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FOOD POISONING OF BACTERIAL ORIGIN.

It is the purpose of this article to discuss briefly three of the types of food poisoning of bacterial origin which are encountered most frequently.

A common form of food poisoning due to micro-organisms is that caused by the Salmonella group of bacteria. These organisms form a very closely related group of more than one hundred species and can be differentiated only by careful serological and biochemical tests. The best known member of the group is the organism which causes typhoid and in fact many outbreaks of typhoid are caused by the ingestion of food or water contaminated with Salmonella typhi. The paratyphoid bacilli are also members of this group and are responsible for many serious cases. In addition to these well known organisms, however, there are many others of the same type capable of setting up symptoms of gastro-enteritis with, at times, serious and even fatal consequences. The organisms produce their symptoms by invading the body from the intestinal tract and setting up a true infection. That is to say, the disease is an infection in contrast to an intoxication.

It is little realised that domestic animals used for human food are commonly infected with these organisms and that consumption of meat which is insufficiently cooked can lead to food poisoning caused by organisms of this group. This is of more common occurrence in European countries where lightly cooked or even raw meat is a customary article of diet. Again, in the United States of America, poultry are very frequently infected, and authoritative opinion holds that they are the chief reservoir of infection in that country. In Australia, attention has been directed comparatively recently to infections of this kind in domestic stock. Heavy mortalities in sheep have been found to be due to this cause, and fatal infections have also been detected in calves and sheep. It has been known for some time that a particular species of this group very commonly infects pigs, but recently the same species has been incriminated as one of the causes of pneumonia in these animals.

Another source of infection which is not as widely known as it should be is the excretion of rats and mice. Mouse typhoid is an endemic disease of rodents and in big cities the percentage of infection of the rat population has been shown to be as high as 7.5. Consequently, contamination of foodstuffs with the excretions of infected rats and mice can readily give rise to outbreaks of food poisoning of this type. This is the common history where dishes are rewarmed prior to consumption after the final cooking and where products such as meat pies are incriminated as being the foodstuff involved.

Recovered cases of human infection can remain carriers of the organisms and by frequent or constant excretion unknowingly be the cause of an epidemic. Such has been proved to be the case in instances where the carriers have handled food for human consumption in the course of their employment.

The Salmonella class of organisms do not form spores and are not particularly resistant to heat, being killed by a temperature of 60°C. (140°F.) maintained for 30 minutes. Therefore, they should not be a source of food-poisoning in products which are processed by heat above this temperature for a similar period of time unless the foodstuff is permitted to become infected after processing.

Another type of food poisoning of more serious consequences is that known as botulism. In contrast to the type of disease just described, botulism is a true intoxication and not an infection. The responsible organism, Clostridium botulinum, does not invade and multiply in the body but, under suitable conditions outside the body, can grow and elaborate its very potent toxin. The organism cannot grow in the presence of air or in an acid medium and consequently, canned foodstuffs of the non-acid class form in general a suitable medium for its growth. The toxin elaborated by this organism is the most potent poison known and very small quantities can be fatal to human beings. When an outbreak of this type occurs it is found usually that every individual consuming the toxic foodstuff is affected and the mortality rate exceeds 50%.

The causal organism forms spores which are amongst the most resistant to heat that are known. It is a common inhabitant of the soil and therefore can readily contaminate factories and materials prepared for food. Consequently, it is essential to employ heat processes sufficient to destroy these spores in the preparation of all non-acid canned foodstuffs.

The majority of outbreaks which have occurred have arisen from the consumption of home-canned vegetables where the processes employed are in general quite inadequate.

Another class of food-poisoning of bacterial origin on which much research has been carried out in recent years is of a less serious though very distressing kind. Several types of organisms, but most notably Staphylococci, have the power of forming a substance which is known as an enterotoxin. When consumed by humans this toxin has the property of producing, after an incubation period of 2 to 6 hours, a violent vomiting attack frequently accompanied by diarrhoea, which is followed by severe shock and prostration. Recovery is usually rapid and the patient is normal within 24 to 48 hours of the attack. Nevertheless, the symptoms are very distressing, and in young children may be more serious.

Staphylococci which are most commonly responsible for the condition are ubiquitous and a high proportion of strains of this class of organism are capable of producing the enterotoxin. The most common medium amongst foodstuffs are liquid or semi-liquid material which incorporate milk, such as custards and cake fillings. It is of interest to note that these organisms are frequently responsible for causing a mastitis in dairy cows and in these cases vast numbers are shed in the milk and subsequently may be widely distributed.

While Staphylococci and other organisms which can elaborate an enterotoxin are no more heat-resistant than members of the Salmonella group, the enterotoxin itself can withstand temperatures of 100°C. (212°F.) for 20 to 30 minutes. Therefore, it is possible for a material to become infected with Staphylococci under poor conditions of hygiene, and although the organisms are killed by subsequent cooking, the toxin survives and produces its characteristic symptoms when the material is consumed by humans.

