wastage in fresh grapes, Reyneke and Piaget (1952) stated that in laboratory tests with isolated, well-ventilated boxes, the desired concentration of sulphur dioxide could be obtained by spraying the wood-wool of a packed box with 20 ml of a 40 per cent. solution of pure sodium bisulphite. They found that the type and composition of the bisulphites and the pH of the solution greatly influenced the rate of evolution of gas. The method in vogue in South Africa, where commercial-grade sodium bisulphite is used, has proved quite satisfactory.

For export from South Africa the grapes are packed in boxes 16½ in. by 11½ in. by 5½ in. deep, holding 10-12 pounds of fruit. A layer of wood-wool is placed on the bottom and then the bunches, individually wrapped in tissue paper, are packed in and surrounded by wood-wool. A sheet of paper followed by another layer of wood-wool is placed on top. This wood-wool is then sprayed with 18-20 ml of 40 per cent. sodium bisulphite solution or 12-15 ml of 40 per cent. sodium metabisulphite solution.

In America Lutz (1938) recommended a maximum of eight grams of powdered sodium bisulphite per 12-quart basket, to avoid risk of injury, but at this level obtained only a moderate control of mould wastage, although control of shatter was good. Pentzer and Barger (1941) suggested using 0·3-0·4 gram of sodium metabisulphite as a pellet with each bunch. App *et al.* (1951) and Walker, Worthington, and Wiegand (1951) studied the use of chemical treatments in conjunction with transparent film overwraps or case-liners. Over-wrapping, coupled with the maintenance of a very low partial pressure of sulphur dioxide, gave most promising results. Satisfactory sources of sulphur dioxide were five grams of potassium metabisulphite as pellets wrapped in filter paper, or a wood-wool cushion impregnated with an equal amount of sodium bisulphite (or metabisulphite), both placed on the bottom of the box. Suitable films were polyethylene and "Pliofilm", with a cellulose acetate window. The work was done on both the Emperor and Almeria (Ohanez) varieties in standard lug boxes holding 25 pounds of grapes.

Huelin and Tindale (unpublished data) incorporated chemicals in the granulated cork packing (standard in Australia for export packs), and in the wood-wool in a wood-wool and tissue-paper wrap pack, as used in South Africa.

The most promising results were obtained with the latter pack by using SO_2-releasing substances, and with the granulated cork packs by using iodine. It is not practicable to use the latter commercially, because it is difficult to apply and its cost is excessive. A tablet weighing 0·7 gram and containing 15 per cent. of sodium bisulphite, 4 per cent. of spermaceti wax, and 81 per cent. of alum, effectively reduced wastage when placed in each bunch of grapes. The rate of evolution from tablets is much slower than from bisulphite or metabisulphite solutions sprayed on the wood-wool or from the powdered chemical mixed with the cork.

Experiments were carried out in New South Wales in 1941-42 and 1947 (Manuel, unpublished data). The addition of up to 20 grams of powdered potassium metabisulphite per case of 32 pounds of fruit, mixed with the 4½ pounds of cork packing,

reduced wastage and usefully prolonged cool-storage life. The metabisulphite caused only a very slight off-flavour but 20 grams of sodium sulphite caused a stronger taint which was temporarily objectionable to some people. However, a few days after removal from cool storage the residual sulphur dioxide in the fruit was negligible, being 0·01 gram per pound.

EXPORT PACKING IN AUSTRALIA

At the present time grapes exported from Australia are packed in granulated cork. The Fresh Fruit Export Regulations require that not less than 10 grams of sodium or potassium metabisulphite shall be mixed with the cork in each box at the time of packing. There have been complaints of tainting of the grapes by sulphur dioxide and of injury apparently resulting from the use of too much metabisulphite. While 10 grams is a desirable minimum, there should also be a maximum. The available evidence indicates that this should be 20 grams and that 15 grams would normally be an adequate amount. The Regulations should also provide for the use of 10-15 grams of sodium bisulphite, which is a much cheaper chemical.

Granulated cork is now rather expensive, and satisfactory substitute packing materials are being sought. Specially cut white wood sawdust, with uniform size particles free from sharp points likely to puncture the berries, has been successfully used in American export packs. Similarly prepared and winnowed sawdust from Australian timber has been found by the author to be as satisfactory as granulated cork in respect of condition and appearance of the grapes. Nevertheless, they were unacceptable to the fruit trade in Singapore because of the colour of the sawdust and a somewhat unreasoned preference for existing packing materials. Metabisulphite or bisulphite is used with the sawdust in the same manner as with cork.

East Asian buyers are very satisfied with the South African export pack in paper and wood-wool, and this pack is common in America. There is no reason why it should not be quite satisfactory under Australian conditions, using either tablets with the bunches or a solution sprayed onto the wood-wool.

In view of the American experience, which is now passing into commercial practice, polythene film case-liners, in conjunction with smaller amounts of metabisulphite or bisulphite, should be tested experimentally. On a small scale, grapes have been exported from Western Australia to Singapore in small cellophane bags and packed with shredded cellophane, and have turned out well. Pre-packing fumigation of the grapes with one per cent. of sulphur dioxide gas for 20 minutes should give sufficient protection where the period of storage or overseas carriage is short. It may be the most convenient treatment for grapes exported from Western Australia to East Asia.

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Evaluation of Canning Processes

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IN RECENT YEARS A NUMBER OF ADVANCES have been made in the evaluation of canning processes. The most important has been the realization that if a process is deemed to be safe for the point in the can which receives the least severe heat treatment, it is not necessarily safe for the can as a whole. A method of process evaluation has been developed which takes into account the thermal process received by all points in the can.

It has also been discovered that the headspace in a can possesses appreciable resistance to the flow of heat into the can. This may have important consequences when a thermal process is evaluated theoretically from a knowledge of the thermal properties of the pack.

Research has also demonstrated the importance of the cooling phase in process evaluation and of errors in temperature measurement due to heat conduction along the thermocouple wires.

PROCESS EVALUATION

Standard Method

The standard procedure for process evaluation is as follows:

- During processing, temperature measurements are made at the point in the pack receiving the least severe heat treatment. In a pack heating by conduction this is generally the centre. It is not always possible, however, to determine the temperature history experimentally, and it has then to be calculated from a knowledge of the thermal properties of the pack.
- From a knowledge of the thermal resistance (at various temperatures) of the organisms to be destroyed, the temperature readings are converted to lethal rates and plotted against the time.
- The area under the resulting lethality curve, an example of which appears on page 49, is a measure of the effectiveness of the process in destroying organisms.
- This area is usually expressed in terms of an equivalent number of minutes at 250 °F. This is known as the "sterilizing value" F_o of the process, and represents a hypothetical process in which the product would be heated instantaneously to 250 °F, held at that temperature for F_o minutes, and instantaneously cooled.
- From bacteriological data relating to the type of organisms to be destroyed and their resistance to heat treatment under the actual physical and chemical conditions within the food pack, an estimate is then made of the adequacy of the process.

