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THE UTILIZATION OF CITRUS RESIDUES.

The disposal of citrus residues from juice processing plants is now a serious problem, since approximately 200 tons of waste material are produced daily throughout Australia, and the cost of dumping, particularly in the capital cities, is heavy. Dumping is, moreover, extremely wasteful as the residues are potential sources of stock feed, pectin, and essential oils. In the United States the utilization of these by-products has become extremely profitable for the industry, and any measures which may create useful outlets for present waste products merit immediate consideration in this country.

Types of Residues.

The citrus residues at present wasted, mainly orange residues with a small proportion of lemon and grapefruit residues, consist of:-

(a) Halved peels from hand and mechanical reamers.
(b) Rag from screening reamed juice.
(c) "Rumblings", i.e. washings from rumblers, consisting of the disintegrated outer peel and oil cells; also washings from Avena machines which contain much less disintegrated peel.
(d) Quartered peels from the Smith and Searls mechanical juice extractor, usually with most of the oil bearing layer removed.
(e) Pulp from the screw press of the Smith and Searls extractor.

Several methods for the utilization of these residues will be outlined

Recovery of Essential Oils.

Citrus oils of "cold-pressed" quality may be recovered from the washings from rumblers or Avena machines by partially concentrating the oil emulsion in settling tanks, and separating the oil by centrifuging. A number of processors are operating citrus oil recovery plants of this type.

The less desirable distilled oils are prepared by steam distillation of oil-bearing residues, either rumblings or whole peel. Several processors are producing marketable products in quite crude equipment, e.g. a closed vessel (tank or drum) with ports for filling and emptying, a steam inlet, and a steam outlet leading to a condenser coil in a tank of cold water. The oil-water distillate is allowed to settle and the oil skimmed off.

An experimental machine is in course of development, by a Sydney manufacturer, to produce an oil of "cold-pressed" quality from reamed peels by a process of rolling and washing.

The Manufacture of Marmalade Mixture.

A small quantity of citrus residues is used in marmalade mixture. The production of this jam could be increased, but it is not likely to account for more than a small proportion of the total residues. Problems in connection with marmalade mixture are being given attention, and are forming the subject of separate reports.

Ensilage.

In a recent report from Palestine, Bondi and Meyer[1] describe the preparation of ten tons of ensilage from citrus residues in a cement silo. The coarsely sliced material was packed down hard, and then covered with straw and two feet of earth. After eight months, the ensilage was in excellent condition, and gave good results in feeding tests. Dr. E. G. Hallsworth of Sydney University is at present investigating this process.

The chief disadvantage of ensilage is that it is wet and bulky material, which would be difficult to transport. The process cannot be recommended for treating residues from metropolitan plants, but it may be of value for country plants, where the ensilage could be used as a stock feed in the vicinity.

Drying of Citrus Residues.

Dried citrus residues may be used as a stock feed[2] but are more valuable as a source of pectin. As pectin production involves considerable plant and experience, it is not expected that more than a fraction of the present residues could be used in this way. Hence, if drying is undertaken in the main centres, the dried material should be capable of being used both as a stock feed and for pectin production.

Citrus pulps from the screens and from Smith and Searls' extractors are sufficiently well disintegrated for drying, but peels need to be sliced or ground in a suitable mill. In a small scale test at this laboratory, a mixture of pulp and shredded peel was dried in about two hours, using a vertical circulation of air through three inches of material, at a temperature of 140°-150°F. and a velocity of about 200 feet per minute. The material was turned over every half hour. Unfortunately it tended to stick together and required breaking apart thoroughly. A type of drier, e.g. a rotary drier, which breaks up the material continuously to prevent it caking, would be most suitable for large-scale production.

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(1) Empire Journal of Experimental Agriculture 10: 89 and 93 (1942).
(2) W.H. Cory, "Value of orange pulp for livestock feeding" California Citrograph 25 (No.1): 32-33 (1939).
J.M. Jones, "Dried citrus pulp as a cattle feed", Cattleman 26 (No.2) : 57-58 (1939).

To avoid destruction of pectin, drying should be commenced as soon as possible after pressing, and the moisture content of the dried material kept as low as possible. Kertess and Green[3], in investigations on the retention of pectin in apple residues, found that mould did not develop on residues containing 20 per cent. or less of moisture. However, it is an advantage to reduce the level of moisture still further, as enzymic deterioration can proceed in the presence of moisture, even if mould is inhibited.

Liming. In the United States, particularly in Florida, citrus residues have been treated with lime before drying for stock food. The process is described in papers by Rosseau[4] and van Antwerpen[5]. The waste material is often very wet, due to the practice of floating the residues to collection pits, and liming enables much more free moisture to be pressed out and facilitates subsequent drying. The action of the lime is due to the coagulation of pectin, which is largely responsible for the water-retaining property of citrus residues.

The process described by these authors is briefly as follows. The wet material is disintegrated by a hammer mill, having a $\frac{3}{8}$ inch screen, while a 2 per cent. solution of calcium hydroxide is mixed with the mass. It is then thoroughly mixed and stored for a short period to complete the action of the lime. After steaming, it is pressed between rollers and dried in a rotary drier. The liming process is covered by United States patents 1,991,942.(1935)(to Cole and Hall) and 2,187,501.(1940)(to Lissauer).

A drying test with limed material was carried out in this laboratory. The sample was comparable to that used in the previous test, and was mixed thoroughly with 1 per cent. of calcium hydroxide (increasing the pH from 4.0 to 6.5). The residues came from the plant with practically no free moisture and did not require additional pressing. Drying took $1\frac{1}{2}$ to 2 hours, and there was no trouble with caking.

The limed material would be suitable for stock food but inferior as a source of pectin. More acid would be required for extracting the pectin from this product, and a considerable excess of calcium would be incorporated in the extract.

Preparation of Leached Residues.