The foregoing descriptions will serve to show that most classes of foodstuffs might serve as suitable media for the growth of organisms capable of inducing food-poisoning. Therefore, it is apparent that all possible hygienic measures should be employed in the preparation of food destined for human consumption, and that adequate processes for each product should be used to ensure that disease or even death does not arise from a lack of appreciation of the risks involved.

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LABORATORY EXAMINATION OF TINPLATE CONTAINERS FOR FOODSTUFFS.

Since the publication in Vol.2, No.2, of the Food Preservation Quarterly of the article entitled "Can Seams and Closing Machine Adjustments" approximately 2000 cans of foodstuffs, prepared at various Australian canneries, have been examined at the Homebush Laboratory of the Division of Food Preservation.

In addition to physical, chemical, and bacteriological examinations of their contents, these cans have been tested to determine their potential capacity for preventing the entrance of micro-organisms after the completion of processing. The methods used, and the results and implications of these tests, will be discussed in a series of articles in the Quarterly.

SPOILAGE OF CANNED FOODS.

At the time of placing in the can, most food materials carry variable populations of mixed types of bacteria, yeasts, and moulds, some of which are capable of growing and multiplying in the product under favourable conditions. With certain exceptions such as dried foodstuffs, the food materials in the closed can are usually subjected to heat processes with the object of destroying all the contaminating micro-organisms or, in some cases, only those types which are capable of growth at the temperatures at which the cans are held after processing. Microbial spoilage of canned foods which are heat-processed in the can may be caused either by organisms which survive the heat process or by those which gain access to the contents of the can after the completion of processing. When spoilage of canned foods is encountered it is therefore necessary to determine whether underprocessing or infection of the product after processing is responsible. The methods used in our laboratory for this purpose include bacteriological and physico-chemical examinations of the can contents, and physical examinations for the detection of leaks in the cans. An outline of methods and the interpretation of the bacteriological evidence obtained has been given in previous issues of the Quarterly.

Briefly it can be proved that spoilage of canned foods which have been heat-processed in the closed can has in most cases been due to infection of the can contents after processing if the spoilage organisms belong to the following groups:-

(a) Non-sporing bacteria, yeasts, or moulds.

(b) Sporing bacteria of insufficient heat-resistance to withstand the heat process.

Before going on to a description of the methods used for can testing the question of commercial losses due to leaky cans will be discussed.

COMMERCIAL LOSSES DUE TO LEAKY CANS.

Prior to the commencement of our canning investigations there were no available data regarding the extent of spoilage in Australian canned foods, and although there are authentic records of occasional extensive losses, there was no evidence to show whether such spoilage was due to underprocessing or to infection through leaky cans. During the past eighteen months we have investigated several outstanding cases of commercial losses due to leaky cans. In some cases the contents of the cans were spoiled by invading bacteria, whilst in others the cans were either rejected at the cannery on account of leakage of portion of their contents during or following retorting, or required resealing and reprocessing because of loss of vacuum after processing. Out of a total of 185,000 leaky cans from five different canneries the following groups were segregated:-

Rejected Cans		Reprocessed
Spoiled (Blown)	Leakage of Contents	Loss of Vacuum
25,000	40,000	120,000

The rejected cans taken in each case from New South Wales canneries represented between 4 and 10 per cent. of the daily output and the losses frequently extended over a period of many days' production. In addition, we have had numerous examples of spoilage due to leaky cans from several other Australian canneries, but the number of cans examined has been too small to permit an accurate estimate of total or percentage losses.

Where cannery records are kept, it should be possible to obtain fairly reliable data regarding commercial losses due to spoilage. The position is not so clear in regard to low-vacuum cans, because of the varying practices at different canneries. In some cases, cans which show marked loss of vacuum during the period of holding on the cannery floor are rejected, whereas in other instances the cans are regarded as commerically sound if the contents show no evidence of spoilage. Cans with very low vacuum or those without vacuum should be classified as doubtful because the can ends are likely to become springy under certain conditions of storage and the cans may then be suspected of spoilage. Such cans would in all probability be rejected by the inspecting officers of the defence services.

Whilst there are several possible causes of low vacuum in processed cans, the evidence we have obtained from laboratory examinations and from discussions with canners has shown that leaky cans are a very common cause of this condition. To sum up, there has been sufficient evidence produced to show that, during the past two years, leaky cans have been responsible for extensive commercial losses of Australian canned foods and for the production of large numbers of low-vacuum cans.

SPOILAGE DUE TO FAULTY CANS.

Faulty cans may leak in varying degree depending upon the size and position of the leaky areas. The size of the opening required to allow the entrance of micro-organisms depends upon the size of the invading micro-organism, and this may vary between $\frac{1}{50000}$ inch in the width of certain bacteria to $\frac{1}{5000}$ inch in the width of certain yeasts and mould spores. It will be seen, therefore, that holes of microscopic size are sufficiently large to allow the entrance of most spoilage organisms. These organisms are frequently found in air and water, and it will be readily seen that the admission of either air or water into the can after processing may introduce organisms into a product which has previously been sterilized by the heat process. Spoilage of the can contents as the result of introduction of either air or water into the can does not invariably occur because:-

(1) The air or water prior to entering the leaky area of the can may be free from micro-organisms. Generally, there are fewer organisms in a given volume of air as compared with the same volume of water provided that the water has not been previously sterilized, so that the chances of introducing infection are less when air and not water is introduced into the can.