An important assumption made in the standard method is that if a process is found to be adequate for the point in the can which receives the least severe heat treatment, then it is adequate for the can as a whole since organisms situated at other points in the can would be more severely heated. No such assumption is made in the new method.

The New Method

It is necessary first to define the meaning of the term "thermal destruction of bacterial spores". The spore population c in any medium after heating is a function both of the initial spore population c_o before heat treatment and the temperature T during the heating. This relationship may be written in the simple form:

$$c = c_o f(T)$$

where f is some function which need not be specified here.

Consider what is meant by the value of c. A value less than unity was at one time taken to indicate complete destruction of all spores. If this interpretation were correct, it would only be necessary to ensure the destruction of all spores at and near the point which receives the least severe heat treatment in order to achieve a safe process for the whole can.

But consider the case when $c = 0{\cdot}1$ in each of 100 cans. The total value of c for all the cans would be 10, that is, 10 spores

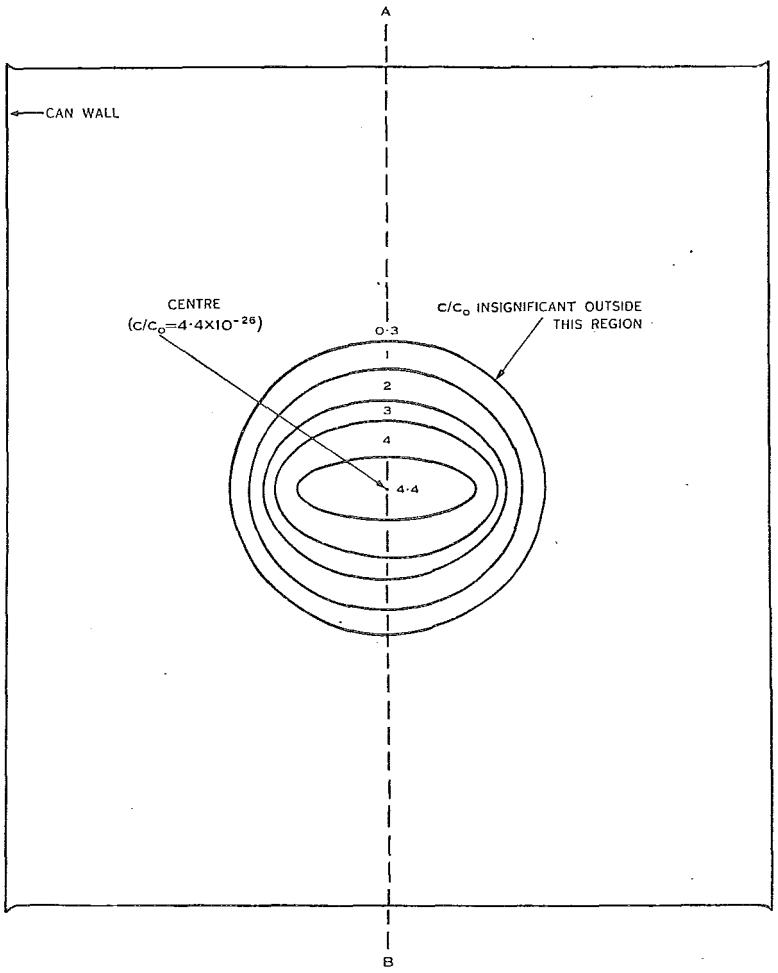

Fig. 1.—Section through a No. 2½ can (401 × 411) showing lines of equal probabilities of survival c/c_o.

could be said to survive in 100 cans. Thus c may be regarded as a measure of the probability of survival of a spore. When $c = 0{\cdot}1$ this means there is one chance in 10 that a spore will survive.

Using this interpretation of c it is clear that one cannot correctly evaluate a thermal process by reference to one point in a can. The value of c must be evaluated for the can as a whole, since the probability of survival, even for points some distance from the centre, is not negligible compared with the value at the centre.

In practice, in packs heated by conduction the volume throughout which c is significant is still only a small fraction of the volume of the can. With liquid packs virtually all points in the can have a significant probability of survival.

Figure 1 shows a section through a No. $2\frac{1}{2}$ can (401 × 411). The curves in the figure are lines of equal survival ratio c/c_o (multiplied by 10^{26}) in the plane of the axis AB of the can. Surfaces of equal c/c_o, obtained by rotating about AB, are seen to be concentric ellipsoids centred on the slowest heating point. The latter has a survival ratio $c/c_o = 4{\cdot}4 \times 10^{-26}$. To get the survival ratio for the whole can the value of c/c_o must be summed throughout that part of the can where its value is significant. For the above can the sum is 68×10^{-25}, which is 15 times as great as at the slowest heating point.

Stumbo's Method

In the form in which the method was propounded by Stumbo (1948), Hicks (1951), and Gillespy (1951), it was too difficult mathematically to be useful to most canners and food technologists. This objection has, however, been largely overcome since Stumbo (1953) developed a very much simpler method of calculation.

To establish his simplified formula Stumbo imagined the can divided into iso-F regions (i.e. regions which received the same thermal process). These consisted of concentric shells similar to those shown in Figure 1. Denoting by F_λ the F value associated with a particular region λ and by F_c the F value at the centre, a straight-line relationship was found between $(F_\lambda - F_c)$ and v, the fraction of the total can volume enclosed by the region λ. This relationship was true for values of v up to 0·4. This relationship could then be used for calculation, since the region for which the probability of surviving is significant is generally less than 0·15 of the total can volume.

The formula found for F_s, the F value for the can as a whole, was:

$$F_s = F_c + D_r\left(1{\cdot}084 + \log\frac{(F_\lambda - F_c)}{D_r}\right),$$

which corresponds to $v = 0{\cdot}19$ (i.e. all probabilities c are summed within a region about the centre up to 0·19 of the total can volume). In this formula D_r is the decimal reduction time of the organism at 250 °F and F_c, being the F value at the centre of the can, is the value used in the old method for the whole can.

The most difficult term to evaluate in the above formula is F_λ, which may be obtained by using the following method devised by Stumbo. Let g represent the difference at the end of the cook between the temperature of the retort and the temperature at any point in the can. Stumbo showed that if g_c is the value of g at the centre and g_λ its value at the shell λ, then when $v = 0{\cdot}19$, $g_\lambda = 0{\cdot}5\ g_c$. Knowing g_λ, it is a simple matter to find F_λ from charts and tables commonly used in process evaluation.

Old and New Methods Compared

A number of important conclusions arise from a comparison of the old and new methods.

If we denote by R the ratio of the probability of survival as estimated by the new and old methods respectively, then it is clear that R will always be greater than unity. This means that the estimates of adequate process time for the same apparent degree of safety are greater by the new methods than by the old.

