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Aspects of Senescence in Plant Materials*

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SIGNALS OF SENESCENCE IN ISOLATED FLOWERS AND LEAVES

THE aging phenomena at the cellular and subcellular levels are of general biological interest. If senescence is viewed as a continuous change in cellular organization and function, it seems pertinent to study metabolic patterns in early phases of development as well as in later stages of maturation.

Information obtained from plant materials which are particularly suitable for experimentation may serve as background for studies with organisms in general.

* This article is based on the opening lecture given by the author, as a guest speaker, to a symposium on "Food Preservation and the Organization of Plant and Animal Tissues" at the Food Science Conference held in September 1961 at North Ryde, N.S.W.

Transformations through the stages of cell division, expansion, and senescence are telescoped into a relatively short period in flowers. In rose petals the upsurge in metabolic activity was found by Siegelman, Chow, and Biale (1958) to accompany development and maturation. The respiratory peak was reached when the flower was fully opened. The stimulating effect of low concentrations of dinitrophenol (DNP), which was most pronounced in the early stage of petal unfolding, waned with the advance of maturation and senescence. The results from inhibitor studies suggested that during the stage of full petal expansion the terminal oxidase was principally a metal enzyme. Similarly, in the perianth segments of *Magnolia grandiflora* a rapid rise in oxygen uptake was observed (Griesel and Biale 1958) after bud opening. The peak in respiration corresponded with the stage of full bloom. Shortly after pollen

shedding the stamens began to drop and the perianth segments started browning, indicating onset of senescence. Respiratory activity dropped markedly during the breakdown stage. In the aroids the peak in respiration of the spadix and the appendix occurred (James and Beevers 1950; van Herk 1937) when these structures reached their maximum size.

The climacteric has been considered as the "beginning of the end" in the life of fruit. Marked decline in resistance to fungal and bacterial invasions is a feature of the post-climacteric stage. Associated with the climacteric are the colour transitions and the chemical changes that characterize the ripening process either on or off the tree. Solubili-

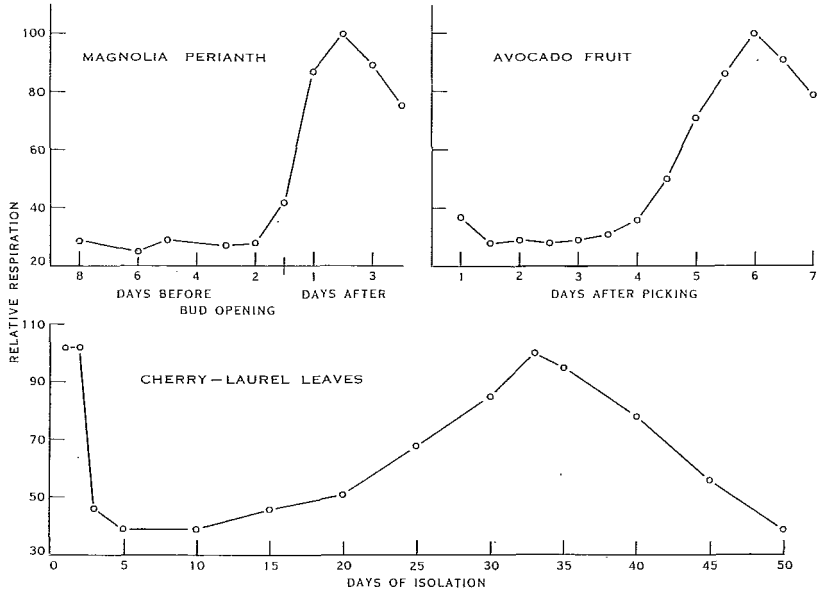

Fig. 1.—The respiratory upsurge in relation to senescence. Data for these curves were obtained as follows; for magnolia from Griesel and Biale (1958), *for avocado from Biale* (1960a), *and for cherry-laurel from James* (1953).

In contrast to floral structures, fruits do not exhibit a respiratory upsurge during the stage of rapid cell enlargement. In most species in which the rise, known as the "climacteric", has been observed it was recorded only at the end of the stage of cell maturation. The climacteric delineates the phases of cell division, expansion, and maturation from breakdown, and it is therefore considered (Biale 1960*a*, 1960*b*) as the signal of senescence in fruits exhibiting the climacteric. Normally, following commercial harvest, the respiratory activity declines to a pre-climacteric minimum which is characteristic of a particular species under a prescribed set of external conditions. The magnitude at the peak is also species specific.

zation of pectic substances with or without the splitting of the polygalacturonide chain is perhaps one of the most unique chemical reactions linked closely to senescence in fruits. Several investigators considered enzymatic activities such as polygalacturonase and malic decarboxylase as signals of the climacteric. Shifts in the metabolic pathways were also implicated. However, in some of these cases the physico-chemical alterations in the tissue and the appearance or disappearance of inhibitors in the course of homogenization might be responsible for the observed difference. Of relevance in this connection is the observation by Young (1960) on the localization of leucoanthocyanins in latex cells in ripe bananas as compared to their widespread

distribution throughout the tissue in pre-climacteric material. Since these substances bind with proteins, the lack of activity has been interpreted erroneously as an indication for the absence of certain enzymes during the green stage.

The climacteric signal for senescence has been established in a great variety of fruits. However, there are several species for which either the evidence is insufficient or the indications for a non-climacteric pattern predominate (Biale 1960*a*, 1960*b*). In the orange and the lemon, for example, a continuous and steady decline in the rate of oxygen uptake or carbon dioxide evolution was noted throughout the stages of maturation and senescence. In these fruits no marked chemical transformations are associated with ripening. The intensity of respiration varies for the different species and varieties within the climacteric as well as non-climacteric fruits. The rate is no doubt affected by a combination of factors which include enzymatic protein content, availability of catalytic organic acids, phosphate acceptors, and endogenous uncoupling agents.

A respiratory hump was observed (James 1953) also in completely expanded leaves after a period of active photosynthesis. The rise was associated with a change from green to yellow colour characteristic of senescence and with depletion of protein nitrogen. Since the studies were conducted on material detached from the plant, the process might be viewed as a starvation phenomenon, unlike the situation in fruits which are provided amply with respiratory substrate. Typical curves for upsurge in respiration as a prelude to senescence are shown in Figure 1 for a flower, a fruit, and a leaf.

EXTERNAL REGULATION OF SENESCENCE

The climacteric-exhibiting fruits lend themselves particularly well to experiments designed to prolong or accelerate the aging process. The pre-climacteric minimum and climacteric peak values as well as the duration of the rise may be used as indices of responses induced by changes in external conditions. The environmental factors most widely used (Biale 1960*a*, 1960*b*; Pratt 1961) are temperature, oxygen and carbon dioxide tension, and metabolically active gases such as ethylene.

Both low and high temperatures induce changes leading to accelerated senescence. Climacteric-exhibiting fruits grown in tropical and in subtropical regions of the world such as avocado, banana, and cherimoya (*Anona cherimolia* Mill.) are particularly sensitive to temperature extremes. In most varieties of the banana physiological disorders and abnormal ripening result from temperatures below 12°C and above 27°C. The climacteric of the avocado at 5°C and at 30°C is suppressed to the extent of causing undesirable quality. However, by lowering temperature within the physiological range the onset of the climacteric rise is postponed, the duration of the rise is prolonged, and the peak values are lowered. By inducing quantitative rather than qualitative changes senescence in fruits is regulated.

Similar considerations apply to the oxygen factor. At the lower extreme of the oxygen scale anaerobic conditions are induced in the fleshy organ and qualitative changes in metabolism ensue. Thus an acceleration in senescence results either from the toxic products of fermentative reactions or from the low rates of formation of phosphorylated compounds essential for maintenance of cellular organization. The response to anaerobiosis varies for different fruits. In the avocado the climacteric is completely suppressed and a sharp decline in carbon dioxide evolution ensues. In the orange and lemon, on the other hand, fermentative carbon dioxide production is maintained for a considerable time. The objective in prolonging the life of the fruit is to find that level of oxygen tension at which both respiration and fermentation rates are at a minimum. This threshold value appears to be in the vicinity of 5% oxygen for a number of fruits investigated. The effects of oxygen were found to be interrelated with temperature. As limiting temperatures are reached, the benefits accruing from decreased oxygen are minimized.

Further retardation of the onset of senescence has been achieved through the enrichment of the atmosphere with carbon dioxide at relatively low levels of oxygen. The addition of 5 to 10% carbon dioxide to 2·5, 5, or

10% oxygen resulted in a shift of the time of onset of the climacteric rise, a decrease in slope of the rise, and a lowering of peak values compared to air or corresponding oxygen levels without added carbon dioxide. The precise conditions responsible for prolonging the life of the fruit vary for different species and in some cases for different varieties within the same species. If levels higher than 10% carbon dioxide were used, the benefits due to suppression of metabolic activity were counteracted by gas-induced injuries. The level of oxygen used in combination with carbon dioxide is also critical. In lemons, for instance, respiration was retarded and storage life lengthened when 10% carbon dioxide was added to 5% oxygen, but not when the same level of carbon dioxide was combined with 21% oxygen (air). In the latter situation a carbon dioxide stimulated respiration was noted. In Figure 2 the observed carbon dioxide effects on three species are shown. In order to explain this unexpected response of lemons, fruit were placed for a short time in an atmosphere containing $^{14}CO_2$. The radioactivity was incorporated rapidly into malic, citric, and aspartic acids. Conceivably these three acids could be formed by well-known single-step reactions from oxalacetate. The observed carbon dioxide fixation offered, therefore, support for the hypothesis that the rise in respiration by lemons in atmospheres high in carbon dioxide might be caused by the formation of the catalytic acids required for the functioning of the Krebs cycle. When low concentrations of ethylene were added to the carbon dioxide atmospheres an additional stimulation of respiration was noted, but the magnitude was lower than in a comparable mixture of air and ethylene without carbon dioxide. The inference from available results was that the stimulation of respiration in lemons by ethylene is brought about by a different mechanism from the stimulation by carbon dioxide.