(2) Organisms originally present in the air or water may be filtered out by the fine particles of metal or by the sealing compound within the seam.

(3) The heat of the can and contents may be sufficient to kill any organisms gaining entrance to the can. This is most likely to occur when the organisms are introduced during the period immediately following retorting.

(4) Organisms gaining entrance to the can may be incapable of subsequent growth in the product. A good example of this is shown with acid products such as canned fruits in which only certain types of organisms such as yeasts and lactobacilli are capable of growth.

The chances of spoilage in leaky cans of these products will depend upon the presence of these organisms in the admitted air or water, and if they are absent, as might frequently occur, such cans will not become spoiled. Another factor of some importance is that yeast cells which are considerably larger than most bacteria are less likely to gain entrance through microscopic openings in the cans. In addition, there is the possibility of leaky areas becoming sealed by the drying and concentration of the syrup used in fruit cans.

These facts may partly explain the reason for the relatively low commercial losses experienced by fruit canners. To illustrate the difference between can standards required for different products, it was found by several Australian canning firms that cans which were quite satisfactory for fruits were entirely unsuitable for vegetables.

METHODS FOR EXAMINATION OF CANS.

The methods for examination and testing of cans are designed primarily to detect leaks and at the same time to determine whether the cans conform to the commonly accepted standards for correct construction. Following visual examination, the cans are prepared for leakage tests and are finally subjected to a detailed examination.

Visual Examination.

The points looked for in the visual examination are signs of leakage of contents, and indications of damage to the can, together with evidence of other abnormalities such as springiness or bulging of ends. The absence of visible evidence of leaks cannot be taken as an indication that the can is non-leaky for it is quite possible for leaky areas through which spoilage organisms may invade the can to become sealed by particles of food material, liquid, or rust. Again, visible leaks may be due to damaged or punctured cans or to distortion of the seams as the result of gas production by spoilage organisms growing inside the can.

Preparation of Cans.

The contents of the can are removed through an opening cut out from one end in such a manner that damage to the end seams is avoided. After rinsing, the can is immersed in boiling water and held there for one hour with the object of removing food particles entrapped in the seams. It is difficult to assess the efficacy of this treatment for completely removing such food particles, but boiling has been proved to be necessary in the case of obviously leaky cans in which leaks could not be demonstrated prior to this treatment. Water-soluble substances should be readily removed, but insoluble materials such as vegetable and meat fibres and perhaps fat may resist removal. In at least one overseas method a detergent is used in the boiling water to facilitate the removal of fatty substances, but this has not been tested in our laboratory.

After removal from the boiling water, the can is drained and the residual water is withdrawn by means of a pipette. The can is then dried for one hour in a hot air oven at 100°C. (212°F.) or for a longer period at a low temperature, e.g. 130°F. That a complete drying out of the water from the seams is necessary in order to detect leaks has been proved by tests on specially set up cans with leaky seams tested both before and after immersion in water.

The combination of boiling and drying as outlined has been shown to have no adverse effect on can seams in that the tendency to leak was not increased by this treatment.

In the case of externally lacquered cans the treatment causes a disintegration of the lacquer and may reduce its protective effect on seams, but the lacquer is not used expressly for this purpose, and, since it is applied after the cans have been retorted and partially cooled, it would afford no protection during the vital period between retorting and cooling.

In the case of cans to be submitted to a puncture leak tester the hole from which the contents have been removed is soldered up by a covering disc of tin-plate, but this is not necessary with a special type of tester which accommodates cans with openings at one end.

Testing for leaks.

After being fitted up for the particular type of leakage tester the cans are subjected to internal pressure by means of compressed air. After taking the internal pressure up to 2 lb. as indicated by a pressure gauge attached to the equipment, the can is immersed in water preferably in a glass jar and examined for leaks as shown by air bubbles issuing from the interior of the can. Care must be taken to distinguish true leakage bubbles from those due to entrapped air in the seam or to air attached to the exterior of the can. The latter can be wiped off, whilst the entrapped air will eventually be forced out and cease to appear as bubbles. A continuous stream of bubbles issuing whilst the can is under pressure is accepted as clear evidence of leakage. After marking the areas leaking at 2 lb., the pressure within the can is increased by increments of 1 lb. to 5, 10, 20, and finally to 30 lb. and re-examined for leaks at each pressure level. The pressure to which cans can be taken without serious distortion depends upon the dimensions of the can and the type of tester used. With the puncture type tester, the approximate buckling pressures for different can sizes are given in the following table:-

Can No.	Dimensions (inches) Diameter	Height	Buckling pressure lb./sq.inch
10	$6\frac{3}{16}$	7	10 - 15
$2\frac{1}{2}$	$4\frac{1}{16}$	$4\frac{11}{16}$	20
2	$3\frac{7}{8}$	$4\frac{9}{16}$	30
	$3\frac{7}{8}$	$5\frac{12}{16}$	30
	$3\frac{7}{8}$	$6\frac{4}{16}$	30

With the special tester used for cans opened at one end, distortion is avoided, and cans up to No.10 size can be safely taken up to 30 lb.