For packs heating by convection, since the differences in the amount of heating received by different parts of the can are small, values of R are very large. If the old method is regarded as being concerned with one millilitre of product at the centre, then values of R for liquid packs would be only slightly less than the total volume of the can measured in millilitres. Since a No. $2\frac{1}{2}$ can (401 × 411) holds 800 ml, R in that case would be roughly

600, and for a No. 10 can (603 × 700), which holds over 3000 ml, it would be over 2000. The consequences of the new approach to process evaluation are clearly important when considering liquid packs.

For packs heating by conduction typical values of R for recommended processes in standard can sizes are much smaller, ranging between 3 and 80.

These values may at first be considered high but it must be realized that there are other factors which can give rise to much higher errors. For example, it is possible to get a variation of at least 1 in 1000 in the initial contamination c_o and the final probability of survival c is proportional to c_o; or again, as has been pointed out (Hicks 1952), the use of a value 10 per cent. too large for the slope of the thermal death-time curve for the organism would give a value for the probability of survival for the can 1000 times too small. Variations of such magnitude are, however, not uncommon, and affect both methods.

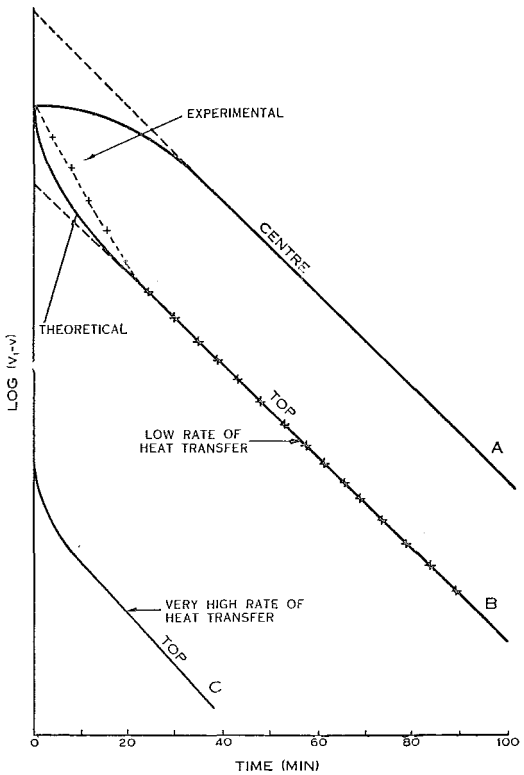

Fig. 2.—Heating curves at the centre of the product and the centre of its top surface. V_1 *is the retort temperature and* v *that of the product.*

A number of factors are found to influence the value of R in packs heating by conduction:

It increases considerably with increasing can volume, being as low as three for the small 8Z tall can (211 × 304) and 70 for the large No. 10 can (603 × 700).

For a particular can it decreases slightly with increasing length of cook.

It is affected by the resistance of organisms to heat treatment. For *Cl. botulinum* 2·78 minutes at 250 °F is necessary to reduce the spore concentration by a factor of 10^{10}; with a more resistant organism requiring 5 minutes at 250 °F to produce the same reduction in spore population, the value of R would be 60 per cent. higher. As Gillespy (1951) has pointed out, the calculation of thermal processes by the old method does not depend on the absolute resistance of the organisms to be killed, but only on the slope of the thermal death-time curve.

According to the old method, processes were regarded as equivalent if they gave equal F_c values (i.e. if the centre of the can received equal processes). By the new method this is no longer true, as can be seen by the equivalent processes for the following two cans:

Can Size	F_s	F_c
8Z tall (211 × 304)	5·4	3·9
No. 10 (603 × 700)	6·5	4·5

These have been calculated by the new method, in which a process is regarded as equivalent for two cans of different sizes when the probability that a spore will survive in the can as a whole is the same for both cans. Since

$$c = c_o \ 10^{-F_s/D_r}$$

where c_o is the total initial contamination for the can as a whole and depends on the volume of the can, equivalent processes for cans of different size have *different* values of F_s as well as different values of F_c.

Consider also processing at different retort temperatures; by the old method two processes at different retort temperatures are equivalent when the F_c values are the same. Values for a No. 2 can (307 × 409) at

retort temperatures 260 °F and 230 °F respectively are:

Retort Temperature	F_c	F_s
260 °F	4·5	7·7
230 °F	4·5	6·0

Thus although equivalent by the old method, these processes are not equivalent by the new. If the first process is adequate then the second is inadequate, and if the second is adequate, then the first is too severe.

EFFECTS OF HEADSPACE

At room temperatures the headspace of a can consists of gases and water vapour at a pressure below atmospheric. The rate at which heat is transferred through such a layer of gas is not necessarily large. Recently (Evans and Board 1954) a method was developed for measuring the rate of heat transfer through the headspace and an analysis made of the effects of the rate on the evaluation of canning processes.

A formula was developed for the temperature reached in a can with a finite rate of heat transfer to the product from one end. On examining this formula it was found that a simultaneous measurement of the temperature history at two points in the can gave a means of measuring both the thermal diffusivity of the product and the rate of heat transfer through the headspace.

The two positions in the product used for measurement were its centre and the centre of its top surface. Typical experimental curves are shown in Figure 2, in which log $(V_1 - v)$, where V_1 is the retort temperature and v is the temperature at one of the measuring points, is plotted against the time. For the centre, the experimental and theoretical curves coincided; they are shown as curve *A*. For the centre of the top surface, however, a slight divergence occurred at the beginning of the process, but the curves were coincident for most of the time; they are shown as curve *B*. The slopes and the intercepts of the extensions of the straight-line portions of these curves with the temperature axis were used to evaluate the thermal diffusivity of the product and the rate of heat transfer through the headspace.

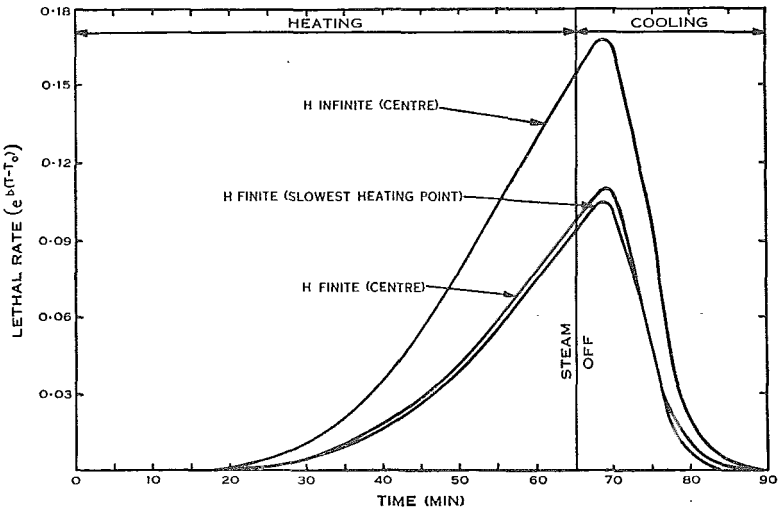

Fig. 3.—Lethality curves with high and low values of H *(the rate of heat transfer through the headspace).*

Values of the rate of heat transfer were very low, being between 6 and 10 B.T.U./(ft)² (hr) (°F). It had previously been assumed that heat passed rapidly from the retort to the top of the product, in which case a heating curve such as curve *C* in Figure 2 would have been obtained.