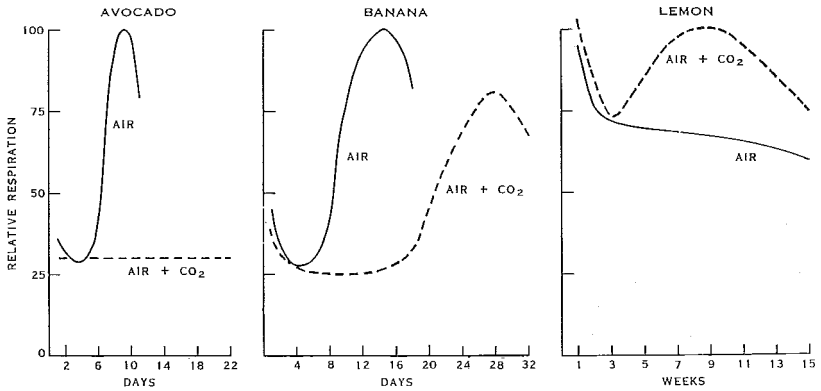

Fig. 2.—Effects of external carbon dioxide on the respiratory drift associated with senescence. In all cases the carbon dioxide level was 10%. *Based on data from Biale* (1960b).

The effects of ethylene on senescence have been studied for the past four decades with particular emphasis on commercial fruits and vegetables. Minute quantities of this gas stimulated the rate of respiration and accelerated ripening. In fruits with the climacteric pattern, ethylene was effective only if applied during the pre-climacteric phase and was responsible for hastening the time of the onset of the rise without altering the shape of the curve and without changing the chemical composition. Moreover, the response was essentially the same within a concentration range of 0·1 to 1000 p.p.m. On the other hand, in the non-climacteric fruits the rate of respiration depended on concentration and the stimulation could be induced any time after harvest. In both classes ethylene hastened in a very pronounced way the degradative processes characteristic of senescence.

INTERNAL SIGNALS OF SENESCENCE

The role of ethylene as the endogenous triggering substance for the onset of the climacteric rise has been a subject of lively controversy. The proponents (Pratt 1961) of ethylene as the causal agent indicate the striking parallel between ethylene production and oxygen consumption, the high concentrations within the tissue compared to the external environment, and the responses brought about by minute quantities of the applied gas.

TABLE I

Ethylene Production in Relation to Respiration*

Fruit	Temp. (°C)	Ethylene (μl/kg-hr)	Respiration (ml CO_2/kg-hr)	$C_2H_4/CO_2 \times 10^3$
Avocado	20	88	156	0·56
Apple	20	77	13	5·9
Banana	20	4	80	0·05
Cherimoya	20	186	129	1·44
Lemon	25	0	6	0·0
Orange	25	0	8	0·0
Passion-fruit	20	354	45	7·9
Peach	20	31	35	0·88
Pear	20	135	33	4·5
Pineapple	25	0	42	0·0

* For more detailed information refer to Biale (1960*a*).

The opponents (Biale 1960*b*) point to the great variability in the ethylene–carbon dioxide ratio for the ethylene-producing fruits (Table 1), to the divergence between the two processes in response to changes in temperature and oxygen, and to the lag in ethylene formation compared to the respiratory rise in some cases. The introduction of precise gas chromatography coupled with sampling of internal atmospheres might throw new light on this problem. Thus far the new methodology has resulted in a controversy (Burg and Burg 1961) as to whether a subcellular particle is the seat of ethylene formation. Up to now it has been established that ethylene production is an aerobic process, though the precursor may be formed anaerobically.

Whether ethylene is or is not the native triggering agent, the mode of its action requires further clarification. Does it stimulate respiration by uncoupling oxidation from phosphorylation, does it alter the permeability characteristics of the cell, or does it act on some specific enzymes? These questions are tied up with the more general consideration as to whether senescence or the prelude to senescence should be looked upon as a purely degradative phase in the life of the organism or as a phase in which synthesis is tied up and actually required for breakdown. In order to answer these questions some insight into metabolic changes accompanying the climacteric was needed. Experimental attempts along this line were made with the avocado fruit at the cellular and subcellular level.

The question arose whether the increased rate of oxidation during the climacteric is the result of lifting a phosphorylative limiting condition. If ADP is present in low concentrations and the system is tightly coupled, one may bring about uncoupling by the use of 2,4–dinitrophenol (DNP). In fact, this is the situation when slices of avocado tissue from pre-climacteric fruit are presented with 10^{-4} or 10^{-5}M DNP. The effect of DNP decreases with the progress of the climacteric with eventual complete lack of response at the peak.

The following two hypotheses were advanced to explain these findings: (*a*) an endogenous uncoupling substance formed with the climacteric rise exerts an effect similar to that of DNP, (*b*) increase in energy-requiring activities during the climacteric brings about a greater turnover of ATP and makes available phosphate acceptor. If hypothesis (*a*) is correct, one would expect the phosphorylative activities to be lower in ripe than in green avocados. Experiments (Young, Bieleski, and Biale 1961) with ^{32}P have shown, however, that the rate of uptake of phosphate and the rate of incorporation into organic esters are actually higher in climacteric peak

fruit. DNP lowered the rate of incorporation into nucleotides and hexosephosphates during both stages. The phosphorylative capacity of ripe tissue was demonstrated also in the mitochondrial fraction. The cytoplasmic particles of the avocado fruit are capable of oxidizing pyruvate as well as other acids of the Krebs cycle, of oxidizing and reducing DNP and cytochrome *c*, and of passing electrons to cytochrome oxidase, the terminal enzyme in respiration.

The phosphorylative efficiency in the mitochondrial system of the avocado fruit was measured by P/O values, that is by micromoles of phosphorus esterified for each microatom of oxygen taken up as a result of oxidation of Krebs cycle acids. It was found that this ratio increased in the course of fruit ripening. Until additional data are obtained on respiratory control, judgment has to be reserved on the nature of the coupling system at the peak of the climacteric compared to the pre-climacteric stage.

CONCLUSIONS

The phosphorylative processes in mitochondria, the esterification rates by tissue slices, and the net formation of proteins and some enzymes suggest that senescence or the period immediately preceding it is characterized by synthetic activities. The occurrence of degradative reactions is not excluded and frequently presents the obvious symptoms. In senescent tissue it is possible to observe marked changes in permeability resulting in liquid-logging of intercellular spaces, leakage of cell contents, decrease in time required for plasmolysis, and rise in apparent free space. The loss of integrity by membranes was ascribed by Sacher (1959) to insufficient levels of auxin. Conceivably, the entire vesicular network and not only the plasma membrane is subject to change with aging. Little is known about the changes in structure and function of the various components of the cell. It has been pointed out by Varner (1961) that a decline in metabolism might be the result of breakdown in communication between nucleus and cytoplasm. There is certainly a need for more knowledge about the levels of enzymes, nucleotides, and other cofactors as related to senescence.

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Chilling Injury in Stored Fruits and Vegetables

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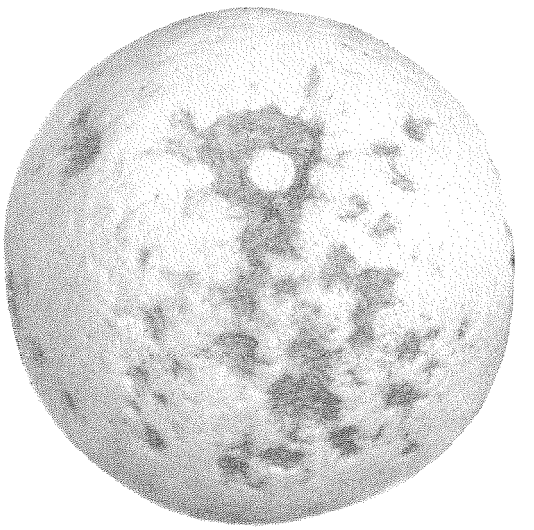
Adapted from a paper entitled "Chilling Injury in Plants" given at the Food Science Conference held in September 1961 at North Ryde.