The leaky areas are first examined by naked eye or with the aid of a lens and, when necessary, cross sections are made by means of a fine toothed jewellers saw blade, a three-cornered file, or a power-driven cutting disc. Leaks may be due to perforations or cracking of the tin-plate, defective soldering, or to incorrectly formed or damaged seams in the double-seamed sanitary can. Perforations or cracks are usually obvious, while defective soldering can be detected by separating and examining the soldered seams. In the case of leaks occurring at the junction of the side and end seams in the sanitary can it is difficult to determine whether the soldered portions of the side seam are implicated. The condition of these soldered areas can be determined by removing the end of the can, taking care to avoid damaging the body, and then retesting the can in the leak tester used for cans with one open end.

Leaky areas due to damage or incorrect formation of double seams are examined by means of seam sections. The description of the technique employed and the methods for assessing the causes of such leaks will be given in a subsequent article.

Reliability of the Method for Detection of Leaks

It is recognized that an internal pressure test does not simulate the conditions found in cans except during the short period following the release of pressure in the retort, when the internal pressure in cans which are not pressure-cooled may reach 25 lb. per square inch. When the cans are cooled and develop vacuum the negative pressure within a can having 10 inches vacuum would be approximately 5 lb. per square inch and in one with 20 inches vacuum, about 10 lb. per square inch.

Despite these objections, the internal pressure test method has been proved satisfactory for disclosing weaknesses in seam construction, and it will be shown in a later discussion that leaky seams are in most cases below the accepted standards for good seams.

In judging the reliability of the internal pressure test for detecting leaks, the results obtained have been related to the bacteriological findings on spoiled cans, and to visual evidence of leakage of portion of the can contents.

Up to the present, all cans showing bacteriological evidence of spoilage due to invasion of the cans after processing have been leaky, usually at pressures of 10 lb. or less, although pressures between 10 and 20 lb. were sometimes required to detect leaks.

Visibly leaky cans have generally shown leaks at pressures below 10 lb., but there have been a few exceptions in which cans apparently leaking at the junction of side and end seams after retorting and cooling were non-leaky when tested. After removal of the cover at the suspected end, leaks were detected through the soldered area at the end of the side seam. It was concluded that leakage of portion of the can contents had occurred through these areas during retorting and cooling and that the seams became effectively sealed after completion of cooling.

By means of the internal pressure test our laboratory examinations covering about 2000 cans have disclosed that approximately 30 per cent. of cans from various Australian canneries showed leaks at internal pressures of 10 lb. or less per square inch. Whilst it is true that commercial losses due to leaky cans have not been regularly high during this period there have been instances of losses as high as 10 per cent. The fact that a large proportion of such leaky cans may escape spoilage should not be taken as an indication that there is no pressing need to improve the condition of cans and can seams. It should be the aim of can manufacturers and food canners to reduce the possibilities of spoilage in canned foods due to leaky cans. It is of vital importance at the present time that wastage of tinplate, food materials, and manpower should be kept as low as possible, and most important of all that the risks of food poisoning should be reduced to a minimum.

The ideal of hermetically sealed non-leaky cans is not impossible of attainment, and has in fact been reached in a fair proportion of cans examined in this laboratory. The adoption of the internal pressure test should assist can makers and canners in maintaining high standards and should be of value for the prompt detection of faults which arise from time to time.

The next article in this series will deal with further details of can examinations and will outline recommended standards for seams.

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SUBSTITUTE CONTAINER INVESTIGATIONS BY THE DIVISION OF FOOD PRESERVATION.

In order to save tinplate, many materials which were formerly packed in tinplate containers are now packed in containers made wholly or partly of paper or cardboard.

The Commonwealth Tinplate Board is responsible for the control and allotment of the tinplate available in Australia, and last year an advisory Tinplate Substitute Container Committee was set up to assist the Tinplate Board in its work. Among the members of this Committee are a number of men who can give technical advice and information. These include several container manufacturers, a representative of the glass industry, a member of the staff of the Chemistry Department, University of Melbourne, a representative of chemical industry, and three members of the staff of C.S.I.R. However, it was soon realized that laboratory investigations would be necessary to provide the Committee with much of the information it needed. The C.S.I.R. Division of Food Preservation and Transport had been interested in this problem from very early in the war period and had carried out a small amount of laboratory work. This work was now greatly expanded and made a co-operative investigation with the C.S.I.R. Division of Industrial Chemistry.

Most of the commodities packed in substitute containers contain some water, and the water-content will vary with the relative humidity of the storage atmosphere, increasing under humid conditions and decreasing under very dry conditions.