Of the six to ten B.T.U./(ft)²(hr) (°F) about two could be accounted for by natural convection and radiation. In order to account for the remainder, distillation must have taken place in the headspace. In this process water evaporates where the edge of the top of the product touches the can, and condenses on the cooler central areas of the top surface, the whole process corresponding to heat being transferred from the top of the can to the top of the product.

Consequences of Low Rate of Heat Transfer

Since the rate of heat transfer from the top is low, an immediate consequence is that the slowest heating point is not at the centre of the pack but slightly above it. For a No. $2\frac{1}{2}$ can (401 × 411) for which the height of the pack is 10 cm, the slowest heating point is a little over 0·5 cm above the centre; for a 1-lb squat can (401 × 211) the pack is 5·5 cm high, and the slowest heating point is found to be 0·6 cm above the centre.

The most important consequence is that the lethal value for a process as calculated from the thermal properties of the product and the thermal resistance of the organisms is much less than if the headspace presented no resistance to the flow of heat. This effect is greater, the larger the proportion of the total heat flowing into the can that is assumed to flow through the top, i.e. the effect is greater for squat cans than for tall ones.

With a No. $2\frac{1}{2}$ can (401 × 411) the F value of 5·2 minutes for a typical process (assuming an infinite rate of heat transfer through the top) was reduced to 4·6 minutes for both the centre and the slowest heating point when the rate of heat transfer was 7·6 B.T.U./(ft)^2(hr) (°F). For a 1-lb squat can (401 × 211) under similar conditions the effect was very much greater; an F value of 4·2 minutes was reduced to 2·5 minutes at the centre and 2·4 minutes at the slowest heating point. Lethal rate curves for the 1-lb squat can are shown in Figure 3, where $e^{b(T-T_o)}$ is a measure of the rate of destruction of organisms, b being a constant characteristic of the organism and medium.

In the cases considered it was found that the difference between the process for the centre of a can and the slowest heating point was never very great, so that either point or, in fact, any intermediate point could be used in an experimental evaluation of a thermal process.

It is important to realize that although there is such a large effect on the lethal value of a process when the temperature history is calculated, the thermal resistance of the headspace does not affect the lethal value when the temperature-time relationship is obtained experimentally. As long as the measuring point is either at or between the centre and the slowest heating point, the rate of heating obtained is independent of the fact that only a very small proportion of the heat enters the product from the top.

When, on the other hand, an experimental determination is made of the temperature history in a can, and the thermal process has to be calculated for a can of a different shape or size, it is important to take into account any effect due to the thermal resistance of the headspace.

Owing, probably, to the very rapid rates of heating and the variability of processing conditions, observations made on liquid packs to determine any effects of the headspace on rates of heating have so far proved inconclusive.

THE COOLING PHASE

The cooling phase of a canning process is not in general adequately treated when an evaluation of a process is made although its importance has been pointed out by many authors (Ball 1923; Gillespy 1951; Hicks 1951). Sometimes a process is evaluated for the heating phase only, and the cooling phase is looked upon as an additional safety factor. This procedure, although not so objectionable for liquid packs, is not advisable for solid packs, as it is uneconomic and can lead to over-processing.

As can be seen from Figure 3, where the area under the graph is a measure of the effectiveness of the process, the cooling period is only slightly less effective than the heating period in the destruction of organisms.

In practice the variation in processing conditions during the cooling phase is very great. The time taken to bring the retort temperature down may vary from two or three minutes to 15 minutes depending on whether the cooling medium is air, still or flowing water, or water from a hose. The size of the stack and the position of a can in the stack may also influence the cooling rate considerably. It is therefore important when evaluating a process to pay particular attention to the cooling phase and to make measurements under cannery conditions.

With packs heated by conduction the first few minutes of cooling are very important, as heating at the centre of the product continues for several minutes after

the steam is turned off. This effect is clearly shown in the curves of Figure 3.

The usual procedure for calculating the temperature fall during the cooling period is based on the method given many years ago by Ball in which the lag factor j for the cooling period is assumed to be 1·41. Although this is said to be close to experimental values, it does not take into account the short period of heating which is found to take place after the steam is turned off. On the other hand, it is not certain that the method of calculating the temperature during cooling by assuming the same thermal properties as for the heating phase is correct. Under ideal conditions there would be no theoretical objection to this assumption, but the variability of the processing conditions and even a possible disturbance of the thermal properties of the pack on suddenly cooling the outside, particularly with semi-liquid products, could lead to wide divergence between theory and experiment.

THERMOCOUPLE CONDUCTION ERRORS

Another phenomenon which is not generally realized is the possibility of error in the measurement of temperature at the centre of a can due to conduction along the thermocouple wire. It is known that metals are much better thermal conductors than foodstuffs. This applies particularly to copper, which is frequently used in the measurement of centre temperatures. Compared with a typical conductivity of 0·0015 cal/(cm) (sec) (°C) for foodstuffs, that of copper is 0·9 cal/(cm) (sec) (°C). This means that if sufficiently thick copper wire is used for temperature measurement at the can centre during the heating phase, the heat conducted along the wire can raise the temperature at the measuring point above what it would be in the absence of the wire. During the cooling phase the measured temperature would be lower.

Because of this the measured F value for the heating phase would be too large and for the cooling phase too small. Over the process as a whole one would expect the measured F value to be larger than the correct value.

The magnitude of the error is not known, but indications are that the use of copper wire below about 30 S.W.G. can lead to significant errors in the determination of F. Since the thermal conductivities of other metals are appreciably lower than that of copper, much larger gauges of such metals can be employed without appreciable error. Also, as liquid packs heat so rapidly no significant thermocouple conduction error can be expected unless the thermocouple wire is unusually thick.

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Indirect Estimation

Earlier articles in this series appeared in **C.S.I.R.O. Food Preservation Quarterly,** *Vol. 13 (1953), pp. 3-8, 21-31; Vol. 14 (1954), pp. 8-18, 26-31, 46-52, 74-6; and Vol. 15 (1955), pp. 28-32.*

PART VII OF THIS SERIES (KEFFORD 1955) discussed the determination of moisture and total solids contents in foods by methods based on removal of water or on chemical reactions with water. In general, however, such methods do not yield results quickly enough to be useful in process control and quality control examinations. Whenever possible, therefore, the analyst prefers to use short-cut methods based on physical properties of foodstuffs related to moisture content. Such properties are specific gravity, refractive index, and electrical conductivity or capacity.