Before extraction of pectin, residues are leached with cold water, and this operation can be completed before drying. The following method has been suggested by the U.S. Department of Agriculture.

"After the removal of seeds, the pomace is ground in a suitable mill so that the pieces are approximately one-half inch in length. The ground pomace is added immediately to boiling water (approximately 30 gals. of water to 100 lb. of pomace), and the temperature is maintained at about

(3) New York Agricultural Experiment Station, Tech. Bull. 179 (1931).
(4) Food Industries 10: 556 (1938).
(5) Industrial and Engineering Chemistry 33: 1422 (1941).

194°F. (90°C.) while the mixture is agitated for 5 to 7 minutes. At the end of this treatment period, sufficient cold water (approximately 50 gals. per 100 lb. of pomace) is added to lower the temperature of the mixture to 135°F. (57°C.) or below, and after agitating for 5 minutes the water is drained off and discarded. The wet pomace is added to cold (ordinary temperature) water in ratio of approximately 35 gals. to 100 lb. of pomace, agitated for 10 minutes, and the water is then drained off and discarded. The extraction with cold (ordinary temperature) water described in the last sentence is repeated once. The leached pomace is pressed in a suitable press, dried, and ground.

"In order to reduce loss of pectin by enzyme action, the processing of the pomace should be commenced promptly, as soon as it is available from the juice extraction plant. Not more than 45 minutes should elapse between juice extraction and heating of the pomace in boiling water, and not more than 10 minutes should elapse between grinding the pomace and subjecting it to treatment with boiling water. Otherwise, considerable loss of pectin may result, and the physical condition of the pomace may also be changed in such a way as to seriously retard the processing operation.

"In order to reduce the loss of extractable pectin, it is advisable that soft water be used in the processing of the citrus pomace, particularly for the final extraction. Water having a hardness of 12 parts per million or below is satisfactory."

In a test in this laboratory, residues were leached by the above procedure and dried in the same way as the untreated and limed samples. Drying took about two hours and the material did not stick excessively. The dried material is eminently suitable for pectin, but its nutritive value is considerably reduced, as most of the soluble substances, including sugars, have been removed by leaching.

Manufacture of Pectin.

Stages in the manufacture of pectin include leaching the residues in cold water, extracting the pectin with a hot acid solution and filtering the extract. Powdered pectin may then be produced by (a) spray drying, (b) concentration and precipitation with alcohol, or (c) precipitation with aluminium, which is subsequently removed by acid alcohol.

It is estimated that the Australian requirements of powdered citrus pectin are in the region of 100 tons per annum. The yield of pectin from citrus residues is of the order of 10 per cent. from dried residues and 1-2 per cent. from wet residues.

General information on pectin is given in "Fruit Pectin" by W.A. Rooker (Avi Publishing Co., 1928) and "Pectin" by W.E. Elwell (University of Washington, 1939).

Leaching.

Leaching is carried out as previously described. Dry residues should be soaked for about 30 minutes before leaching. Material which has been leached before drying can, of course, be extracted immediately. The leaching removes some of the pectin, but only of low jelly grade. High-grade pectin requires hot dilute acid to bring it into solution.

Extraction.

The amount of extracting solution required is equivalent to about 2-2½ times the weight of wet residues or 5-10 times the weight of dry residues. The time and temperature of extraction, and the acidity of the extracting solution, have been considered by a number of authors. Elwell suggests a pH range of 2.3-4.0. Rooker recommends adjusting the pH to 3.5 and heating either at 190°F. for 60-80 minutes or at 212°F. for 30-40 minutes. The extract is then pressed out in a suitable press.

A number of authors (Wilson, Myers and Baker and Hinton[6]) favour the use of fairly acid solutions (pH about 2.0) at 180°-190°F. It is generally claimed that there is less destruction of pectin at this range than at 212°F., and the high acidity is extremely efficient in dissolving the pectin. The writer's experience is in general agreement with these claims, though in experiments with apple residues quite as good results were obtained by boiling for 40 minutes at a pH of about 3.5 (as recommended by Rooker). High acidities are likely to bring about some demethylation of the pectin. A little demethylation may be an advantage in improving jelly grade, but it needs to be carefully controlled. Demethylation tends to lower the optimum pH of gelation[7], and for most jams and jellies it is desirable not to let this fall below pH 3.0.

The procedure described by Wilson involves extracting leached citrus residues 2 to 3 times with 1 per cent. sulphurous acid at 180°-190°F. After filtration, the sulphurous acid is removed.

In the investigations at this laboratory on citrus residues, the pH of extraction has been varied from 2.0 to 4.3. Within this range, jelly ing power tends to increase with increasing acidity. However, below pH 3.0 the residues become much more gelatinous after heating, and are extremely difficult to press. Hence the writer prefers boiling for 45 minutes with 0.015-0.02 normal hydrochloric or sulphuric acid or 0.025 molar citric acid, which gives an extract of pH 3.0 - 3.5. This extract can be pressed easily in a suitable press, leaving a fairly dry residual cake.

Filtration.

Rooker recommends decolourising pectin extracts with activated carbon and then adding a filter aid before filtering. Bender, Douglas, and

(6) Industrial and Engineering Chemistry 17:1065 (1925).
University of Delaware Agricultural Experiment Station, Bull.168 (1931).
Food Investigation Board Special Report 48 (1939).
(7) University of Delaware Agricultural Experiment Station, Bull.234 (1941).

and Cuthbert have been granted a patent (U.S. 1,787,467 (1931)) for percolating the extract through a filter bed of coarse open texture containing activated carbon. It is doubtful if the carbon treatment is as essential for citrus as it is for apple pectin, as most of the colour in the citrus extract is insoluble and is removed by filtration.

Wilson mentioned filtration through paper pulp. The writer has not found this very effective, and has mainly used a filter aid (1-2 per cent. of "Dicalite Speedflow") for this purpose.