The dry materials likely to be packed in substitute containers can be classified fairly completely into two groups:-

1. A large proportion of the commodities handled by grocers such as flour, cornflour, starch, custard powder, spaghetti, pepper, are not seriously affected by variations in water-content provided that they remain too dry to support mould growth. The lower limit for mould growth varies with the material, but is usually in the range 80 to 85% relative humidity. Most dry foods are likely to become mouldy or musty if allowed to reach equilibrium water-content in air at or above 80% relative humidity. Commodities stored in the usual ways in most parts of Australia, excepting in the tropical coastal regions, are not likely to be exposed to humidities above 80% for periods of more than a few days, so that packages of relatively low resistance to water-vapour transfer are usually satisfactory for materials in this first group.

2. There is an important second group of commodities which have a very short storage life unless the water-content is kept very low. These materials cannot be allowed to reach equilibrium with the air without serious damage even in the driest parts of Australia. Consequently, they require packages which are very resistant to the transfer of water-vapour. Among the most important commodities in this group are dried milk, dried egg, dried meat, and dried vegetables.

One of the tasks undertaken by this Division is the collection of data on the water relations of foodstuffs and other commodities in order to estimate the resistance to water-vapour transfer which is necessary in packages for particular materials.

This Division has also been responsible for carrying out tests on the various types of substitute containers at present available in Australia, paying particular attention to their resistance to the transfer of water-vapour.

The following are some of the more important conclusions arising out of this work.

1. A large proportion of the containers manufactured at present are much too permeable to water-vapour to be suitable for such materials as dried egg. This does not, of course, mean that they have not a large field of usefulness.

2. Most of the more efficient containers use wax as proofing agent, but not all waxed containers have high efficiency. A fairly heavy coating of wax seems to be necessary to obtain high resistance to water-vapour transfer.

3. Protein materials such as animal glue, gelatine, and casein have little value in restricting water-vapour transfer, though they appear satisfactory for preventing the wetting of container walls by such commodities as treacle. With suitable additions of other materials, they may also be satisfactory for oil-proofing.

4. Asphalt is the only adhesive studied so far which gives a really useful increase in resistance to water-vapour transfer.

5. Most of the lacquered containers we have seen have been very permeable to water-vapour.

More detailed information on substitute container investigations will be published in the Bulletin of the Tinplate Container Committee, the first number of which will be issued shortly.

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DISCOLOURATION IN CANNED SWEDE TURNIPS.

Some general notes on discolouration in canned foods were given in the last issue of the Quarterly. The following additional notes on swede turnips may also be of interest.

Swede turnips normally develop a bright golden colour during processing, but a dull leaden or even darker colour sometimes appears in commercial packs. Investigations at this Laboratory have shown that contamination with iron (not more than twenty parts per million in some cases) can cause serious discolouration.

Darkening has been produced experimentally by blanching in slightly rusty plain iron equipment. Even in such equipment, discolouration was reduced to a minimum by using fresh water and blanching for not more than five minutes. If the period of blanching was excessive (e.g. more than ten minutes) or the water had been previously boiled in the vessel for a long period, darkening was much more serious. Therefore, if plain iron equipment must be used for blanching swedes, the time of blanching should be reduced to a minimum and the water should be changed after every 3 - 4 batches. The use of water containing appreciable amounts of iron is to be avoided.

Similar darkening has been obtained by boiling diced swedes in solutions of ferrous bicarbonate containing 50 parts per million or more of iron.

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ELECTRICAL MOISTURE METERS FOR DRIED FOODSTUFFS.

REASONS FOR DEVELOPMENT.

The increased production of dried foodstuffs has brought about a demand for a very rapid means of determining water-content so that the drying process can be controlled more closely. The standard methods* for determining water require several hours drying either in an air oven or in a vacuum oven operated under specified conditions. These methods involve fairly accurate weighing of small samples, and care in calculation. Distillation methods in which the volume of water is read off directly are also used for some materials, but these methods require a separate piece of apparatus for each of simultaneous determinations, and the equipment will be difficult to obtain for new plants.

Close control of the drying process is possible only when very rapid determinations of water content can be made, and none of the standard chemical methods entirely meets the requirements. A method is required which allows of immediate adjustment of the drying schedule whenever this is desirable. A large number of tests is usually necessary to check on the effects of variations in the process which may be either intentional or unavoidable. Great accuracy is not always required, and for many products, determinations correct to within 0.5% would be satisfactory.

MEASUREMENT OF ELECTRICAL QUANTITIES.

The variation of the electrical properties of a material with its water-content provides the basis for attempting to determine water-content by electrical measurements. Most electrical quantities can be measured very accurately, although in some cases the instruments required may be rather expensive or difficult to obtain. However, for special applications some progress has been made in the development of simple, reliable, and robust instruments which are really useful in the manufacturing plant.