Measurements of specific gravity and refractive index are widely applied for the estimation of solids content in fluid and semi-fluid canned foods in which the solids present in greatest amount are sugars, e.g. fruit juices, syrups, jams, and tomato products. Methods based on the measurement of electrical properties have so far been applied mainly to foods of low moisture content, such as cereal products and dehydrated foods (Joslyn 1950).

Moisture or solids contents estimated by indirect methods are no more absolute than those determined by drying, since the physical measurements are converted to solids content by reference to tables, which relate specific gravity and refractive index either to the concentration of a pure solute, such as sucrose, or to the solids content of a natural product, determined by drying. The conversion tables most frequently used are the "International Sugar Tables" relating specific gravity and refractive index to the percentage weight of sucrose in pure solutions in water (Association of Official Agricultural Chemists 1950).

In the food industry the term "solids content" and also terms such as "density" and "strength" are used rather loosely to describe concentration; sometimes the quantity expressed represents the percentage of total solids and sometimes the percentage of soluble solids. Drying methods determine total solids content (percentage of total solids = 100 — percentage of moisture), and specific gravity and refractive index measurements determine either soluble solids or total solids content according to the method of conversion. In the foods commonly examined by specific gravity and refractive index methods, the total solids and soluble solids contents are approximately related and the insoluble solids contents are low. When reporting results, for instance under the entry "Solids Content" in Specimen Report Form No. 1 (Kefford 1953), it is very desirable to record sufficient detail to allow the true meaning of the results to be appreciated, e.g. "soluble solids content by refractometer, expressed as sucrose". The concentration of some liquid foods is commonly expressed directly in terms of specific gravity or relative density, hence the entry "Syrup Density" in Specimen Report Form No. 1, referring particularly to the density of syrups from canned fruits (see p. 54).

SPECIFIC GRAVITY MEASUREMENTS

The specific gravity of liquid foods is related to the soluble solids content, or it may be a measure of total solids content when a direct relation has been established for the product concerned.

At the same concentration solutions of different sugars have approximately the same specific gravity. Thus it is possible

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

# of Solids Content

By J. F. Kefford

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

to estimate the concentration of solutions of mixed sugars by reference to tables giving the specific gravity of sucrose solutions. The same tables are also commonly used for estimating concentration in foods such as fruit juices and syrups which contain small amounts of solutes other than sugars.

Specific gravity or relative density is determined fundamentally by weighing a fixed volume of a product in a specific gravity bottle (pycnometer) calibrated with distilled water (Joslyn 1950). However, this procedure is usually applied only to products containing much suspended or pulpy material. When examining samples comparatively free from suspended matter or filtrates from pulpy samples, it is possible to make use of the more rapid and convenient techniques of hydrometry (Hirst and Adam 1946; Joslyn 1950).

Hydrometry

Hydrometers are hollow glass "spindles" terminating at the lower end in a bulb weighted with mercury or lead shot and having the upper end in the form of a slender stem within which a graduated scale is sealed. When floated in a liquid, a hydrometer sinks to a depth determined by the specific gravity of the liquid. Thus a reading on the hydrometer scale with the surface of the liquid as a reference point gives a measure of the specific gravity of the liquid.

Hydrometer scales are calibrated to read directly in terms of specific gravity, or in "degrees" according to one or other of several arbitrary systems based on specific gravity or on the concentration of a particular dissolved substance, such as sucrose or sodium chloride. A calibration temperature is inscribed on each instrument and readings made at other temperatures must be corrected to this temperature by reference to appropriate temperature correction tables. Some hydrometers have a thermometer built into the spindle itself for measuring conveniently the temperature of a sample.

The following types of hydrometers are most likely to be encountered in food plants and laboratories.

Specific Gravity Hydrometer.—The scale reads specific gravity directly in terms of water at a specified temperature, e.g. 4 °C (39·2 °F), 15·5 °C (60 °F), or 20 °C (68 °F). According to the calibration temperature of the hydrometer, usually 15·5 °C (60 °F) or 20 °C (68 °F), readings are recorded as specific gravity 20°/20 °C, specific gravity 20°/4 °C, or specific gravity 60°/60 °F.

Brix or Balling Hydrometer.—This hydrometer is calibrated to read directly the percentage by weight of sucrose in pure solutions of sucrose in water, i.e. the number of grams of sucrose in 100 grams of solution. The Brix or Balling scale is in almost universal use in English-speaking countries in the hydrometry of sugar solutions and liquid foods containing sugars.

Beaumé Hydrometer.—As originally designed in France, this hydrometer was marked 0° in pure water and 15° in a 15 per cent. sodium chloride solution, then the scale was extended to 70°. The Beaumé scale is sometimes used for sugar solutions, and the readings, in degrees Beaumé (°Bé), are related to sucrose concentrations by reference to conversion tables. Beaumé

readings for liquids heavier than water are converted to specific gravity by means of the formula:

$$\text{S.G.} = \frac{145}{145 - {}^\circ\text{Bé}}.$$

Salometer or Salinometer.—This hydrometer has a scale reading from 0° to 100°, on which 0° is the reading in pure water at 60 °F and 100 °Sal is the reading in a saturated salt solution (26·5 per cent.) at the same temperature. Salometer readings are thus approximately equal to percentage sodium chloride by weight multiplied by 4; or 4 °Sal is equivalent to 1·06 per cent. salt and to 1 °Bé approximately.

Twaddell Hydrometer.—The scale is divided into 200 degrees (°Tw) representing a range of specific gravity from 1 to 2. Twaddell readings are converted to specific gravity by dividing by 200 and adding 1·000. This hydrometer is seldom used in the food industries, being applied chiefly in measuring the density of acids.

Tables are available showing the relations between specific gravity, percentage by weight of sucrose, and various hydrometer scales; and also tables of temperature corrections (A.O.A.C. 1950*a*, *b*).

Syrup Density

Soluble solids content in products such as syrups from canned fruits and fruit juices may be measured by means of Brix hydrometers and recorded directly as density in degrees Brix (°Brix).

A set of Brix hydrometers covering a range from 0° to about 60° is required. For accuracy in reading, each spindle preferably measures only 10 °Brix, and is graduated in 0·1° intervals.

The sample is poured into a tall glass cylinder, e.g. a measuring cylinder (100-350 ml), large enough in diameter to permit the spindle to float freely without touching the sides. The cylinder must be clean and dry, the liquid free from air bubbles and its surface free from froth and scum. A Brix spindle with an appropriate range is lowered into the liquid with a spinning motion to detach adhering air bubbles. The liquid must be sufficiently free from suspended insoluble matter to allow the spindle to come to a true resting point. In pulpy products the spindle tends to "stand up" and such products must be filtered if a Brix reading is required. When the spindle is at rest the scale is read to the bottom of the meniscus, with the eye level with the liquid surface.

The temperature of the sample is also taken and if it differs from the calibration temperature of the hydrometer a temperature correction is applied. Over the normal range of laboratory temperature the corrections are small (approximately 0·5 °Brix per 10 °F), but they become significant when determinations are made on hot syrups.