THE value of cool storage for fruits and vegetables stems from the fact that low temperatures delay ripening and fungal rotting. The maximum delay is obtained by storing at as low a temperature as possible. However, the risk of freezing injury prevents the use of temperatures below 28–32°F, the lowest practicable temperature depending on the fruit and the adequacy of temperature control. Above the freezing range chilling injury still occurs in many fruits and vegetables, and to avoid it even higher storage temperatures must be used. Chilling injury associated with breakdown and discoloration of internal and surface tissues or with abnormal ripening occurs in tropical fruits, citrus, plums, peaches, some varieties of apples, tomatoes, cucumbers, and sweet potatoes. Pitting or storage spot of citrus, woolliness of peaches, soft or deep scald of apples, and internal browning of apples are common examples. As chilling injury limits the use of low temperatures for many fruits and vegetables, and therefore reduces their life in cool storage, its nature and cause need investigation.

Molisch (1897) suggested the term "chilling injury" for cold injury in the absence of freezing, and subsequently many whole plants were tested by Mobius (1907), Sellschop and Salmon (1928), and Seible (1939). The times to show visible injury at 34–41°F varied from only 1–2 minutes to as long as 3 weeks. For stored fruits the most thorough studies of the development of low-temperature disorders for various times and temperatures are those of van der Plank and Davies (1937), who showed that in the range of temperature for chilling injury a disorder develops more quickly at higher temperatures but ultimately reaches a higher level at the lower end of the range. They regarded the later slow development of pitting in grapefruit as due to an increase of susceptibility during storage.

It often appears that the climacteric, or phase of most rapid ripening changes, is the period of maximum susceptibility to chilling injury. If the temperature is too low for normal ripening it causes abnormal changes, ranging from abnormal texture to serious breakdown and discoloration.

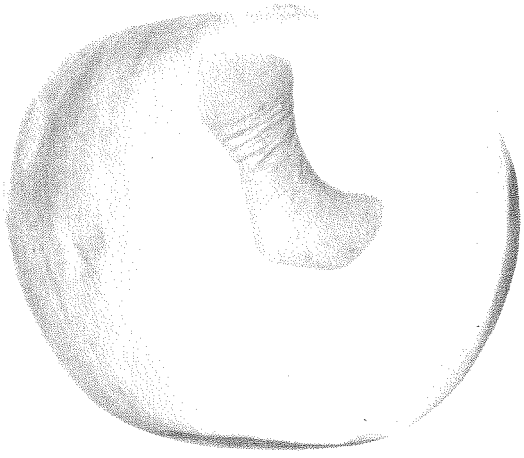
Trout and Hall (reported by Huelin 1942) have also shown that chilling injury in oranges can include "latent" injury which develops into visible rind disorders after removal to higher temperatures. In contrast Smith (1954, 1958) showed that chilling injury may sometimes be prevented by holding the fruit for a few days at higher temperatures at a critical period during storage.



Pitting or storage spot on a Washington Navel orange.

Presumably this treatment enables the chilling changes to be reversed before going too far.

The visible disorders, which involve death and breakdown of cells, appear in the last stage of chilling injury. Attempts have been made to detect microscopic and chemical changes at earlier stages. Lewis (1956) observed that the protoplasmic streaming of living cells can cease within two minutes' exposure to low temperatures. Lieberman *et al.* (1958) found that one week's chilling of sweet potatoes at 45°F was sufficient to double the loss of potassium from cut slices, but that more than five weeks were required to cause a marked decline in the oxygen uptake of the subcellular particles known as



Soft or deep scald on a Jonathan apple.

mitochondria. Shichi and Uritani (1956) found a decline in oxygen uptake of cut disks of sweet potato after chilling, but Eaks and Morris (1956) and Eaks (1960) found the respiration of whole citrus fruits, sweet potatoes, and cucumbers to be increased by chilling. Some methods have detected chilling injury much earlier than others, and the most sensitive techniques are probably those that produce minimum alteration to the cell.

How does the low temperature cause chilling injury? Kidd and West (1924) suggested a disturbance of the metabolic balance. Living cells are maintained by a large number of chemical reactions, many of which use the products of other reactions. Lowering of temperature slows down all these reactions but not necessarily in the same ratio. If the utilization of an intermediate product is slowed down more than its production, the concentration of this product could increase until it injured the cells and finally caused death and breakdown. This reasoning has been presented mathematically by Plank (1941, 1943). Alternatively, it is suggested that the low temperature affects the integrity of subcellular structures by freezing their lipid components. The latter theory fits better some forms of chilling injury where the transition from no injury to very serious injury takes place, like freezing, in a narrow temperature range. In the case of soft or deep scald of apples the range is only 4°F.

It is clear that investigation of the nature and cause of chilling injury has only begun, and that we have not yet been able to associate it with definite intermediate products of metabolism or with any observed change of physical state. Nor have we followed the course of chilling injury from the first detectable changes to visible disorders in any detail. Light and electron microscopy, biophysics, and biochemistry will probably all contribute to further understanding of the harmful effects of low temperatures on fresh fruits and vegetables.

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Ripening of Bananas

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ONE of the earliest projects undertaken by the then Council for Scientific and Industrial Research was a study of methods of handling bananas grown in northern New South Wales and Queensland, so that recommendations could be made to ensure that fruit reached consumers in the southern States at an optimum stage of ripeness.

In 1927 the Manager of the Queensland Committee for the Direction of Fruit Marketing, who had made a study of banana marketing in the U.S.A., reported that heavy losses then being experienced in the Australian industry more than justified the carrying out of investigations based on procedures which had been adopted in the U.S.A.

A circular issued by the C.S.I.R. Division of Food Preservation and Transport (Anon. 1934, revised 1941) and an earlier report (Young *et al.* 1932) covering the investigations which resulted made a number of basic recommendations for the transport and ripening of bananas which still hold good.

Enquiries made after two recent explosions in banana ripening rooms showed considerable ignorance of the basic phenomena of banana ripening. In this circumstance it appears worth while to restate the general principles of banana ripening and to make certain recommendations in the light of recent developments.

Principles of Ripening

Bananas should be harvested while still hard and green and firm enough to stand handling and transport. With such fruit the pulp contains about 70% of water by weight while the remainder is almost entirely starch. As ripening takes place the fruit softens and becomes yellow, the starch turns into soluble sugar, the astringent tannins are oxidized, there is an increase in acidity in the skin and pulp, and a marked increase in respiration with various volatile substances liberated which give the fruit its characteristic aroma and flavour.

The rate at which these changes occur depends mainly on the maturity of the fruit when picked and the temperature at which it is stored, although other factors are also involved. One factor having a considerable influence on the ripening of bananas is the presence in the storage atmosphere of traces of certain gases such as ethylene, propylene, and acetylene.

Although the exact mechanism of the "trigger action" of these gases in stimulating ripening is still not fully understood, it is known that very small amounts of ethylene can promote uniformity of ripening and accelerate the maturation of slow ripening fruit.

Added ethylene has little or no effect on fruit once it commences to ripen and is producing ethylene naturally. Since ripening bananas produce ethylene naturally, it is undesirable to store together fruit of mixed maturity. Bananas, in common with other fruits, produce carbon dioxide gas at a relatively fast rate during ripening. Unless this is removed by proper ventilation of the store, ripening will be delayed. Ventilation is also necessary to supply oxygen and to control humidity.

Proper ripening thus calls for control of temperature, humidity, and carbon dioxide concentration as well as the use of a ripening stimulator.

Temperature

During winter the best temperature for ripening rooms is 66°F. Below that temperature ripening is slow and the fruit is liable to be hard in texture and deficient in

flavour. At higher temperatures the flavour of winter fruit is poor and quality may deteriorate very rapidly. In the summer months keeping the temperature in the range of 66–70°F usually proves satisfactory. If temperature is allowed to go above 70°F a good colour may result but the flavour suffers and the fruit has a shorter life. Above 75°F a condition known as "boiling", in which the fruit softens while the skin is still green, usually develops.

Thermostats controlling the heating and/or cooling units should be placed in the air stream above the stack of fruit, preferably in the centre of the room. When ripening fruit it is the temperature in the cases which is of primary importance. This should never be allowed to exceed 75°F. Case temperatures should be obtained by placing the bulb of the thermometer in the centre of the case and waiting sufficiently long to get an accurate reading. Since thermometers are not always accurate they need checking periodically with a standard thermometer known to be correct. The build-up of an excessive case temperature can often be prevented by the speeding up of the fans. In this connection it should be remembered that changes in case temperature may lag considerably behind room temperatures.

Humidity

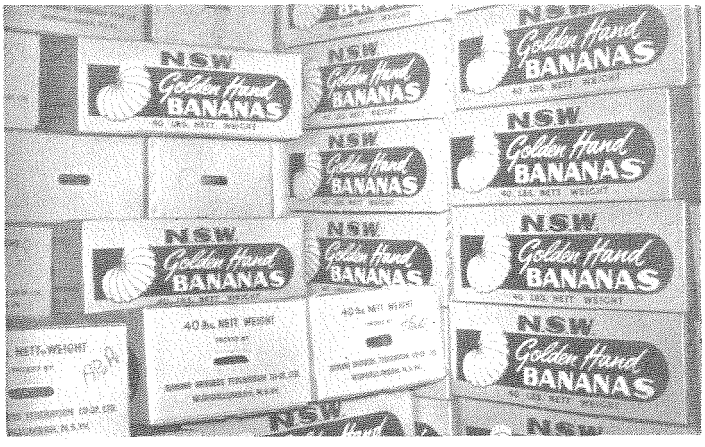
An 80–85% wet-bulb reading is satisfactory until fruit colouring begins, when the humidity should be reduced to 70% by ventilation or, in summer, by condensing moisture on refrigerator coils. Too low a humidity at an early stage of fruit ripening results in a poor skin colour, often with a somewhat wilted appearance. The eating quality of the fruit may suffer. With a high humidity, after active ripening is in progress, the skin becomes soft and fragile with an increase in the incidence of "black end" and the ulcer-like lesions caused by fungi (anthracnose).