During measurement, the material is usually held between two insulated metal electrodes which are connected to the measuring circuit and source of current. The measurement depends on both the quantity and the nature of the flow of electricity through the material in the cell with respect to the applied voltage. Alternating current over a very wide range of frequencies may be used, but the use of direct current is not likely to be successful because polarisation causes the current to decrease and give variable readings. The quantity measured may be either the resistance or capacitance of the part of the electrical circuit between the metal electrodes. In practice it is often more

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* For example, see article "The Determination of Moisture in Dried Vegetables", Food Preservation Quarterly, Volume 2, No.2, pp.14-16.

convenient to measure related quantities or some combination of these; the main requirements are that the effect is convenient to measure and varies consistently with the water content.

VARIABLES AFFECTING THE ELECTRICAL PROPERTIES OF A MATERIAL.

As the water-content by itself does not determine the current through the cell, it is necessary to standardize the technique of measurement so that the water-content remains as the only important variable. The most important variables to consider are the composition of the material, its particle size, packing density in the measuring cell, quantity in the cell, and temperature.

The composition of the material on which the determinations are made must be reasonably constant except for water-content. This requirement is met by some dried foodstuffs, but it may not be met by the different varieties of a vegetable or for the same vegetable under different treatments.

It is usually necessary to grind a sample of the dried material so that it can be poured into the measuring cell. The particle size of samples for determination should either be fairly uniform or should contain constant proportions of various particle sizes. Provided that the setting of the grinding mill is kept constant, there seems to be no need to select particles over any narrow range of sizes.

The packing density must be kept constant and the total quantity of material in the cell must be measured. There are various methods of achieving the desired accuracy, and the latitude allowed depends largely on the design of the cell and the measuring circuit. Serious errors are possible and precautions must be taken to minimize them.

It will usually be necessary to take into account the effect of temperature changes. The magnitude of the corrections is likely to depend on the composition of the material, including the water-content; but a single correction may be sufficient where great accuracy is not required. The most satisfactory procedure is to avoid irregular changes by working in a constant temperature room if this is available in the factory.

CALIBRATION AND CHECKING OF INSTRUMENTS.

The original calibration of an instrument is carried out by comparison with determinations made by an approved method of moisture determination appropriate to the product. It is of course essential that the standard method give consistent results for the material under test, and it must not be forgotten that no one method is satisfactory for all materials. A separate calibration is required for each material; and if the material is handled in widely different particle sizes, it is convenient to have a separate calibration corresponding to each particle size.

Once a particular instrument is calibrated, it should be possible to transfer the calibration to similar instruments. This procedure depends on uniformity in the manufacture of the measuring instruments including the measuring cell.

It is very desirable to check the calibration of an instrument frequently, and the most satisfactory procedure seems to be to carry out a few determinations by the standard method together with the routine determinations on the electrical instrument.

THE MOISTURE CONTENT SCALE.

When the quantity of water in the material is less than 5%, the other variables affecting the electrical properties tend to mask variations due to water-content. There is also a loss of sensitivity at low water-contents and it becomes more difficult to distinguish between different levels of water-content. In other words the scale becomes cramped in the range of low water content, but opens out with increasing water-content.

The falling off in the accuracy of determination as the water-content of the sample is decreased is one of the greatest difficulties in producing an instrument suitable for dried vegetables.

RESULTS OBTAINABLE.

To sum up; as long as the limitations of the instruments are appreciated and the material and processes are well standardised, excellent results are possible. If a constant temperature room is available, a great deal of time can be saved in calibration and measurement.

On the other hand, an electrical moisture meter can be very misleading if the effects of variables other than water are not reduced to a minimum.

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EXTENDING THE STORAGE LIFE OF APPLES BY THE USE OF SKIN COATINGS.

(This article which represents a revision and extension of one published in a previous issue of the Quarterly has already appeared in this year's March issue of the Agricultural Gazette of New South Wales.)

INTRODUCTION.

For the past three seasons extensive experiments on the skin coating of apples have been carried out in New South Wales at the Homebush Laboratory, and in 1942 at country centres, by the Council for Scientific and Industrial Research and the Department of Agriculture.

Following on successful experiments in the laboratory, large scale trials were carried out in 1942 at Batlow, Orange, Crookwell, and Armidale. Large-scale experiments have also been carried out in Tasmania where about 60,000 bushels of apples were treated successfully in 1942 by the Australian Apple and Pear Marketing Board under the supervision of the Council for Scientific and Industrial Research. Smaller trials have also been carried out in South Australia and Victoria by officers of the State Departments of Agriculture. The results given here relate only to fruit grown in New South Wales.

It has been shown that a very thin film of wax, oil, or other suitable protective material applied to apples prolongs their life, retards yellowing to a marked degree and reduces wastage from certain storage disorders. Fruit treated with a suitable coating is also of better flavour, firmer, generally less wilted and generally brighter than untreated fruit. Such skin coatings are particularly valuable for increasing the life of apples in common or unrefrigerated storage, and the life during and after cool storage is also increased by treatment. Treated apples can also be cool-stored at temperatures above those at which certain cool storage disorders may develop without the reduction in storage life which usually follows cool storage at higher temperatures. The effect of such coatings is due to the fact that the diffusion of oxygen and carbon dioxide through the skin of the fruit is restricted; consequently the life processes of the fruit are slowed down and therefore its storage life is increased.