Some authors prefer the more acid extracts on account of ease of filtration, as viscosity tends to decrease at the lower pH. However, the extracts prepared by the writer at pH 2.0 had so much fine suspended material that they were extremely difficult to filter.

Extracts containing starch can be treated with a diastatic enzyme preparation before filtration. Such preparations are usually contaminated with pectin-destroying enzymes, and, to minimize their effect, Baker[8] suggests hydrolising the starch at pH 3.2-3.6 at 850°F. until the starch-iodine colour changes to brown, and then heating to 180°F. to inactivate the enzyme. Alternatively, the residues can be heated at 180°F. for 5 minutes to gelatinize the starch, and then treated with the enzyme before leaching. Ripa patented a method (Ger. 547,804 (1929)) for absorbing the starch on porous vegetable material such as ground nut shells and then filtering.

However, these procedures have been developed for purifying apple pectin. It is doubtful whether they are necessary for citrus pectin.

Preparation of Powdered Pectin. Powdered pectin may be produced by spray-drying the filtered extract, but this process retains all the impurities, such as residual colour, sugars, glucosides, and other soluble substances which remain after leaching, and the acid used for extraction.

High-grade pectin, which is practically devoid of colour and flavour, can be most readily obtained by concentrating the extract in vacuo to a thick syrup, and then adding alcohol to a concentration of 60 per cent. The pectin is precipitated in a fibrous mass, which can be readily filtered, washed, dried, and powdered. The alcohol can be subsequently recovered.

An alternative procedure, which avoids concentrating, is to precipitate the pectin with aluminium. The original method, based on the patent of Jameson and Taylor (U.S. 1,497,884, (1924)), involves adding calculated amounts of aluminium sulphate and ammonia to form colloidal aluminium hydroxide, which precipitates the pectin. The precipitate is separated, washed with water, dried and ground. The aluminium is then removed as chloride by washing with 85 per cent. alcohol containing 5 per cent. of hydrochloric acid, and can be used again.

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(8) University of Delaware Agricultural Experiment Station, Bull. 204 (1936).

Baker and Goodwin have shown that aluminium chloride can be used as a precipitating agent without formation of the colloidal hydroxide. If the pectin extract is adjusted to pH 4.5 with ammonia, and a concentrated solution of aluminium chloride of pH3.5 is added, a flocculent precipitate of pectin is obtained. The writer has prepared solid pectin by means of aluminium chloride without difficulty, but has not so far been able to avoid serious loss of jelly grade in the process.

Solid pectin is usually sold in standard grades. 100-grade pectin is of such a jellying power that it can form a good jelly with 100 parts of sugar. As prepared, the solid pectin is standardized to an exact grade by diluting with glucose or other sugar.

Powdered pectin often gives difficulty in re-dispersing before use, and is particularly liable to clumping. The following patents propose a variety of treatments to facilitate dispersion.

Baier and Harris - U.S. 1,945,963. (1934). Acetone - dicarboxylic acid is added as dispersing agent.

Cowgill - U.S. 1,973,613. (1934). The pectin is dried in a film with added glycerine, and the glycerine then removed by a solvent.

Baier - U.S. 2,147,960. (1939). The pectin is mixed with a glucose hydrate, and passed between hot rolls to form coarse flakes.

Wilson - U.S. 2,159,194. (1939). The pectin is embedded in liquefied glucose hydrate, which is then crystallised.

Olsen - U.S. 2,261,858. (1941). The pectin is dispersed by metal ions of aluminium, copper, iron, nickel, or chromium in low concentration.

Testing of Powdered Pectin and Pectin Extracts. There are a number of chemical methods for determining pectin. The method of alcoholic precipitation is extremely crude, and includes many other substances besides pectin. More accurate are the calcium pectate method of Carre and Haynes(9) and the volumetric method of Hinton, which can be used after an initial alcohol or acetone precipitation.

However, a chemical determination is practically useless for evaluating extracts or powdered pectin, as it fails to detect large variations in jelly grade. The viscosity of extracts is a somewhat better guide, but even this is not related exactly to jellying power. The only sound test is to prepare a jelly under standard conditions, and to determine its strength with a suitable instrument. Standard jellies may be prepared with imported 100-grade pectin, and compared with those of local manufacture. If a suitable instrument is not available, pressure with the finger may be used for comparison, and experienced testers attain a high degree of skill in this method.

Rooker and others give methods for preparing jellies which involve adjusting the pectin solution to a standard pH and boiling it with a

(9) Biochemical Journal (16): 60 (1922).

definite proportion of sugar down to a constant weight. It is then poured into jelly glasses for setting. Hinton recommends preparing jellies at pH 2.0 mixing with glycerine to give a concentration of 65 per cent. The writer prefers to avoid the somewhat tedious and uncertain methods which involve boiling down, and prepares the jellies at pH 3.2, using a citrate-phosphate buffer. These conditions approximate more to those in commercial jam and jelly making. A pH of 2.0 is well below the usual range of commercial products, and pectins which have been rather severely demethylated during preparation may have good jellying power at pH 2.0, but inferior in the range 3.0-3.5.

The jellies are prepared in 50 ml. beakers by mixing 10 grams of the pectin extract with 20 grams of 75 per cent. invert sugar syrup buffered to pH 3.2. This is well mixed and brought to the boil and 20 grams of cane sugar added. When this is dissolved, the mixture is allowed to set. It is preferably left overnight before testing. The final jelly contains 70 per cent. of sugar, of which about one-third is inverted. This method is applicable only to fairly concentrated extracts, and boiling down would have to be adopted for dilute extracts.

The invert syrup is prepared by dissolving 300 grams of cane sugar and 15.8 grams of crystallised citric acid in 100 ml. of boiling water. Heat until the sugar is dissolved, and continue heating in a boiling water bath for 30 minutes, when most of the sugar should be inverted. Then add 17.7 grams of dibasic sodium phosphate $Na_2HPO_4 12H_2O$.