With the amount of water vapour given off by the ripening fruit, artificial raising of the humidity should not be necessary in winter, when refrigeration is not normally used. In summer the drying effect of refrigerator coils may, on occasion, necessitate raising the ripening room humidity through evaporating water by heat or by misting, using as a control a simple industrial type of humidistat operating independently of the temperature control.

In well-constructed rooms (the design and construction of most modern rooms appear quite satisfactory) with ample refrigeration coil surface and no open vents, there should be no difficulty in maintaining the required humidity level. Humidities may run a little higher with gas than with electric heaters. If humidity is persistently low the trouble is likely to be due to poor insulation or too small a refrigeration unit.

Wet- and Dry-bulb Thermometers

The wet- and dry-bulb thermometer must be placed where it is exposed to air movement or the readings obtained will not be representative of the actual conditions. The covering of the wet bulb must be kept clean and the water supply for the wick should be



Cartons containing banana hands, open stacked six high in a ripening room.

regularly replenished with distilled or rain water.

Use of Ethylene

To start the ripening process the ethylene should normally be added as soon as the fruit is placed in the ripening room and should be replenished twice daily, or more frequently if the room leaks, until ventilation is commenced. Should the fruit be hot on arrival it should be cooled to 70°F before gassing is started. In winter use 1 part in 10,000 and in summer 1 part in 20,000 of the empty volume of the room. It has become the custom to use town (coal) gas, where available, to ripen bananas. It proves effective because of its content of around 3% ethylene. Modern town gas, however, may contain a considerable proportion of refinery gas and have a concentration of ethylene and propylene double that of coal gas. If this is the case a concentration of only 1/2000 is needed in lieu of the 1/1000 originally recommended. Since town gas in concentrations of more than 5% is highly explosive, as recent fatal accidents unfortunately demonstrated, the use of town gas, or acetylene, is no longer recommended. Pure ethylene gas is readily available in small cylinders, with a suitable metering device, from Commonwealth Industrial Gases Ltd. at a reasonable price. At the current cost of 2*s.* 3*d.* per cu. ft. ethylene treatment should not exceed 1·2*d.* per 80 lb box of fruit.

Heating

Because of the risk involved, even with an automatic cut-off of supply should the flame go out, the use of gas for room heating is no longer recommended. Instead we advocate the use of fully insulated safety electric strip heaters, which should be placed in the delivery air stream. The provision of explosion ports, essential where town gas is in use, is still desirable with electric heating even when ethylene is used for ripening.

Cold Fruit

When fruit arrives at the ripening room at a case temperature lower than 55°F the room temperature should be raised slowly, with gentle ventilation, over a period of 12 to 24 hr until it reaches 66°F. When that temperature is attained in the cases the ventilation vents should be closed and the first addition of ethylene made.

Ripening of Hands

In recent trials (1961–62) with which research workers of the C.S.I.R.O. Division of Food Preservation were associated, waxed hands of fruit placed in fibre cartons ripened better than single fruits in standard wooden cases. The fruit in hands suffered less mechanical damage and had a longer shelf life, and there was a much slower development of "black end". It was found that the temperature of the fruit in the carton (packed with 42 lb of fruit) followed the air temperature more closely than did single fruits in the centre of a case containing 75–80 lb.

Cartons containing hands should be open stacked, preferably not more than 5 or 6 cartons high. The use of racks facilitates such stowage. Because of greater convenience in retailing and economy in packing, cluster packing is likely to prove popular. This system is already in successful commercial use in Brisbane and marketing hands or clusters is likely to be adopted elsewhere when circumstances permit. Bulged pressure packs should not be used because of the danger of seriously damaging fruit.

Stages of Ripeness

The following terms, which for the most part are self-explanatory, are in fairly common use in the ripening of bananas: hard green, sprung (green but showing a definite flexibility), colour show, half colour, green tip, full colour, full ripe, flecked (well developed brown to black skin spots), and deteriorating (pulp soft).

Other Fruits

Fruits other than bananas, for example papaws, mangoes, tomatoes, melons, and pears, can be artificially ripened by the use of ethylene. Higher temperatures than those used with bananas (up to 85°F) seem to be desirable with papaws to minimize the development of ripe rots. The use of ethylene is almost essential to obtain a uniform ripening of honeydew melons, and the conditions recommended for bananas have proved very satisfactory.

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Instant Mashed Potatoes*

By D. McG. McBean

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ALTHOUGH potatoes form an important item of the Australian diet, the average annual consumption per person has been dropping steadily. Why are we eating fewer potatoes? Firstly, as our population tends to become more urbanized its diet tends to become lighter and more varied. Partly to blame, too, may be the largely mistaken belief that potatoes are unduly fattening and lack the protective nutrients found in other vegetables. Of even greater importance may be their bulkiness (they contain 80% water), which makes them inconvenient to store in modern homes, and the time taken up in their preparation, especially in the tedious job of peeling. A detailed study of the dehydration of potatoes was made during the years of the 1939–45 war. Techniques have been developed, especially during the past decade, which are having a marked impact on present-day potato marketing in the U.S.A. and Europe.

"Instant", a prefix which has caught the imagination of the consuming public, especially in the U.S.A., can be truly applied to modern potato preparations which can be prepared for eating within a fraction of a minute merely by the use of a hot reconstituting liquid and a minimum of effort to stir.

It is significant that during the past five years, consumption per head of potatoes in the U.S.A. has increased for the first time in 50 years. The reason undoubtedly lies with the convenience of processed potatoes, which are being marketed now in steadily increasing quantities. In 1961 more than 40% of the 12,000,000 tons of potatoes produced in the U.S.A. were factory processed. This compares with a mere 2% which were processed, largely in the form of potato crisps, in 1940. During 1960, more than 600,000 tons were dried while 1,000,000 tons were frozen. It is worthy of record that in 1961 the total production of potatoes in Australia was 450,000 tons.

* This article is based on a lecture given at the 12th Annual Convention of the Australian Section of the Institute of Food Technologists held at Terrigal, N.S.W., in May 1962.

Judged by the rapidity with which products such as instant coffee are gaining in popularity in Australia it would seem the time is opportune for merchandizing potatoes as an instant product.

Efforts to dry mashed potatoes in a form capable of rapid reconstitution are by no means new and references are to be found to techniques tried well over a hundred years ago. Some of the early attempts differed only in minor detail from others made during the period 1912–48, when cooked mashed potatoes were extruded on to a heated surface to produce dried shreds. In 1949–50 a similar product, resembling thin-bore spaghetti, was produced on a pilot scale in the U.S.A. but it was never marketed. Attempts made to dry mashed potatoes in conventional or adapted commercial spray driers have resulted in damage to the potato starch cells by the atomizer heads. A number of techniques involving freezing as an essential part of processing were tested by different workers. Following their cooking the potatoes were mashed and frozen. After being thawed slowly the mash was pressed so as to give a cake with 40–45% moisture suitable for drying in conventional driers.

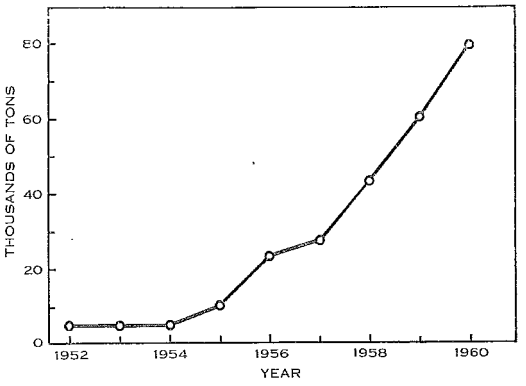

Fig. 1.—*United States production of dehydrated potato.*

In a number of multi-stage drying techniques the cooked mashed potato was dried, often to about 40–45% moisture, and left for several hours to equilibrate and granulate. The resultant crumbly material was then further dried to the required moisture level.

Other methods of obtaining a moist crumbly material suitable for final drying were those of Volpertas (1937, 1939), Rivoche (1948), and Rendle (1943), in which dried mashed potato powder was added to a wet mash until the resultant mixture had 40–45% moisture. Solvent extraction of water has also been tried but because of the difficulty of removing the final traces of solvent, usually ethyl alcohol, the technique has never passed the laboratory stage.

From a wealth of experimental data there emerges the basic fact that to be successful a process must avoid damage to the individual cells of the potatoes, since if starch granules are released the reconstituted product is gluey. Of the two processes adopted for the present large-scale production of dried potato in the U.S.A. and elsewhere, the "add-back" or granule technique which has been mentioned is the older. The more recent, the flake process, gives a dried product with an appearance resembling soap flakes.