TYPES OF COATINGS.

The most satisfactory coatings are those formed from certain oils, waxes, and dewaxed shellac.

Castor oil and dewaxed shellac are soluble in alcohol which is the only suitable solvent that can be used without injuring the fruit. Consequently, a mixture of castor oil and shellac dissolved in alcohol can be used, and such a preparation has given very satisfactory results with a number of varieties. All other oils and waxes have to be prepared as emulsions using special soaps. Such emulsions have their special uses, but have not been as generally effective as the alcoholic solution of castor oil and shellac. As the alcoholic solution dries very quickly and leaves no contact marks, it is particularly suitable for treating the fruit by hand-dipping methods. In use, the solution becomes more concentrated through evaporation of the alcohol and this stronger solution may cause the subsequent development in treated fruit of core-browning, alcoholic flavours, or breakdown. Alcohol should therefore be added from time to time at the rate of usually $\frac{1}{2}$ to $\frac{3}{4}$ gallon for every 30 bushels treated to bring the solution back to its original strength. The strength of the solution can be determined by titrating with caustic soda solution in the same way as the maturity test for oranges is carried out.

Alcohol is inflammable and the necessary precautions should be taken when the solution is being used.

The emulsions are more difficult to prepare but can readily be manufactured commercially in a concentrated form and then only require dilution with water for use. However, they dry slowly and leave contact marks when hand-dipping methods are used, but can be applied very satisfactorily in a machine which incorporates a hot-air drying tunnel. A large number of emulsions of waxes and oils have been prepared and tested on fruit in the laboratory and some of these have given good results in larger trials.

METHODS OF APPLICATION.

(a) Hand Dipping: This method is very satisfactory when the alcoholic solution is used, and large quantities of fruit can be treated inexpensively by the grower, as special equipment for drying the treated fruit is not necessary. The only equipment required is a tank to hold the solution, several perforated dipping-boxes or baskets and a gently sloping draining-table of corrugated sheet iron along which the solution drained from the freshly dipped boxes of fruit runs back into the tank. A suitable dipping-tank in which the fruit can be treated in case lots using a standard bushel-size dipping box would be 22 inches long, 14 inches wide, and 16 inches deep, and could conveniently be made from galvanized iron. A reinforced, specially smoothed hardwood or hemlock bushel case fitted with rope handles and perforated for rapid drainage makes a suitable container for dipping the fruit.

In operation the fruit is gently transferred from the field case to the dipping-box which can readily be done by placing the empty dipping-box on top of the full field case and carefully inverting the two cases. The dipping-box is then submerged for a few seconds in the tank of solution, care being taken to cover every apple, and then drained on the draining-table for a minimum of two minutes. After draining, the fruit is transferred back to the original box which is not stacked up for storage for a few hours in order that the fruit will be free to dry. It is desirable to raise the cases off the floor during this time by placing them on 3 x 2 inch studs. If several dipping-boxes are used the boxes can be thoroughly drained while others are being filled and dipped. By this method, one man can treat 20 to 25 bushels of fruit per hour.

(b) Machine Treatment: A suitable machine consists of a tank to hold the solution or emulsion, and an elevator, with under drainage back to the tank, which carries the fruit from the tank to a drying-tunnel. The fruit is slowly carried through the tunnel against a current of hot air and is discharged from it into a bin for boxing. Such a machine will rapidly handle fruit treated with castor oil and shellac in alcohol and its use is practically essential for treating satisfactorily large quantities of fruit with emulsions. Such plants are in operation for waxing oranges.

COST OF COATING.

The cost of the materials for the alcoholic solution of castor oil and shellac is approximately 3s. per gallon. If the solution, which is easily prepared, is made up in bulk at a central point in each district, the cost to the grower should not be much more than 4s. per gallon. One gallon of solution is sufficient to treat 25-30 bushels of apples. The cost of hand treatment including labour would be approximately 4d. per case.

The cost of the concentrated emulsion would be about 10s. per gallon from the manufacturer. As the concentrated emulsion is diluted with one part of water before use, one gallon will treat 50-60 bushels of apples. The cost of treatment for materials and labour would therefore also be about 4d. per case.

RESULTS OBTAINED WITH COATINGS.

The best results have been obtained with castor oil and shellac in alcohol. Under favourable conditions, the use of this preparation has increased the life in common storage of Jonathans, Delicious, Granny Smith, and Democrat apples in New South Wales by 50 per cent.

The most striking effect of treatment has been a marked retardation of yellowing, and treated Granny Smith apples have remained green for five months in common storage. In almost all cases, treated fruit was less wilted, firmer, crisper, and more juicy than untreated fruit, and flavour and acid were retained much better. Treatment with castor oil and shellac in alcohol sometimes caused lenticel spotting on the Jonathan, Granny Smith, and Rome Beauty varieties, but it was generally slight on fruit treated at the right stage of maturity. Treatment has consistently practically controlled Jonathan Spot, greatly reduced the incidence of bitter pit, and delayed the development of mealy breakdown.