There are various possible methods of determining jelly strength. The instrument used by the writer (which is due to Kizevetter[10]) consists of a vertical spindle, which moves freely in a sleeve mounted on a suitable frame, and is fitted with a plunger of spherical surface (1.6 cm. diameter by 0.5 cm. depth) at the lower end. The plunger rests on the jelly, and shot is slowly poured into a cylinder at the top of the spindle until the weight forces the plunger into the jelly. The shot is then tipped out and weighed. This method is only applicable to strong jellies.

The Baker[11] jelly tester, which has been widely used, is made from the plunger and barrel of a hypodermic syringe, and develops a gradually increasing pressure by running water into a closed vessel. The pressure required to break the jelly is read on a manometer.

Summarized Suggestions for Handling Residues.

Two alternative procedures may be suggested for the treatment of citrus residues at central plants in the main producing centres. The disintegrated residues may be dried without further treatment, in suitable driers which prevent caking, and the product used as stock feed or for pectin production.

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(10) Bulletin of the Pacific Scientific Institute of Fisheries and Oceanography 13, (1937) (in Russian).
(11) Industrial and Engineerinf Chemistry 18: 89 (1926).

If difficulty is experienced in drying untreated residues, the liming procedure may be applied. Limed pomace would not be suitable for pectin manufacture, but this difficulty may be overcome by introducing batches of leached pomace when required. Pomace leached by the method described is superior both to untreated and limed material as a source of pectin, as the enzymes are inactivated and loss of jelly grade is minimized.

With regard to pectin production, there should be a ready market for concentrated pectin extracts in the main producing centres and it may be possible to proceed with the manufacture of powdered citrus pectin by one of the precipitation methods.

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VITAMINS.

The term vitamin is widely used but difficult to define. It was coined some 30 years ago by Funk because of the experimental demonstration that animals fed on a diet adequately supplying all the obvious necessary types of nutrient - protein, carbohydrate, fat, minerals - died quite quickly if the various substances were purified, but could be kept healthy by the addition of small amounts of some crude foodstuffs. Funk postulates that the latter must contain unknown substances necessary for health and gave to these the general name of vitamins. Later, varying symptoms exhibited by experimental animals on different deficient diets showed there must be many different vitamins and they were distinguished by letters as Vitamin A. At first, the distribution of a given vitamin could only be determined by measuring the amounts of different foodstuffs which had to be added to maintain health on a diet known to be deficient by itself. Working in this way, rich sources of several vitamins were found, concentrates made, chemical structures of compounds with vitamin activity determined, and chemical methods of estimation worked out. This changed the status of these vitamins, from mysterious substances known only by the effects produced in their absence, to organic compounds of known structure. There is a tendency in technical writings to refer to vitamins of known structure by their chemical names and to use "vitamins", a term really a confession of ignorance, for the factors which have not yet been identified chemically. The word should thus eventually become obsolete, but at present the rate of discovery of new factors essential for rats (which are easier to experiment with than man) is probably more rapid than the determination of structure of known vitamins.

From the chemical point of view, the vitamins are a very mixed collection of substances, some of fairly simple structure, some very complex. Some compounds usually listed as vitamins, e.g. nicotinic acid, have never been given a letter, as their chemical structure was known before their dietary need was established, and others have been rather arbitrarily excluded because they were recognised as essential before the term vitamin was coined. The only common property of the vitamins is that they have to be supplied regularly to the animal body, which needs them but cannot make them for itself. In some cases compounds chemically related to the

vitamin will do, the body making the comparatively slight change necessary. This formation of vitamins from chemically related precursors is important chiefly for vitamins A and D.

The different types of nutrient needed in a satisfactory diet serve in the main different purposes in the body, though their functions overlap to some extent. Fat and carbohydrate provide fuel and power for bodily activities. Protein gives building material for growth and for the continual replacement of worn-out muscle tissues which goes on even in adults. Some minerals are required in comparatively large amounts to form bone; others taking part in special processes in the tissues are needed in smaller quantities. The substances listed so far either act as fuel for the body or are incorporated in its tissues. The vitamins do not seem to act in either of these ways; the very small amounts in which they are needed would be insignificant as fuel and they are not found built into permanent body structures. Where their function is known they regulate certain of the chemical processes by which the body maintains its vital activities.

There has been a tendency in recent years to write of vitamins as if they were all that mattered in a diet, and much advertising has stressed this view. The rather natural reaction to this has been to produce a belief in some quarters that insistence on an adequate vitamin intake is a scientific fad or advertising "ballyhoo". Vitamins are necessary but so are also other types of nutrient, and an unbalanced emphasis on vitamins alone is undesirable. For those concerned with food processing, however, an article on vitamins alone may be justified, as they are much more likely than the other good essentials to be destroyed or removed in processing. As canned and dried foods are so largely destined at the present time for Service use, most attention will be given to those vitamins likely to be short in Service rations.

Several of the vitamins most likely to be short in the human diet are available on a large and growing scale as synthetic products. Their use medicinally or to fortify foods is a separate subject and will not be further considered here.

Vitamin A.

This occurs as such in animal products only, notably milk, eggs, and some fish oils. The body can also make it from carotene, a yellow pigment found in all green leaves and mainly responsible for the colour of carrots and many other yellow fruits and vegetables. Little carotene is lost during canning or dehydration processes, but losses during storage at high temperatures can be serious. Severe deficiency of vitamin A produces marked symptoms which are rarely seen in this country. Slight deficiency can be of military importance as it causes some types of "night-blindness". No amount of vitamin A will allow one to see in complete darkness, but a deficiency will cause loss or impairment of vision at low-light intensities.

Vitamin B_1 (Thiamin).