Granule Technique

Tubers for processing, which may be freshly dug or stored, are washed thoroughly prior to being lightly peeled, usually in an abrasive peeler. After slicing into pieces about $\frac{3}{4}$ in. thick the potato is steam-cooked at atmospheric pressure for 30–40 min and mashed while still hot. The "add-back" of dry granules is made simultaneously with mashing by a mild shearing and pressing action so as to minimize damage to starch cells. When the required moisture content is obtained the mixture is air cooled on a fine mesh vibratory screen. The mixture, piled to a depth of 6–9 in., is then left to granulate on rubber belts for about an hour. Granulation probably results from an equilibration of water, a toughening of cell walls, and a retrogradation of starch. Cell agglomeration, which tends to be self-perpetuating and takes place with the formation of lumps, is countered by gentle mixing. At this stage enough sodium metabisulphite to give 200 p.p.m. of sulphur dioxide in the final product is added, as well as an antioxidant such as butylated hydroxyanisole (B.H.A.). The crumbly mass, now ready for final drying, is fed to a dehydrator by a ribbon mixer and vibratory feed. After drying, the product is screened to remove any lumps or pieces of skin.

Granules passing through a 60 mesh are suitable for retail packaging while the coarser granules, usually in the 40–60 mesh range, are reserved for use in the "add-back" process.

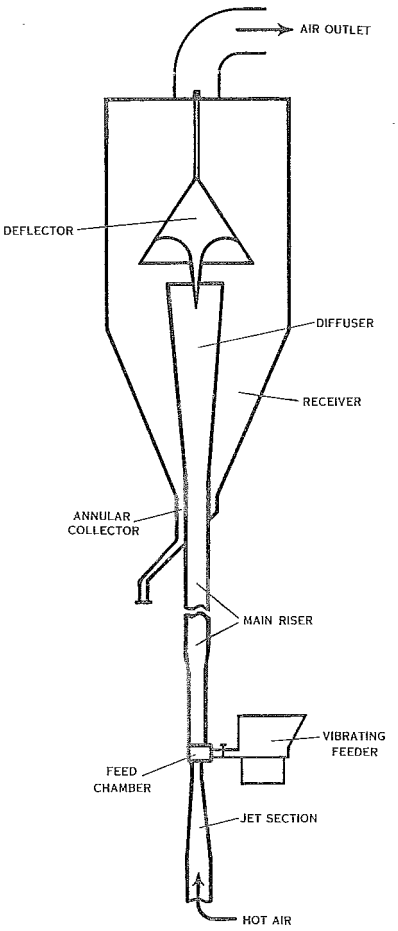

Fig. 2.—Air-lift drier for air-suspension drying of potato granules.

The drier of the pneumatic type operates in a similar fashion to an inverted spray drier. Particles are introduced into an air stream moving at 1500–2000 ft/min and heated to about 300°F. Higher air speeds will result in abrasion damage. As the particles dry they are carried upwards by the air stream to strike a deflector from which they fall to an annular collecting ring. The average time for the particles to remain in the air stream is 6 sec but the larger particles remain in the hot air considerably longer. The used air containing moisture is exhausted and not recirculated. On leaving the air stream the particles have a moisture content of 10–12%. They are dried to 4–6%, usually on a fluidized bed drier, by hot air which is blown up through a ceramic plate having many 400 mesh holes. This air stream moves the particles so violently that they resemble boiling liquid.

Although the basic ideas for the granule technique stem from British patents it was developed commercially in California by the U.S. Department of Agriculture Western Utilization Branch working in collaboration with several major food processing concerns.

Flake Technique

Roller driers had been in use in the U.S.A. for at least half a century for the production of potato flour and starch.

Cording *et al.* (1954), of the U.S. Department of Agriculture Eastern Utilization and Development Division, were the first to report a successful drum or roller flake process for mashed potatoes. In 1959 this process received the first Industrial Award made by the Institute of Food Technologists. For the flake process potatoes are washed as for the granule process but peel has to be removed thoroughly for there is no subsequent sieving. Contour peeling by lye or steam under pressure is practised to minimize weight loss. After peeling and thorough washing the potatoes are lightly sulphited to prevent enzymic browning and are then sliced as in the granule process. Pre-cooking for 20 min at 160°F results in swelling but not bursting of the starch cells. Pre-cooking allows the use of potatoes of a wider range of quality than in the granule technique, for which a good-quality mealy potato is essential.

After pre-cooking, the slices are cooled for about 20 min in cold water at about 50°F, so as to retrograde the starch. The slices are then steam-cooked sufficiently to allow easy ricing or mashing. The ricing equipment employed usually consists of a helical screw which forces the potato through slots with insufficient pressure to burst the starch cells.

At this stage a mixture of sulphites and an antioxidant is metered into the mash. Monoglyceride may be added as an emulsifier and a small amount of dried skim milk solids may be used to improve texture. The mix is applied to the drier by applicator rolls which maintain a continuous dense film on the drying surface of the drum. Any small lumps are ironed out by a "Teflon"-covered steel roll set 7/1000 in. from the heated surface. A doctor knife removes the dried sheet from the drying surface of the drum, which is maintained at a temperature of about 300°F by pressure steam. The dried sheet is broken into $\frac{1}{2}$-in. flakes by a slitting roll. The desired moisture content of 4–6% is obtained by a single pass over the drum. Drying time is 15–20 sec.

reducing sugars and amino acids combine to give dark pigmentation, and the oxidation of the small amount of fatty constituent occurring in the product, giving a pronounced off-flavour. Both these deteriorative changes depend upon time and temperature, the rate of change increasing with length of time and rise of temperature. The problem of packaging must be considered in the light of marketing factors, length of time before consumption, and storage temperature. In addition to the use of sulphur dioxide and an antioxidant in processing, the removal of oxygen from the package may be beneficial. The replacement of air by inert gases, such as nitrogen or carbon dioxide, should present no special difficulty with modern automatic packaging facilities.

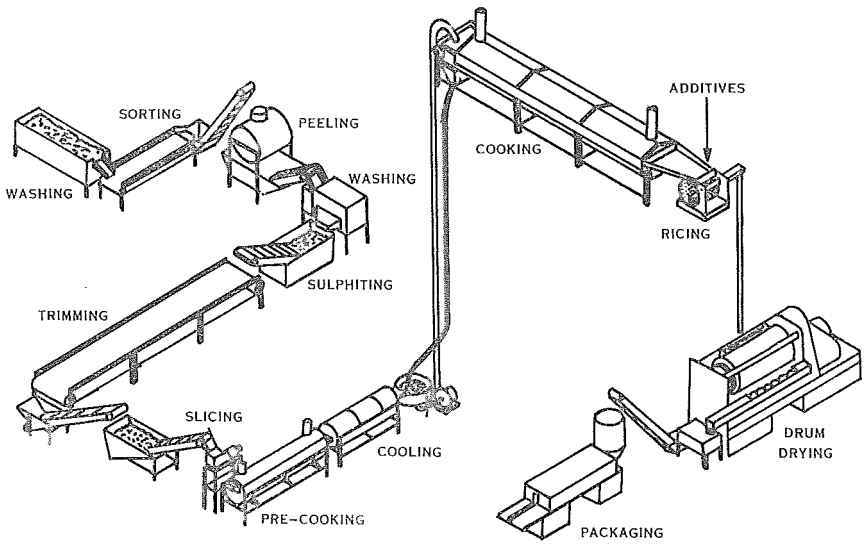

Fig. 3.—Flow-sheet of potato flake manufacture.

Packaging and Storage

Packaging is one of the most costly aspects of producing dried potato mash. Both granules and flakes absorb moisture very readily, and unfortunately a high moisture content means a short storage life. Water-vapour-proof packaging must be used, which limits selection to metal cans or a suitable laminate containing a metal layer. Deteriorative changes which may take place after processing include the "browning" reaction, whereby

Comparison of Processes

The main points of comparison worthy of consideration by the would-be commercial processor include the following:

● The quality of potato used is more critical in granule than in flake production. Separation by specific gravity has been recommended to remove potatoes of low specific gravity before granule processing. Apart from any effect on the quality of the

final product, potatoes of low specific gravity will, of course, give a lower yield of dried mash.

● Costs are lower for granule production in so far as peeling need not be very thorough because pieces of skin can be sieved out after initial drying. There is, however, some evidence that fragments of skin can confer an earthy flavour on the product.

● Pre-cooking and cooling of potatoes in flake production are a necessary, but costly, technique. In the granule process the "add-back" and conditioning procedure is likewise expensive in time. Although comparative figures are not available, single-stage drum drying of flakes must be a cheaper means of moisture removal than the multi-stage procedure necessary for granule production.

● Packaging and distribution costs are less for granules than for flakes since the packing density of the former is about three times the latter. From the retail aspect, however, the bulkier pack of the flakes may prove more attractive to those housewives who tend to buy on container size rather than on weight.