The corrected reading is recorded as density in degrees Brix. It represents also the percentage of soluble solids, expressed as sucrose.

Cut-out Brix

The syrup density in a fruit pack usually differs considerably from the density of the original syrup filled into the can, because the soluble constituents in the pack, i.e. the sugar in the syrup and the natural solutes in the fruit, diffuse uniformly throughout the entire contents. Diffusion occurs rapidly during heat processing, then more slowly during storage until equilibrium is reached in periods ranging from 2 days to 2 weeks in different products (Adam 1933-34; Ross 1955). The final equilibrium syrup density, often called the "cut-out Brix", should not, therefore, be measured until at least one week after canning. However, the cut-out Brix may be estimated soon after canning by mixing the entire can contents in a high-speed blender and measuring the density of the strained liquid (Sumner 1948; Townsend *et al.* 1954).

Original Syrup Density

In the course of examinations of canned fruits it is sometimes desired to estimate the original syrup density and the original filled weight. Hirst and Adam (1932) present a scheme for calculating these quantities for English canned fruits such as berry fruits, plums, etc. The calculations are possible only when data have been accumulated on the loss in weight of fruits in syrups of different final densities, and on the relation between the percentage of fruit and the final density reached by syrups of different initial density.

REFRACTIVE INDEX MEASUREMENTS

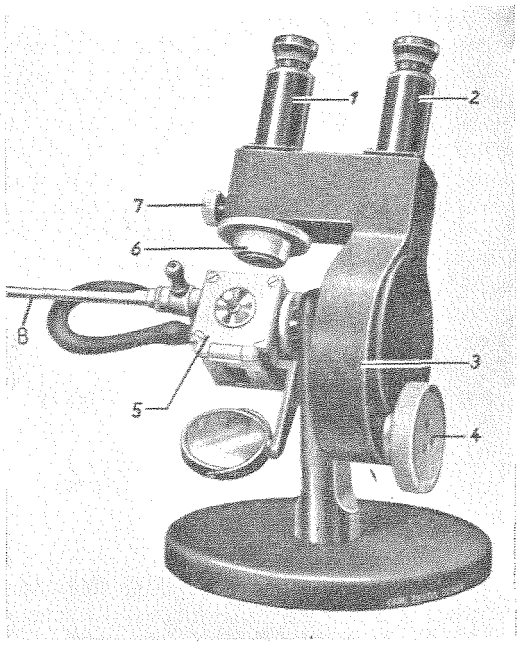
The refractive index of a solution is related to the soluble solids content. In liquid foods in which the solutes are mainly sugars, refractive index may be used as a measure of soluble solids content (Joslyn 1950), the reading being converted to percentage of soluble solids, expressed as sucrose, by reference to standard tables (A.O.A.C. 1950*c*). For some foods relations have been established between refractive index and total solids content.

The refractometric method for estimating solids content has two important advantages over the specific gravity method: it is applicable to less fluid products such as jams, sauces, and pulps that cannot be tested by hydrometry, and it requires only a very small sample.

To measure refractive index in foods several types of refractometer are used (Müller 1941). Although these instruments differ in design, all use the critical angle of total reflection as a measure of refractive index. The observer sees an optical field partly obscured by a shadow with a sharp boundary, the position of which is determined by the refractive index of the sample.

Abbé Refractometer.—The Abbé refractometer illustrated on this page is the type most commonly encountered. It gives a direct reading of refractive index for the sodium lines (n_d), with an approximate range of 1·3 to 1·7 and a precision of $\pm$ 0·0002, corresponding approximately to $\pm$ 0·1 per cent. in soluble solids content expressed as sucrose. The construction and operation of the instrument are discussed here briefly.

Mounted on a solid base and frame, the refractometer consists of a prism system with a water-jacket and a thermometer, a telescope with a compensator to eliminate dispersion, a scale sector and magnifier, and a mirror. The instrument is set up with the scale sector at the left of the observer, in front of a source of white light, such as a well-lighted window or a suitable bench light, and the mirror is adjusted to give maximum illumination in the optical field. The prisms are opened, and with a glass rod a few drops of the test sample are placed on the lower prism. Only sufficient liquid is required to fill the space (0·10-0·15 mm) between the clamped prisms. The prisms are clamped, the eyepiece is focused sharply on the cross wires, and the shadow on the field is brought into view by moving the scale arm. If the shadow shows a coloured border it is achromatized by turning the graduated ring of the compensator until the edge of the



An Abbé refractometer (reproduced by permission of E. C. Heyne & Co., Australian agents for Carl Zeiss, Jena). (1) *Observation telescope;* (2) *scale magnifier;* (3) *casing for glass scale;* (4) *operating wheel for setting the shadow boundary;* (5) *prisms with temperature control;* (6) *compensator;* (7) *compensator control head;* (8) *thermometer.*

shadow is just turning blue. At this point definition is sharpest, and the boundary is brought into exact coincidence with the junction of the cross wires. The magnifier is sharply focused on the hair line and turned so that the scale is well illuminated, and the refractive index is then read to four decimal places. The temperature is read on the thermometer in the instrument. Immediately after use the prisms are opened, cleaned with paper cleansing tissue wet with distilled water, and dried with paper tissue.

It is essential to protect the prisms from damage, particularly the polished surface of the upper prism; for instance, samples must be free from solid particles, such as seeds in jam.

Air bubbles and suspended insoluble material in samples have the effect of making the shadow boundary rather "fuzzy", and accuracy in reading is improved by using centifruged or filtered samples. However, Horner (1940) observed that the refractive indices of filtered samples of tomato products were significantly lower than those of corresponding centrifuged samples, probably because of retention of pectin by the filter or adsorption of other constituents. With most products satisfactory readings are obtained if larger suspended particles are separated out with the glass rod when placing the sample on the prism. Another useful technique, for pulpy juices, is to bring the prisms together and pipette a drop of sample into the small funnel-shaped orifice between the prisms. Surface tension draws clear liquid away from the suspended particles.

Periodically the adjustment of the refractometer scale is checked by determining the refractive index of distilled water (1·3330 at 20 °C) and of the test prism supplied with each instrument.

Several types of direct-reading Abbé refractometers are manufactured, e.g. sugar refractometers having, in addition to the refractive index scale, a parallel scale reading directly the percentage by weight of sucrose in pure solutions in water, and butyro refractometers for dairy products.

Some Abbé instruments are adapted for alternative illumination through the prism from above, thus making it possible to measure the refractive index of dark-coloured or opaque samples by reflected light.

Refractive index varies with temperature, and refractometers are calibrated in terms of refractive index at 20 °C (68 °F). An International Temperature Correction Table (A.O.A.C. 1950*d*) sets out corrections to be applied to sugar concentrations determined by refractive index measurements at other temperatures in the range 10°-30 °C (50°-86 °F). The order of the correction is 0·05-0·1 per cent. sucrose per 1 °C (1·8 °F).