Severe deficiency of this vitamin causes the often fatal disease beri-beri, at one time prevalent among seamen and widespread in tropical countries. Over 50 years ago Tokoki, by a simple change in diet, reduced its incidence from 30 per cent. of sea-going personnel in the Japanese Navy to under 0.5 per cent. His very successful work was based on a wrong theory, for he attributed the disease to a shortage of protein, but the high-protein foods added to the rations happened also to increase the supply of thiamin. An account of this work was published in English but largely neglected, and 20 years later beri-beri was still regarded as a disease due to infection till work in Netherlands East Indies, Philippines, and Malaya demonstrated that it was indeed due to some deficiency in the diet and could be cured by extract of rice polishings. Many years of intensive chemical work all over the world led to the isolation of pure thiamin, elucidation of its somewhat complex chemical structure, its synthesis, and finally to its production on a factory scale. Slight thiamin deficiency causes rather vague but undesirable symptoms - depression, irritability, easy fatigue. The intake required varies with amount of carbohydrate taken, thiamin being needed by the body to utilise carbohydrate. Active men thus need more than sedentary. In normal American diets potatoes are quoted as the chief source, here probably meat and bread. All except a few highly refined foods contain thiamin but in amounts so small that in ordinary circumstances it is probably the most likely vitamin to be under supplied. Unprocessed cereals are good sources, as also are pork and peanuts, but commercial cereal products, especially precooked breakfast foods and polished rice, may have lost most of their thiamin. Thiamin is water-soluble and thus liable to leaching during processing, but is fairly stable to heat except in alkaline conditions. It is destroyed by sulphite which should therefore not be used in processing potatoes unless its use is essential on other grounds.

Vitamin B_2 (Riboflavin).

This is widespread in fruit and vegetables and also found in milk. It is fairly stable to heat during processing but is destroyed by light. The effects of deficiency in man are not well known.

Vitamin C. (Ascorbic Acid).

Absence causes scurvy, while slight deficiency causes slower healing of wounds and perhaps lowered resistance to other diseases. It is the most likely vitamin to be under-supplied in Army diets, as it occurs in fruit and vegetables, which are often impossible to supply fresh, and it is difficult to retain the vitamin completely in processed and stored foods. It is water-soluble and very unstable in the presence of oxygen in many vegetables, especially if they have been shredded or crushed. The main sources in Australia are citrus, tomato, pineapple, blackcurrant, paw-paw among fruits; and cabbage, cauliflower, parsnip, potato, and turnip of the vegetables. A number of extraordinarily rich sources are known, but difficult to use on a large scale because of limited supplies, e.g., rose hips,

green walnuts, and sweet peppers. The preservation of vitamin C in canned and dried vegetables is particularly important, as they will be its main source in forward areas where fruit is not available. It can be lost by destruction in processing or by washing out during blanching. In canned vegetables the juice should always be used if possible, as it will contain a fair part of the total vitamin C which, nutritionally, is the chief reason for having processed vegetables at all, except as flavourings and, in some cases, suppliers of carotene. No animal products contain much vitamin C but there is a little in milk and fresh meat.

Vitamin D.

The main industrial importance of this vitamin is the production of concentrates from fish liver oils. It is probably only important in the diet during infancy, pregnancy, and lactation. It is found only in animal products, notably eggs and milk, but the body may be able to make it from certain vegetable precursors.

Many other vitamins known to be essential for rats are not discussed here owing to lack of information on their importance in human nutrition.

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THE NUTRITIVE VALUE OF TROPICAL FRUITS IN AUSTRALIA.

The nutritive value of fruits is due mainly to their content of sugar, starch, and vitamins, and to a lesser extent to cellulose, fruit acids and pectin substances. The protein content of fruits is in general very low, and the fat content is also low, except in the flesh of the olive and the avocado. While sugar and starches provide energy for the body, the value of cellulose and pectic substances is due chiefly to their stimulation of peristaltic activity. Many fruits are important sources of essential vitamins particularly ascorbic acid (vitamin C), and from this aspect tropical fruits compare very favourably with those grown in temperate climates.

The composition, from the nutritive point of view, of the principal tropical fruits grown in Australia is shown in the accompanying table together with data for the apple, apricot, and orange as representative of temperate climate fruits. While the considerable variability in composition within any one class of fruit is not indicated, the figures quoted are considered to be typical for the particular fruits; in most cases they represent an average of many samples. The figures have been obtained mostly from the results of overseas investigations, but results from this laboratory, principally in regard to vitamin C, have been used to check, and if necessary correct, overseas data.

Avocado.

The flesh has a smooth buttery texture due to a high oil content which increases as the fruit matures and varies considerably with variety

nevertheless, when ripe, this fruit is easily digested. The variety Fuerte is richest in oil with 26 per cent., whereas some West Indian types have an oil content of only 8 per cent. Unlike other fruits, the avocado has a low sugar content which, again unlike other fruits, decreases as the fruit matures from 2 to 3 per cent. down to less than 0.5 per cent., and it also has a higher content of protein than other fruits. Because of the high oil content, the avocado has a high energy or fuel value, the Fuerte variety being approximately equal to bread in energy value. It is comparatively rich in minerals and is higher in copper content than most other fruits. There is an appreciable carotene content and a vitamin C content of 25 milligrams per 100 gm. which is about the same as that of the tomato. In some parts of Central America when meat and fish are scarce the avocado becomes the main article of diet.

Banana.

This well known fruit has a high food value and, being particularly rich in sugar when ripe, can almost be classed as an energy food. It contains more phosphorus than most fruits and has useful amounts of carotene and vitamin C. When ripe, as indicated by a yellow skin flecked with brown spots and a softening flesh, all the starch has been changed to sugar and the banana is easily digested. When pulped or puréed, it is a valuable food for infants. Bananas are as important a food in the tropics as cereals are in temperate zones.

Banana Passion Fruit.

This fruit grows well along the N.S.W. coast but is not very well known. It has a very attractive flavour and is rich in vitamin C.

Custard Apply.

It is low in vitamin C but still contains twice as much of this essential vitamin as apples or apricots.

Guava.