Future Developments

The director of research and development of a major U.S. manufacturer has complained that since his company started manufacturing granules five or six seasons ago there have been constant costly major changes in processing techniques. The aim of the U.S.D.A. Western Utilization and Research Branch investigators has been to develop a granule technique to avoid "add-back". A statement published recently implies that a successful technique is being developed which calls for partial drying on a heated drum prior to a final drying in a stream of hot air. In October 1961 scientists of the U.S.D.A. Eastern Utilization Research and Development Division described a process for producing flakelets with a packing density of 46–50 lb/cu. ft. (against 15 lb/cu. ft. for flakes and 50–55 lb/cu. ft. for granules). This technique is the same as for flakes up to the ricing stage, when about 93% is drum dried to about 10% moisture. The remaining 7% of the mash is cooled and added back to the flakes. Paddles then compact and laminate the mixture, which is fed to a vibratory drier. Air heated to around 260°F is led through the bed of flakelets from below and dries the laminate to 4–6% moisture in about 30 sec. The dried flakelets then go on to a vibratory cooler and are sifted to remove powder before packing. It will be seen that through the ingenuity of the food technologist we have an "add-back" process using preliminary drum drying to cut processing costs and a drum-drying process employing "add-back" and vibratory drying to give a denser packing material.

Probably it is still too early to forecast the technique most likely to be adopted in the future, but one thing which seems certain is that a bright future exists for marketing instant potato in Australia. Because of this, the processing of the product appears to merit the serious attention of food manufacturers.

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ERRATUM

C.S.I.R.O. Food Preservation Quarterly
Vol. 22, No. 2, June 1962

Page 50, 1st column, line 10: *For* "3 by 3 in. timber" *read* "3 by 1 in. timber".

Packaging Prunes in Flexible Film Pouches

By E. G. Davis

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AT the request of the Australian Dried Fruits Association, research workers in the C.S.I.R.O. Division of Food Preservation have studied the packaging of high moisture content prunes in flexible film pouches. Their aim was to develop a process to ensure microbial stability of the prunes after packaging, and to assess the performance of various pouch materials during processing and storage. This article reports the performance, under differing processing and storage conditions, of pouches made from a range of film materials.

In one experiment, prunes were filled into pouches at a temperature of approximately 180°F and sterilization depended upon the residual heat of the pack.

With materials of adequate resistance to steam temperatures, sterilization of the filled and heat-sealed pouches by direct heat treatment in live steam was possible. This was done in a second experiment in which the prunes were filled hot and the closed pouches given an additional heat treatment in live steam. The latter process should permit lower filling temperatures and reduce the likelihood of subsequent microbial spoilage. The use of steam, however, imposes limits on the choice of packaging materials, as a number of those commonly used break down at temperatures approaching 212°F.

Experimental

Materials.—Details of the film materials tested and the number of pouches included in the tests are given in Table 1.

Preparation of Test Packs.—In Experiment 1, 80 lb of dried prunes of an initial moisture content of 18·4% were divided into four batches, each of which was heated 10 min in boiling water, drained, and check weighed (12 oz) into 301 × 411 plain tinplate cans. The filled cans were passed through live steam in an exhaust tunnel for 10 min prior to transferring their contents into film pouches made from various materials. The pouches were heat-sealed, after the removal of excess air, and placed in single layers on wooden platforms to cool at room temperature.

In Experiment 2, 50 lb of the same dried prunes were divided into four batches. Each batch was heated 13 min in boiling water, drained, and check weighed (12 oz) into film pouches. The filled pouches, heat-sealed after the removal of excess air, were pasteurized in live steam for 9 min at atmospheric pressure in an exhaust tunnel, and cooled as described in Experiment 1.

Storage and Examination.—Packs from each treatment in Experiment 1 were divided into three groups which were stored at 100°F and 90% R.H., 100°F and 15–25% R.H., and 77°F and 35–45% R.H. Six pouches of each treatment in Experiment 2 were stored at 100°F and 20% R.H. and 77°F and 35–45% R.H.

Two pouches from treatments E and F in Experiment 1 and three from the remaining treatments at each storage condition in both experiments were weighed immediately before storage and also at intervals of 1 wk over a total storage period of 9 wk. At the same time all pouches were examined for general appearance and evidence of film breakdown.

Determinations of the moisture content of the prunes were made in triplicate, for each experiment, after the boiling water treatment, after the heat process in live steam, and with several of the treatments at the end of the storage period.

Water vapour permeability determinations on the film samples were made using the standard TAPPI method.*

* TAPPI Standards. "Water vapour permeability of paper and paperboard." Method T448/M–49.

TABLE I

Details of Film Materials Tested

Treatment Code	Type of Material	Nominal Thickness (× 0·001 in.)	Material Supplied	No. of Pouches in Test
Experiment 1				
A	Intermediate-density polyethylene (batch 1)	2·0	6 in. plain tubing	25
B	Plasticized polyvinyl chloride	2·0	6 in. plain tubing	23
C	300 MSAT "Cellophane" extrusion coated with polyethylene	1·75 (polyethylene)	8 in. × 6 in. printed pouches	27
D	300 MSAT "Cellophane" adhesive laminated to polyethylene	1·5 (polyethylene)	8 in. × 6 in. printed pouches	23
E	300 MSAT "Cellophane" extrusion coated with polyethylene (batch 1)	1·5 (polyethylene)	8 in. × 6 in. plain pouches	6
F	300 MXXT/A "Cellophane" adhesive laminated to polyethylene	1·5 (polyethylene)	8 in. × 6 in. plain pouches	6
Experiment 2				
G	Intermediate-density polyethylene (batch 2)	2·0	6 in. plain tubing	12
H	Polypropylene	2·0	Plain film	12
I	Nylon II	2·4	6 in. plain tubing	12
J	Nylon II	1·6	4¼ in. × 7½ in. printed pouches	12
K	Polyethylene terephthalate (0·0005 in.) extrusion coated with polyethylene (0·0015 in.)		5¼ in. × 5½ in. plain pouches	12
L	300 MSAT "Cellophane" extrusion coated with polyethylene (batch 2)	1·5 (polyethylene)	5 in. × 7½ in. plain pouches	12

Results and Discussion

High moisture content prunes are generally packed with 33–35% moisture. At this level the equilibrium relative humidity (E.R.H.) is approximately 85%. Until recently, prunes were marketed in Australia in large tinplate containers, and thus were not susceptible to moisture loss. The use of flexible film containers for small retail packs introduces the problem of drying out during storage. For retention of acceptable quality the moisture content of prunes should not fall below 28–30% during distribution and storage. Thus, for a 12-oz pack of prunes with a moisture content of 33% at the time of packing, the maximum rate of moisture loss which may be tolerated, over a 6 months' storage period, is 0·9 g/wk.

In the present studies, the mean moisture contents of the prunes after the boiling water treatments were 29·9% in Experiment 1 and 32·9% in Experiment 2. The mean moisture content of prunes given an additional steam treatment of 10 min in tinplate cans (Experiment 1) rose to 33·2%, and that of the prunes subjected to a 9-min steam treatment after sealing in film pouches (Experiment 2) rose to 34·7%.

The mean rates of moisture change during storage, the mean moisture contents after 9 wk storage, and the water vapour permeability of the pouch materials from both experiments are set out in Table 2.

Experiment 1.—Storage of the test packs from Experiment 1 at 100°F and 90% R.H. resulted in an increase in moisture in all treat-

ments, but a moisture loss was observed during storage at lower relative humidities. Under all storage conditions, the moisture changes in treatment B were higher than those in the other treatments. The water vapour permeability of the material in treatment B was also higher than in treatments A, C, and F.

The rates of moisture change in treatment F were lower than in the other treatments at all storage conditions. Treatment D showed a slightly higher rate of moisture change than all treatments except B.

With the exception of treatment B, all packs stored at 77°F and 35–45% R.H. were satisfactory so far as moisture loss was concerned. Under the more severe conditions, 100°F and 15–25% R.H., all treatments with the possible exception of treatment F showed moisture loss rates greater than 0·9 g/wk.

After 9 wk storage at both 77°F and 35–45% R.H. and 100°F and 15–25% R.H., the moisture contents of prunes from treatment A were within the minimum limits of 28–30%, but those of treatment B were low. After 9 wk at 77°F and 35–45% R.H. the moisture content of the prunes in treatment D was satisfactory, but it was below the minimum limit (28–30%) after 9 wk at 100°F and 15–25% R.H.

The general appearance of the film materials in all treatments was satisfactory at the end of the storage period at low relative humidities. At 100°F and 90% R.H. there was evidence of loss of print from pouches in treatments C and D, but the remaining treatments were satisfactory.

Experiment 2.—All treatments in Experiment 2 showed a moisture loss during storage at both 77°F, 35–45% R.H., and 100°F, 20% R.H., the losses at 100°F being higher than those at 77°F. Packs in treatment J lost moisture more rapidly than in the remaining treatments under both storage conditions. At 77°F, 35–45% R.H., treatment J was the only one allowing excessive moisture loss, i.e. greater than 0·9 g/wk. The water vapour permeability of treatment J was also higher than in the remaining treatments.