The prisms of the Abbé refractometer are water-jacketed for temperature control and the common practice is to circulate tap water, the temperature of which is read on the thermometer in the jacket, and to apply the appropriate correction. It is advantageous, however, when making large numbers of routine determinations, to maintain a constant temperature by circulating water from a thermostat through the jacket. Under some Australian conditions a temperature higher than the standard 20 °C may be preferable in order to avoid condensation of moisture on the prisms.

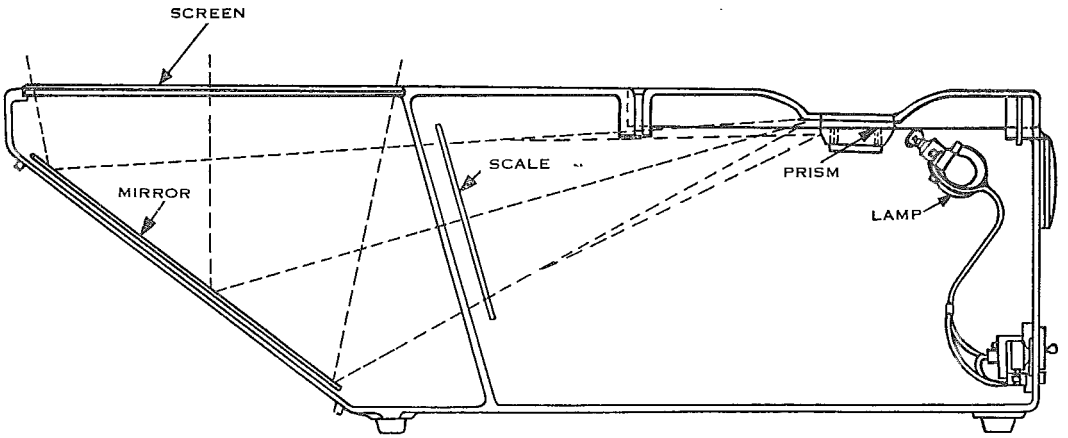
Temperature control is particularly necessary when examining samples from hot batches, e.g. during process control on jams.

Sweet Corn Refractometer.—An Abbé-type refractometer specially designed for maturity grading of raw sweet corn is described by Scott, Belkengren, and Ritchell (1945). This instrument has large prisms with a limited range of refractive indices, mounted over a pan for easy cleaning. Because of the opacity of corn juice samples the prisms have a low clearance and a special optical system is used to avoid errors due to the diffuse shadow boundary.

Hand Refractometer.—Small refractometers of limited range are manufactured for field work on fruits and tomatoes, and raw sugar juices. A few drops of sample liquid are placed on a prism, the instrument is applied to the eye, and the position of the shadow boundary read on an internal scale.

Immersion or Dipping Refractometer.—The prism of this refractometer is immersed in the sample liquid in a small cup illuminated from beneath and the position of the shadow boundary is read on an arbitrary scale in the eyepiece. A larger sample is required than for the Abbé refractometer but smaller samples can be examined in a special cup containing an auxiliary prism. A set of interchangeable prisms, each with a limited range, is supplied. The average precision is high, being of the order of $\pm$ 0·000035 in refractive index.

Projection Refractometer.—A very convenient refractometer for process control determinations, requiring no manipulation to take a reading, was devised in the laboratories



The optical system of a projection refractometer.

of J. Lyons & Co. (Hughes 1942). Its optical system is illustrated on this page. The sample is placed on the surface of a single horizontal prism illuminated from beneath and the position of the shadow boundary is read, without magnification, on a scale projected on a glass screen. Since the light is reflected from the interface of the prism and the sample, and does not pass through the sample, the projection refractometer is particularly suitable for measurements on materials of low transparency, e.g. dark-coloured or turbid products, such as jams, malt extracts, and coffee extracts. There is no provision for temperature control. A sugar scale and a refractive index scale are provided, covering a restricted range of solids contents from 30 to 90 per cent. Solids content can be read to within $\pm$ 0·1 per cent. when the shadow boundary is sharply defined. A reproducibility of 0·5 per cent. in solids content has been observed on jams under factory conditions (Martin 1955).

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NEWS from the Division of

Food Preservation and Transport

EGG INVESTIGATIONS

Investigations on the preservation and processing of eggs and egg products were commenced by the Division in 1938, and except during the war years have been carried out continuously since.

The first major problem studied was the causes of, and preventive measures for, the serious wastage which often occurred in Australian shell eggs exported to the United Kingdom. These investigations, carried out in cooperation with the Egg Producers' Council, showed that the most important form of wastage was bacterial rotting, and that it was caused by certain machines used for cleaning the eggs. Prohibition of the export of washed eggs virtually eliminated wastage in post-war exports.

Subsequent work has included the introduction of the rapid "resazurin" method for the determination of the bacterial quality of egg pulp; a detailed study of the effects of pasteurization in water and oil on the keeping quality of shell eggs; an investigation of the adequacy of the materials used for packing shell eggs in preventing losses by cracking, and the effects on the keeping quality of eggs of coating the shells with various oils, including oils containing certain additives.

At the present time the aim of the investigations is to define the causes of the steady deterioration of the internal physical quality of eggs during storage and, if possible, to find ways of arresting this decline. Included in this work is a study of the constitution and effects of the "Halphen" factor which occurs in some feeding-stuffs and which appears to accelerate the rate of decline of internal quality.

In the earlier stages, the investigations were carried out by officers from several sections of the Division. For the last few years, however, the staff has consisted of Dr. J. R. Vickery (part-time), Mr. F. S. Shenstone (Senior Technical Officer), and Mr. G. Stanley (Technical Assistant).

PERSONAL

Mr. IAN J. TINSLEY, a Research Officer of the Division who has been a graduate research assistant at Oregon State College, U.S.A., since August 1953, has been awarded a prize of 1000 dollars as the outstanding food technology student of the year in the colleges of U.S.A. and Canada. The award, donated annually by Florasynth Laboratories Inc. of New York, is to be used for advanced studies, which Mr. Tinsley plans to complete at the College.

Dr. R. A. LAWRIE and Mr. W. DEER, of the Low Temperature Research Station, Cambridge, returned from England in May 1955 to rejoin the team which is working at the Brisbane Laboratory of the Division on chilled and frozen beef on behalf of the Governments of Australia and the United Kingdom.

Mr. A. D. BROWN, a Research Officer engaged on meat research at the Division's Laboratory at Brisbane, returned from overseas at the end of June 1955. Since August 1954 he had been stationed at the Low Temperature Research Station, Cambridge, where he worked with Dr. M. Ingram on general bacteriological problems of meat.