It has recently been found that some varieties of this hitherto neglected fruit are extraordinarily rich in vitamin C, with an ascorbic acid content of 100 to 500 milligrams per 100 gm., depending on the maturity of the fruit. The vitamin C content is greatest when the fruit is firm ripe and there is more of this essential vitamin in the skin than in the flesh and more in the outer flesh than in the inner flesh, thus types with a greater proportion of outer flesh have more vitamin C. Pink fleshed types have usually most vitamin C and white fleshed types least. A jelly with 250 milligrams of vitamin C per 100 gm. can be prepared from the skins, and the loss of this vitamin in stewing or in canning is unusually low. A vitamin C concentrate in the form of canned outer flesh and skin of guavas prepared in South Africa was used by Allied troops in North Africa. A guava powder with 2000 to 3000 milligrans of vitamin C per 100 gm., and a pleasant aromatic odour and practically no taste can be prepared.

Jujube.

This is a smallish fruit with a comparatively dry flesh which compares with the date in food value owing to its high content of available carbohydrate. It has a distinct and pleasing flavour but the raw fruit is not palatable. It is used for pickles, preserves, as stewed fruit or as a confection. When dried, it can be used in puddings, cakes, or bread. There are no available data on its vitamin content.

Mango.

This fruit is of high nutritive value, being very rich in carotene and vitamin C and having a fairly high sugar content, but it is lower in minerals than other tropical fruits. The pulp has a peach-like texture and is very juicy and aromatic. The mango loses aroma and colour very rapidly after cutting, therefore it must be eaten immediately. It can be cooked and used also for pies or marmalade.

Passion Fruit.

The pulp of this fruit is rich in sugar and particularly high in acid and contains considerable vitamin C. It has been found at Homebush that the skins are very rich in vitamin C (110 milligrans per 100 gm.) and an open pan concentrate containing 155 milligrams per 100 gm. was prepared from the skins, however, it was viscous and very bitter.

Pawpaw.

The pawpaw is a fruit of very high nutritive value, it is very rich in carotene and vitamin C, being as rich as apricots in the former and richer than oranges in the latter. In addition, the milky juice from the leaves or green fruit and, to a lesser extent, the juice of the ripe fruit contains papain, an enzyme very active in the digestion of protein. Many people consider pawpaws to be a valuable aid to digestion. Canned pawpaw has been found to have a vitamin C content of about 30 milligrams per 100 gm. and the usual pack of tropical fruit salad, largely due to its content of pawpaw, contains about 20 milligrams per 100 gm. of vitamin C.

Pineapple.

When ripe, the smooth surface of the skin is yellowish in colour and the leaves at the tip pull out easily. The common Smooth Leaf Variety contains about 10 to 15 per cent. of sugar and is fairly good source of carotene and vitamins B and C but is not as rich in carotene or Vitamin C as most other tropical fruits. The juice contains a protein-digesting enzyme, bromelin. The common variety in Australia is the Smooth Leaf Cayenne which contains about 15 milligrams of vitamin C per 100 gm. The Rough Leaf and Ripley Queen varieties are much richer in vitamin C, the former containing about 47 milligrams and the latter about 34 milligrams per 100 gm.

Persimmon.

The Japanese persimmon is a fruit whose value is not sufficiently appreciated. It is very palatable when fully ripe, has a relatively high energy value, being rich in sugar, is very rich in carotene and rich in vitamin C, and of the drupe fruits it is next to the date in nutritive value.

Rozella or Roselle.

It is a Hibiscus species which is commonly grown in Queensland and is remarkable in that so many parts of the plant are usable. The flowers, seed pods, and young stems can all be used for jams and jellies and the flowers also for pies and tarts.

Breadfruit.

Although not grown in this country, no mention of tropical fruits as foods is complete without reference to the breadfruit which is as important in tropical countries where it grows as cereals are to us. The unripe fruit is boiled or roasted and used like bread and can be sliced and dried. It has a very high energy value and is somewhat like sweet potato in texture and flavour.

In this country, where they can readily be grown, much greater use should be made of the high nutritive value of tropical fruits, particularly guavas, mangoes, and pawpaws. These fruits are far more valuable nutritionally than apples, pears, peaches, plums, grapes and cherries which form so large a part of the fruit diet of most people in southern Australia.

Fruit	Moisture %	Available Carbohydrate %	Acid %	Protein %	Fat %	Fuel or Energy Value Calories per 100 gm.	Ash	Ca	P	Fe	Vitamin Content per 100 gm.				
							mg./100 gm.				A. iu	B_1 mg.	B_2(G) mg.	C. mg.	P.P. mg.
Apple	84	13	0.5	0.3	0.4	60	0.3	4	7	0.3	50	0.012	0.006	4	0.5
Apricot	86	12	1.2	0.8	0.1	54	0.6	14	25	1.0	5000	0.025	0.017	3	0.6
Avocado variety Fuerte	65	3	-	1.7	26.0	265	1.3	45	44	0.3	350	0.06	0.02	25	-
Banana	75	20	0.4	1.2	0.2	100	0.8	9	30	0.6	250	0.06	0.015	10	0.6
Banana Passion Fruit	—	—	-	-	-	-	-	—	—	-	-	0.005	—	44	-
Custard Apple	—	—	-	-	-	-	-	—	—	-	-	—	—	3	-
Feijoa	84	10	0.3	0.9	0.2	60	0.5	—	—	-	-	—	—	-	-
Guava	80	11	0.6	1.0	0.6	65	0.7	15	16	0.3	200	0.03	—	100 to 500	-
Jujube	64	32	0.4	1.2	0.3	140	0.9	—	—	-	-	—	—	-	-
Jack Fruit	—	—	—	-	-	-	-	—	—	-	500	0.06	—	-	-
Mango	81	16	0.5	0.7	0.2	70	0.5	5	16	0.3	5000	0.06	0.05	50	-
Orange	87	11	0.7	0.9	0.2	50	0.5	40	25	0.3	200	0.07	0.06	60	0.2
Passionfruit	81	17.5	2.2	1.2	0.0	75	0.5	—	—	-	—	—	—	25	-
Paw-paw	87	10	0.2	0.6	0.1	45	0.6	20	13	0.3	5000	0.02	0.04	70	-
Pineapple	84	13	1.0	0.4	0.2	55	0.4	18	25	0.4	100	0.07	0.06	15	-
Persimmon (Japanese)	78	19	0.2	0.8	0.4	90	0.6	16	15	0.05	2000	0	—	25	-

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ASCORBIC ACID (VITAMIN C) IN "MARMALADE MIXTURE" JAMS.