In most cases, with varieties other than London Pippin which is unsuited to common storage and with which the treatment was not successful, mould wastage was not increased by treatment with castor oil and shellac. The film on fruit treated with this solution is somewhat sticky at higher temperatures in common storage, but when temperatures are lower, as when the late varieties are treated in this State, and in Tasmania or in cool storage, the coating is satisfactory.

Oil emulsions were less effective than the alcoholic solution but more effective than wax emulsions in retarding yellowing and softening. They tend to increase wilting of the fruit which however is effectively controlled when wax emulsions are used. Wax emulsions, which also reduce Jonathan Spot and bitter pit, although they do not markedly retard yellowing, are valuable for Jonathans which wilt badly in common storage.

The emulsions so far prepared for treating fruit, either experimentally or commercially, are alkaline in reaction and may cause browning around the calyx similar to that caused by alkaline washes sometimes used for spray-residue removal.

An emulsion of peanut oil was used in large-scale trials and, although it increased wilting and made unwrapped fruit very sticky, it was more effective than wax emulsions in retarding yellowing, softening, and loss of flavour, and considerably reduced the development of superficial scald in cool-stored Granny Smith apples.

CONCENTRATION OF DIP.

In most commercial-scale trials with castor oil and shellac a 10 per cent. solution of either two or four parts of castor oil to one part of dewaxed shellac has been used, but injurious effects were produced when the fruit was immature or when prevailing temperatures were high. Some trials with weaker solutions were carried out and it is considered that the best strength for general use on apples is an 8 per cent. solution of two parts of castor oil to one part of dewaxed shellac. For oil emulsions a concentration of 10 per cent. seems to be most satisfactory. Wax emulsions may be used in higher concentrations although a 10 per cent. emulsion will usually control wilting and reduce wastage from Jonathan spot.

PRECAUTIONS TO BE OBSERVED IN TREATING FRUIT.

It has been found that the maturity of the fruit at the time of treatment is of critical importance and, when castor oil and shellac is used, immature fruit should not be treated. Such fruit, particularly if the temperatures are high, is very liable to develop alcoholic off-flavours, skin- and core-browning, and even breakdown after treatment. Furthermore, treated fruit does not ripen and develop flavour to the same extent as does untreated fruit, so that apples should be sufficiently mature to be palatable when treated. This particularly applies to fruit treated eith castor oil and shellac. If fruit is over-mature when treated, the development of lenticel spot and mould will be increased. For treatment, dessert varieties should have a green-yellow ground colour and should be juicy with a fair amount of flavour. Green varieties such as Granny Smith should be treated when the ground colour is light green to yellow-green; if the ground colour is deep green the fruit is immature, and if it is on the yellow side it is over mature. Thus, in general, fruit for treatment should be at the optimum maturity for cool storage when picked.

It should be clearly understood that, unless the fruit is in good condition, free from injuries and handled carefully, its life, even after treatment, may be considerably reduced by the onset of mould. Very large and very small fruit should not be treated, since the former does not keep well and both seem more likely than fruit of normal size to develop alcoholic flavours under adverse conditions. Treatment should be carried out within a day or two from picking; it is particularly important with the earlier varieties that there should be little delay between picking and treatment. Treatment of fruit with castor oil and shellac should be avoided during very hot weather as, under such conditions, even mature fruit is liable to develop off-flavours. The fruit should be kept as cool as possible after treatment, particularly for the first few days. For this reason, as well as for the reason that castor oil and shellac does not always reduce wilting in Jonathans, a wax emulsion may be better for this variety when temperatures are high.

RECOMMENDED COATINGS.

The most generally effective treatment was castor oil and shellac in alcohol, and it is recommended that an eight per cent. soltion of two parts of castor oil to one part of dewaxed shellac should be used on Granny Smith, Democrat, Delicious, and Rome Beauty apples for common storage, and on Democrat, Delicious, Rome Beauty, and Jonathan apples for cool storage. For Jonathans in common storage a 10 per cent. wax emulsion may be better as it controls wilting. A 10 per cent. emulsion of peanut oil seems to be best for Granny Smiths in cool storage, provided that they are wrapped in plain paper, as it is considerably more effective than the solution of castor oil and shellac in reducing the incidence of superficial scald.

Growers who contemplate treating apples for storage are advised first to consult their local fruit inspector or instructor or write directly to the Fruit Storage Officer of the Department of Agriculture at the Food Preservation Laboratory of the Council for Scientific and Industrial Research at Homebush.

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CORRECTION - NOTES ON THE DEHYDRATION OF APPLES.

In the Food Preservation Quarterly Vol.2, No.4, December, 1942, it is stated that in 1943 approximately two million bushels of fresh apples will be dried to yield 4,000 tons of dried fruit. Actually the objective for 1943 is 3,000 tons of dried fruit equivalent to about 1,200,000 bushels of fresh fruit. A ratio of 8:1 between fresh and dried apples is the Australian standard and not 10-15:1 as previously stated.

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