PUBLICATIONS BY STAFF

DETERIORATION OF N.S.W. COUNTRY-KILLED MUTTON AND LAMB CARCASSES. *J. R. Vickery and F. S. Shenstone. Meat Marketing Aust. 4 (2): 8-11 (1955).*

When butchers in Sydney complained that mutton and lamb from country abattoirs in New South Wales deteriorated more rapidly

than meat killed at the metropolitan abattoirs at Homebush, the N.S.W. Department of Agriculture asked C.S.I.R.O. to investigate their claims. The investigations showed that lamb and mutton killed at Goulburn (and probably also at Wagga) is slaughtered, dressed, chilled, and transported (in refrigerated railway vans) under conditions which conform with sound practice and are unlikely to bring about a greater rate of deterioration than in metropolitan-killed carcasses.

At the time of arrival at the metropolitan markets, country-killed lamb and mutton carcasses will be at least three days "old" and may be five days "old" (calculated from slaughter). The average "age" is probably about four days. Since serious deterioration inevitably occurs after seven days post slaughter, irrespective of the origin of carcasses, it follows that the "life" of country carcasses after arrival at metropolitan markets is only about three days.

It is concluded that any disadvantages suffered by country-killed lamb and mutton carcasses are not due to any inherent tendencies to more rapid deterioration, compared with metropolitan-killed carcasses, but simply to the greater time taken to market them in the Sydney area.

* * *

A NEW AMINO-ACID FROM APPLES. *G. Urbach. Nature 175: 170-1 (1955).*

An amino acid with the empirical formula $C_6H_{11}NO_3$ has been isolated from prunings from dormant apple trees. It is thought to be 4-hydroxy-methylproline.

* * *

THE STRUCTURE AND SWELLING PROPERTIES OF NITELLA CHLOROPLASTS. *F. V. Mercer (Botany Department, University of Sydney), A. J. Hodge (Division of Industrial Chemistry, C.S.I.R.O.), A. B. Hope, and J. D. McLean. Aust. J. Biol. Sci. 8: 1-18 (1955).*

The swelling of the chloroplasts of *Nitella cristata* in solutions of different osmotic pressures has been examined in relation to their fine structure, isoelectric point, and permeability towards KCl.

* * *

THE BACTERIAL ENDOSPORE. *W. G. Murrell. 79 pp (Mimeo.) (1955).*

This account of the bacterial endospore follows the form of four lectures delivered by the author as Thomas Lawrance Pawlett Scholar of the Faculty of Agriculture at the University of Sydney in April 1953. The titles of the lectures are: (1) Introduction and cytology of the bacterial endospore. (2) Biochemical nature and metabolic activity of the spore. (3) The biochemistry of sporulation and germination. (4) Heat resistance and the biological role of the spore. Developments since 1953 have been incorporated in the text.

* * *

ADSORPTION OF GLUCOSE ON A WEAKLY BASIC ANION-EXCHANGE RESIN. *T. M. Reynolds. Nature 175: 46-7 (1955).*

A weakly basic anion-exchange resin, of a type used to de-ionize solutions prior to estimation of sugars, has been found to adsorb as much as one per cent. of the glucose when synthetic mixtures of sugars and acids are passed through columns packed with it.

* * *

THE INFLUENCE OF NUTRITION ON THE WATER RELATIONS OF SALMONELLA ORANIENBURG. *J. H. B. Christian. Aust. J. Biol. Sci. 8: 75-82 (1955).*

The growth rates of *Salmonella oranienburg* have been determined in four different basal media in which the water activity (a_w) was controlled by addition of salts and by addition of sucrose. In three complex media the lower limit for growth was between 0·94 and 0·95 a_w but in a simple defined medium the limiting a_w for growth was between 0·96 and 0·97. When an amino-acid mixture containing proline and methionine was added to salt-adjusted simple medium, growth occurred at 0·96 a_w. Subsequent addition of eight water-soluble vitamins extended the growth range to 0·95 a_w.

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

ANSWERS TO INQUIRIES

POTATO CRISPS

What varieties of potato are suitable for making crisps? How can excessive browning be prevented? Does the addition of monosodium glutamate improve the flavour of the crisps?

Generally speaking, the most suitable potato tuber for processing is fairly large, without pigmentation, and with only a few shallow eyes. Peeling and trimming losses prior to cooking range from 15 per cent. with such tubers to as high as 35 per cent. with small irregular potatoes with deep eyes. Suitable varieties are: Sebago, Sequoia, Katahdin, and possibly Saranac. Some crops of the Carman and Brownell varieties are also suitable.

Potato crisps and chips often darken during cooking, on account of a high reducing-sugar content. The darkening does not occur with freshly-dug potatoes but is likely with stored potatoes. Reducing sugars tend to accumulate as the temperature of storage is lowered, as under winter conditions in Victoria or Tasmania, or as the storage period is lengthened. The formation of reducing sugar may be prevented by storing the potatoes at 45-50 °F, or the sugar content may be lowered by the following means:

Holding the potatoes at a temperature of 70-75 °F for two to three weeks. However, rotting and sprouting occur quickly at these temperatures, and a careful watch must be kept.

Holding the sliced potatoes in cold water for one to three hours, or in water at 168 °F for about one minute.

Monosodium glutamate enhances the natural flavour of most vegetables, especially when the flavour is pronounced, but the effect with potatoes is rather small. The most satisfactory method of using the glutamate with potato chips is to sprinkle it on the chips after cooking, possibly along with the salt, and mix it well into them. A suitable concentration is 0·1 per cent. by weight, i.e. $\frac{1}{8}$ oz. of glutamate to 8 lb of chips.

FOOD SCIENCE ABSTRACTS

EFFECT OF RATE OF FREEZING ON PORK QUALITY. APPEARANCE, PALATABILITY, AND VITAMIN CONTENT. *F. A. Lee, R. F. Brooks, A. M. Pearson, J. I. Miller, and J. J. Wanderstock. J. Amer. Diet. Ass. 30: 351-4 (1954).*

Pork chops from the longissimus dorsi muscle were frozen as follows: (1) by plate contact, at −46 °C, in 1½ hours, (2) in a home freezer, at −18 °C, in still air, in 5½ hours, and (3) in an insulated box in a home freezer, at −18 °C, in still air, in 19 hours. Samples of fresh meat and of meat immediately after freezing and after frozen storage for six months were analysed, raw and cooked, to determine certain vitamins, and were examined subjectively. Neither the thiamine, riboflavin, niacin, pantothenic acid, and pyridoxine contents nor the flavour, odour, colour, texture, juiciness, and appearance were affected by the rate of freezing of the raw meat.

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COOKING LOSSES IN THE STEAM BOILER AND IN THE AIR-COOKING PLANT. (*In German.*) *G. Schaper. Fleischwirtsch 5: 299-301 (English summary, 301) (1953).*

The routine method of cooking meat in steam is compared with the new air-cooking method; the latter involves smaller cooking losses. For pork the saving in weight was 3 to 10 per cent.; for boiled ham, 6 per cent.; and for boiling sausages, 5 per cent. Sausages in artificial skins for scalding can be air-cooked without loss of weight.

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