Marmalade jams prepared from whole citrus fruits such as oranges, lemons or grape fruit are potential sources of appreciable amounts of vitamin C depending upon the level of this substance in the particular fruit used, the proportion of fruit present in the final product, and the losses of vitamin during preparation of the jam. "Marmalade Mixture" is a jam prepared from citrus residues left over after the juice has been extracted from the fruit.

In order to produce a product of desirable flavour, appearance, and texture the proportion of these residues which can safely be included is approximately 20 per cent. of the final weight of the jam. Investigations have recently been commenced in this laboratory to determine the means whereby the vitamin C content of these marmalade mixtures can be maintained at a satisfactory high level.

Vitamin C Content of Oranges.

From the limited number of observations so far made it is not possible to quote a wide range of vitamin C concentrations for different portions of the same fruits, but the following results were obtained from a mixed sample of Navel oranges:-

Juice	57	mg. per 100 gm.
Rag (pith)	59	
Inner rind (albedo)	44	
Outer rind (flavedo)	158	
Outer "rumblings"	182	

Since the albedo is very much lower in vitamin C content than the flavedo, it would be expected that thick rinds, which have a higher proportion of albedo, would be appreciably lower in vitamin C than thin rinds. The average vitamin C content of orange residues is estimated at about 100 mg. per 100 gm., and their contribution to the final product would be approximately 20 mg. per 100 gm.

Losses of Vitamin C during Preparation of Jam.

An examination of several samples of commercially prepared marmalade mixtures showed vitamin C contents ranging between 2 and 8 mg. per 100 gm. with an average of 6 mg. per 100 gm. Such losses of vitamin C may be due to delay in commencing the preparation of residues and to the effects of the prolonged boiling which is considered necessary to soften them before the addition of sugar.

Losses from Residues on Standing.

The following changes occurred on standing at room temperatures:-

Delay (hours)	Vitamin C(mg./100 gm.)	
	Shredded Rind	Rag.
0	130	58
1	110	56
3	68	45
6	60	47

Losses from the shredded rind were much more rapid than from the rag.

Losses during Preliminary Boiling.

During the preliminary boiling in water for a period of 60 minutes the vitamin C content of shredded rind was reduced from 120 to 70 mg. per 100 gm. and of rag from 70 to 40 mg. per 100 gm. A loss of approximately half of the initial vitamin is therefore to be expected as the result of this prolonged boiling.

Increasing the Vitamin C Content of the Product.

If the residues are used without delay, which is desirable in the interests of quality, it should be possible to produce a jam containing about 10 mg. of vitamin C per 100 gm. An increase in the proportion of peel should contribute additional vitamin C, but the product would probably be somewhat bitter and generally less attractive. An alternative method would be to enrich the product with an extract of the outer peel. Before extracting the juice, many oranges are now "rumbled" to remove the oil and prevent it contaminating the juice. These "rumblings" are initially of high vitamin C content but when kept in cold water approximately half of the vitamin was lost during a period of 90 minutes. When, however, they were boiled immediately with water for one minute (to destroy the ascorbic acid oxidase), subsequent loss per hour was reduced to about 1 per cent. of the original value.

Possibly the "rumblings" could be screened off, extracted with the minimum amount of boiling water, and the strained extract added to the jam mixture during boiling. Further consideration is being given by this laboratory to this method of increasing the vitamin C content of these jams.

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WATER USED IN COOLING CANS AFTER PRESSURE COOKING.

During the operation of cooling cans after heat processing, a considerable difference of pressure is set-up between the outside and the inside of the can. There is considerable evidence to show that, even in well-made and properly sealed cans, the pressure difference is sufficiently great and the can sealing compound, while hot, sufficiently plastic to enable some small leakage of water to occur into the can contents.

It is clear, therefore, that if the cooling water is seriously contaminated with bacteria and bacterial spores, there will be a grave risk of admitting spoilage organisms to the foodstuff in the cans. While many bacteria thus entering the cans may be destroyed by the heat of the can contents, it is most unlikely that heat-resistant bacterial spores will be killed. If conditions during storage of the cans are favourable to bacterial growth, serious spoilage of the can contents may, therefore, result from the use of contaminated cooling water.

It is difficult to prove directly that contaminated cooling water can be an important cause of spoilage. However, the United States National Canners' Association has obtained good circumstantial evidence during studies of spoilage in canned peas. In certain canneries bacterial spoilage as high as 80 cans per thousand was being obtained even when the heat processes were adequate and the cans were well-made and sealed. Examination of the cooling waters used in the retorts showed them to be heavily contaminated with bacteria and bacterial spores. When the cooling waters were sterilized by chlorination treatments, the extent of spoilage of the canned peas during

peas during storage was reduced to about one can per thousand without any other change being made in the methods of processing.

In the light of these experiences, canners would be well advised to have regular bacteriological examinations made of the cooling water in order to determine the extent of the contamination, which should be less than 100 organisms per 1 ml.

If the bacterial load regularly exceeds this level, then steps should be taken to instal some form of water sterilization, of which, treatment with chlorine is perhaps the most convenient and effective. Manufacturers of chlorine would readily supply details of equipment and methods used in this sterilization treatment and also probable costs.