TABLE 2

Observations on Film Materials and Test Packs

Treatment Code	Water Vapour Permeability of Film (g/100 in², 24 hr at 100°F, 90% R.H.)	Pouch Area (in²)	Moisture Loss and Moisture Content under Specified Storage Conditions					
			77°F, 35–45% R.H.		100°F, 15–25% R.H.		100°F, 20% R.H.	100°F, 90% R.H.
			Moisture Loss (g/wk)	Moisture Content (%)	Moisture Loss (g/wk)	Moisture Content (%)	Moisture Loss (g/wk)	Moisture Gain (g/wk)
Experiment 1								
A	0·617 (0·0022 in.)	84	0·34	31·7	1·8	29·0		0·34
B	6·8 (0·0010 in.)	84	2·5	25·5	8·2	16·3		1·5
C	0·452	84	0·55	—	2·5	—		0·45
D	—	84	0·73	29·7	3·3	26·7		0·67
E	—	84	0·34	—	2·2	—		0·36
F	0·286	84	0·16	—	0·95	—		0·29
Experiment 2								
G	0·515 (0·0021 in.)	64	0·29*	—			1·8*	
H	0·420 (0·0020 in.)	84	0·16	32·6			0·97	
I	0·827 (0·0026 in.)	84	0·54	33·5			2·5	
J	1·65 (0·0016 in.)	80	1·0*	32·1			5·3*	
K	0·520	58	0·32*	—			1·8*	
L	—	75	0·45*	—			1·2*	

* Moisture losses calculated for a pouch area of 84 in.²

The general appearance of packages after the steam process and at the end of the storage period was satisfactory except for treatment L, which showed definite evidence of film breakdown after the steam process. This breakdown, however, appeared to be confined to a thin outside coating of the pouches, possibly the lacquer coating on the "Cellophane". No evidence of internal pressure build-up or heat-seal rupture was observed.

The test conditions 100° F and 15–25% R.H. used in both experiments represent severe storage conditions unlikely to be encountered for extended periods during commercial distribution and storage. Packaged prunes would probably be bulk packed in cartons, and this should decrease the moisture loss from individual pouches compared with the losses observed from the open stacked test packs.

Conclusion

These results indicate that film pouches made from plasticized polyvinyl chloride (0·002 in.) or nylon II (0·0016 in.) materials were unsatisfactory for the packaging of high moisture content prunes. Nylon II (0·0024 in.), intermediate-density polyethylene (0·002 in.), polyethylene (0·0015 in.) extruded on polyethylene terephthalate (0·0005 in.), and polypropylene (0·002 in.) materials should prove satisfactory under normal conditions of storage for the packaging of prunes sterilized either by hot filling or processing in steam at atmospheric pressure. Materials such as polyethylene (0·0015 in. and 0·00175 in.) suitably extruded or adhesive laminated to moisture-proof "Cellophane" should give satisfactory protection to high moisture content prunes sterilized by hot filling, but should not be subjected to processes involving high steam temperatures.

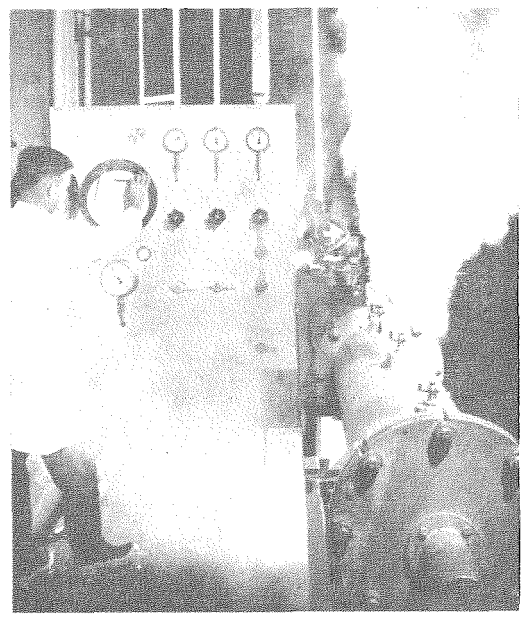
Acknowledgments

The author is indebted to Mr. D. McBean and his staff for their valuable assistance, particularly in the preparation of the test packs and moisture content determinations.

Spin Processing of Canned Foods

A MAJOR problem in the heat sterilization of canned food, using orthodox methods, is the slow rate of the transfer of heat through the product, especially when it is of a viscous nature. Unless special precautions are taken the outer layers of the food, which heat faster than the inner, become overcooked, thus causing undesirable changes in the colour, texture, flavour, and even nutritive value.

These undesirable effects may be avoided by increasing the rate of heating through agitation of the can contents during processing. Research workers in the Division of Food Preservation have developed a spin cooker which rotates the cans on an inclined belt as they are heated by steam at atmospheric pressure. The length of time the can contents



Operating a pressure spin cooker.

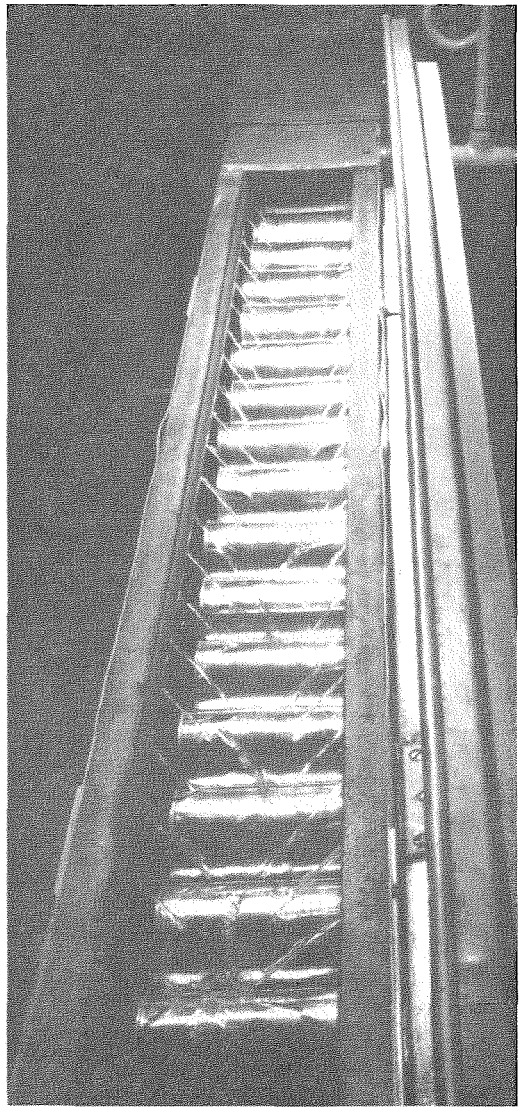
remain at processing temperatures is further reduced by accelerated cooling, achieved by rotating the cans under sprays of water. Experience has shown that in addition to being beneficial with viscous foods, spin processing maintains the quality of heat-sensitive products such as citrus, passion-fruit, and tomato juices, and is excellent for fruits, such as freestone peaches and apricots, which easily become over-softened by cooking.

Industry has been slow to take advantage of this type of processing, probably in the main owing to lack of availability of continuous process commercial equipment. To demonstrate the commercial possibilities of this method of processing the Division has called tenders for a continuous spin cooker-cooler capable of processing 301 × 411 cans of a product such as orange juice with an output of 24 per minute.

Scaling this equipment to handle commercial rates should not prove difficult and it is hoped that the successful tenderer with experience in construction of the prototype will be willing to produce commercial-size units for industry.

With low acid foods, such as meats and vegetables, which require higher sterilizing temperatures, the engineering aspects of agitating cans under steam pressure have posed a number of problems. Valuable information regarding pressure spin processing has been obtained with experimental equipment built to C.S.I.R.O. specifications. The development of suitable equipment for continuous spin pressure cooking on a commercial scale is likely to lead to the production of new lines of canned products which cannot be processed by orthodox techniques without serious deterioration in quality.

D. J. C.



Cooling cans in an atmospheric spin cooker.

Publications

NEW F.A.O. MARKETING GUIDE ON POULTRY PRODUCE

In 1958 the Food and Agriculture Organization of the United Nations started publication of a valuable series of marketing guides* "to promote a better understanding of agricultural marketing, to secure a wider appreciation of its significance, and to indicate ways of improving existing practices". The first of the series, "Marketing Problems and Improvement Programs", which provided an excellent survey of agricultural marketing practices throughout the world, was followed by others, "Marketing Fruit and Vegetables" and "Marketing Livestock and Meat", in which international authorities collaborated with the writer of the first guide, Dr. J. C. Abbott, Chief of Marketing Branch of the F.A.O. Economic Analysis Division, to produce well-written, comprehensive, and authoritative treatises.

In the latest guide, "Marketing Eggs and Poultry", Professor G. F. Stewart, the well-known U.S. food scientist and editor, has joined Dr. Abbott in producing a very readable and in all ways excellent booklet which should be in the hands of both poultry producer and trader as well as others concerned with poultry marketing. The authors, after stressing the need in most countries for marketing improvement programmes suited to local conditions, go on to cover quality of eggs and poultry meat, and their handling, packaging, transport, and storage. Further sections, dealing with marketing services, organizations, and pricing and sales policies, show the authors' wide knowledge of these subjects and keen comprehension of the many problems involved. Although the guide deals primarily with marketing, the part of the producer is not overlooked. Seasonal changes in egg and poultry meat prices, it is pointed out, reflect mainly variations in output. Producers, it is claimed, could do much by careful planning to ensure that their maximum production coincides with seasonal price peaks and market demands which are influenced by observances such as Christmas and Easter, resulting in higher consumption of poultry products. On the subject of storage to avoid seasonal gluts the authors state there is a tendency to underestimate the difficulties in the cold storage of poultry produce and it is stressed that refrigeration is a complex and highly technical business in terms of both equipment and efficient operation.