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DISCOLOURATION OF LYE-PEELED CARROTS.

A discolouration of lye peeled carrots has been reported from a number of canneries. The affected carrots usually leave the lye bath without any visible blemishes, but develop irregular discoloured patches within a few minutes. The discolouration varies from dark green to brown.

This disorder has occurred very spasmodically. Sometimes it is only slight, but in some lines at least 20 per cent. of discoloured carrots have been found after lye peeling, and have been subsequently rejected.

A bag of carrots from a line which had been giving serious discolouration at one cannery was forwarded to this laboratory for investigation. In this factory the carrots are customarily given three minutes in boiling 3-5 per cent. lye.

Preliminary tests indicated that the disorder was closely associated with the lye peeling, as only a slight discolouration occurred after mechanical peeling. Boiling water was without effect.

Contamination with iron is unlikely as the iron content both of sound and discoloured carrots is extremely low (8-9 parts per million).

Mechanism of Discolouration.

After peeling, the discoloured areas appeared to retain a slight amount of alkali. In one sample the discoloured areas had a pH of 6.8, while that of sound tissue was 6.4.

To test whether the discolouration was due to reaction of the alkali with some constituent of the tissue, the pressed juice of raw carrots, of pH 6.5, was made more alkaline up to pH 8.0. The effect on the colour was negligible. After boiling for three minutes, the suspended material coagulated and darkening occurred subsequently in the presence of air. It is

suggested that similar changes occur in the tissue exposed to boiling lye, the alkali facilitating oxygen penetration by breaking down the cell walls in susceptible tissue.

On standing, the discoloured tissue gradually softens and a large proportion can be rubbed off. The success of lye peeling probably depends on the outer tissues being much more susceptible than the cortex to disintegration. Apparently, in some old carrots, parts of the cortical tissue are also susceptible, and discolouration represents the initial stages of complete breakdown. Microscopic examination showed that the discolouration was located in the cell walls.

Methods of Reducing Loss.

It is reported that only old carrots are susceptible, and young carrots give no trouble. This factor, however, is not capable of control at present.

Abrasion peeling should largely avoid the trouble, but not all factories are so equipped, and the disorder may not be noticeable for a considerable period.

Discolouration from lye peeling was not reduced by subsequent boiling in water.

If the discolouration is regarded as incipient breakdown, prolonged lye treatment may remove the tissue completely. This will result in a better appearance, if the discolouration does not extend to more deep-seated tissues. In a preliminary test, four minutes immersion in 4 per cent. boiling lye gave much less discolouration than $1\frac{1}{2}$ minutes in the same solution.

Subsequently, several pounds of carrots were peeled by boiling for three minutes in 4 per cent. lye. A large proportion were discoloured, and were picked out. Half of these were given a second lye treatment, from which they emerged reduced in bulk but practically free from discolouration. The two batches of carrots were then canned. On examination of the canned products the discoloured carrots were still affected, and had an "off" flavour; while those that had been through the lye bath twice were normal in appearance and flavour. The pH (5.2) was practically the same in all the samples of processed carrots.

It is suggested that, whenever a serious proportion of carrots are discoloured, they should be picked out and put through the lye bath again. This practice should result in the preparation of an acceptable and wholesome pack.

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BACTERIAL CONTAMINATION OF CANNED VEGETABLES BY BLANCHING EQUIPMENT.

It is not always realized that the equipment used for the blanching of vegetables prior to placing in the cans may become a potent source of

bacterial contamination, and that the reduction of this contamination requires the adoption of special measures.

The raw vegetables bring with them a mixed bacterial flora including many heat-resistant spores. While the bulk of the less resistant organisms may be killed at the temperature of the blanching operation (208° to 212°F.), considerable numbers of heat-resistant spores will survive and be transferred from the vegetables to the blanching equipment, where the spores will readily lodge and proliferate in crevices and corrosion scales, the conditions with regard to temperature and moisture often being ideal for their growth. Amongst the spores thus accumulating in the blanching equipment will be many types capable of causing spoilage in the canned vegetables during storage. The contamination of the equipment may become so great that the spore load on the vegetables after blanching may be very much greater than before they entered the blancher.

There are two ways in which this acquired contamination may have serious consequences.

(1) The heat process in the retort is designed to kill a certain number of heat-resistant spores which may cause spoilage at ordinary atmospheric temperatures. The total spore load acquired by the vegetables from a heavily contaminated blancher may be so great, however, that the heat treatment customarily sufficing will be insufficient to effect a complete "kill", and spoilage may result during subsequent storage of the cans.

(2) The blanching equipment is very prone to harbour living spores of certain extremely heat-resistant thermophilic organisms which may cause spoilage of the canned vegetables during storage at elevated temperatures such as are experienced in tropical areas.

While it is difficult to eliminate bacterial contamination from this source, much can be done to keep such contamination to a minimum. The first, and perhaps most important, precaution is thoroughly to wash the vegetables with a clean, cold water spray after they emerge from the blancher. This operation should not be regarded as merely serving the purpose of cooling, but the water spray should have sufficient pressure and the layer of vegetable should be sufficiently thin to enable the water to cleanse the surface of all the pieces and thus wash off the bulk of the spores acquired from the blanching equipment. In another article in this issue of the Quarterly attention is drawn to the desirability of having a supply of water comparatively free from bacterial contamination for use in cooling the cans in the retorts. It is obvious that the water used for washing the vegetables after blanching should also have a low bacterial count.

The second precaution helping to reduce the contamination by the blancher is thorough, daily cleansing of all parts of the equipment with hot water containing a suitable detergent. Particular attention should be given to good cleansing of all parts of the equipment normally coming into contact with the vegetable. In the case of steam blanchers, therefore, thorough scrubbing of the conveyor belt is essential, while in water blanchers, this operation must be carried out on all inner surfaces of the main vat, the rotating cylinders, or the baskets.

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