Appendices to the guide give useful information on egg grades and specifications for egg and poultry meat containers. The carefully compiled bibliography, although covering predominantly U.S. publications, is excellent in its coverage of pertinent literature.

H. H.

* F.A.O. Marketing Guide No. 1, "Marketing Problems and Improvement Programs". (12*s.* 6*d.* sterling.)

F.A.O. Marketing Guide No. 2, "Marketing Fruit and Vegetables". (10*s.* sterling.)

F.A.O. Marketing Guide No. 3, "Marketing Livestock and Meat". (10*s.* sterling.)

F.A.O. Marketing Guide No. 4, "Marketing Eggs and Poultry". (10*s.* sterling.)

Obtainable in Australia through Melbourne University Press, 369 Lonsdale Street, Melbourne, C.1, Vic.

CAN HUNGER BE AVERTED?

At its meeting in 1960 the Council of the British Association for the Advancement of Science invited a group of distinguished scientists to investigate the part science could play in relieving the present shortages of food in a number of underdeveloped countries and in averting the catastrophic suffering which would be inevitable should world population outstrip its ability to produce food.

The resulting study covered population growth, food requirements, land resources, potentialities for increasing food production, and associated economic problems.

The investigators' broad conclusion was that the present knowledge, if properly applied, could prevent hunger for at least half a century. The complexity of the problem of applying knowledge was acknowledged and no claim was made that progress would be easy or inexpensive.

World food production appears to be increasing slightly faster than the population but the chief increases are in the developed countries where the population rise is generally lower than in underdeveloped ones. Probably the quickest way of increasing total world food production would be to step up the output from good agricultural land, much of which is in the well developed countries, where the technological requirements for increased production are at hand.

Valuable in the short term, such a development would be unlikely to offer a permanent solution, and it is acknowledged that in the long run the required action must come from the underdeveloped countries themselves.

Food production in underdeveloped countries is largely a matter of individual enterprise and, except for plantation crops such as tea, coffee, and cocoa, is usually avoided by big business concerns. Hence the greater part of the food in underdeveloped countries is produced by peasants with little or no formal education albeit often with a good deal of empirical skill but usually reluctant to change established methods and customs.

The first step in tackling an overwhelming problem such as world hunger is to analyse and define it.

The Food and Agriculture Organization of the United Nations is responsible for collecting, analysing, and disseminating basic information on agriculture and food. Where it sees the need it convenes international meetings. One such meeting was held in Thailand in June 1960 when discussion took place under the following headings: appraisal of the food and nutrition situation, establishment of food consumption targets, nutritional improvement through food policies and plans, and organization and co-ordination.

An interesting record of this meeting appears in a recent publication.*

The technical officers attending the meeting concluded that, although a lack of calories was not a major defect in the area, the average diet was, in general, ill balanced and lacking in protective foods.

It was considered the major obstacle in developing sound food and nutrition policies in the region was an inadequacy of national nutrition organizations and a scarcity of well-trained nutrition workers necessary to provide leadership and guidance. It was advocated that each country should have at least one Nutrition Centre which should be properly staffed and equipped.

It was emphasized that the problems of nutrition, recognized as many-sided, would have to be approached from the points of view of health, agriculture, education, economics, and social welfare. While the foremost difficulty, seen in most countries, was the low level of income of the mass of the population, which restricted their purchase of foods of the right quality, it was felt there was considerable scope for teaching people through the medium of home economics to make better use of their resources.

It was recommended that the report of the meeting should be brought to the attention of an F.A.O./E.C.A.F.E. group of experts in selected aspects of agricultural planning in Asia and the Far East and that, before a regional meeting was convened, intensive case studies and pilot projects should be organized to clarify methodology and the implementing of development projects. An important recommendation was that nutrition research should be supplemented by studies aimed at the improvement of food processing methods.

H. H.

* "Nutrition in Food Policy and Planning in Asia and the Far East." F.A.O. Nutritional Meeting Report Series No. 28, Rome, Italy 1960.

"COMES OF AGE"

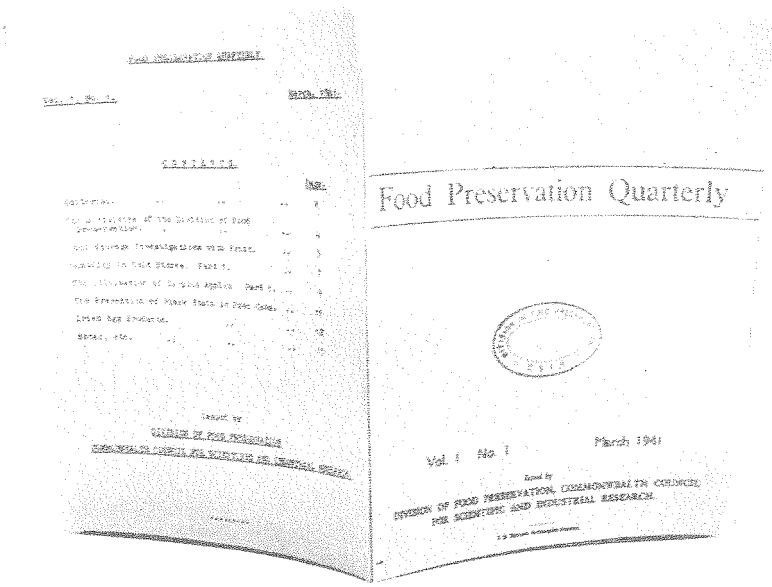
This year marks the 21st anniversary of the *Food Preservation Quarterly*. On introducing its first issue in 1941, for circulation "to those persons responsible for the control of processes in the field of food preservation", the Editor expressed the hope that the journal would contribute to the solution of the problems then confronting the Australian food industry—which were to be greatly accentuated by the development of the war in the Pacific—and would play a part in improving the knowledge of food technologists.

On perusing the early issues of the journal, which in those days was mimeographed, the practical nature of the wide range of subjects covered is evident. The last issue for 1942 recorded an extensive reorganization of the activities of the Division made to meet the worsening war situation. The subsequent issues reflected the seriousness of the international situation, and showed an increasing recognition of the value of science applied to the war effort. As the years passed the contents of the journal indicated the steadily growing influence of the Division in the Australian food industry. With the end of hostilities in 1945 came the announcement that investigations on food processing were to be retained as a permanent feature of the Division's activities, and research on the physics, chemistry, and microbiology of food and on plant physiology was to be resumed.

Of special interest was a commemorative issue of the journal in 1948, marking the tenth anniversary of the establishment of the Central Laboratories at Homebush, which reviewed progress during the preceding decade. It is interesting to compare this review (now out of print) with a similar one for 1956–60 which appeared in the *Quarterly* in September 1961 and to note the progress which had been made. More fresh in the reader's mind will be the description of the Division's new laboratories at North Ryde and of the Food Science Conference organized to commemorate their official opening (*C.S.I.R.O. Food Preservation Quarterly* December 1961).

The present contents of the *Food Preservation Quarterly* reflect the food industry's need for up-to-date technological knowledge and for the scientific facts underlying it.

In meeting this need the journal has to cater for a very different class of reader from that of 21 years ago. The present-day food technologist is far better trained and informed than his pre-war counterpart. The editors of the *Food Preservation Quarterly* feel that they have contributed in some small measure to the improved status of food technologists and hope that the journal, on attaining its majority, will continue to be of service to members of the food industry under the changed circumstances which now exist.



Selected Publications of the Division

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ANET, E. F. L. J. (1962).—Formation of furan compounds from sugars. *Chem. & Ind.* **1962**: 262.

ANON. (1962).—Meat dehydration. C.S.I.R.O. Aust. Div. Food Pres. Circ. No. 6–P.

BAIN, JOAN M. (1961).—Some morphological, anatomical, and physiological changes in the pear fruit (*Pyrus communis* var. Williams Bon Chrétien) during development and following harvest. *Aust. J. Bot.* **9**: 99–123.

BOARD, P. W. (1961).—Problems of stability of canned foods: enzymic aspects. Proc. 4th Int. Congr. Canned Foods: 39–56.

CASIMIR, D. J. (1961).—New methods of sterilization by heat; can rotation during thermal processing. Proc. 4th Int. Congr. Canned Foods: 135–48.

CHANDLER, B. V., and HARPER, K. A. (1961).—Identification of saccharides in anthocyanins and other flavonoids. *Aust. J. Chem.* **14**: 586–95.

CHANDLER, B. V., and HARPER, K. A. (1962).—A procedure for the absolute identification of anthocyanins: the pigments of blackcurrant fruit. *Aust. J. Chem.* **15**: 114–20.

CHRISTIE, E. (1962).—Conduct of taste tests. *Food Tech. Aust.* **14**: 75–7, 86, 124–5, 140, 161–2, 165, 169, 171.

COWELL, N. D., and EVANS, H. L. (1961).—Studies in canning processes. IV. Lag factors and slopes of tangents to heat penetration curves for canned foods heating by conduction. *Food Tech., Champaign* **15**: 407–9.

DAVIS, E. G. (1961).—Performance of electrotinplate containers with Australian foods. C.S.I.R.O. Aust. Div. Food Pres. Tech. Pap. No. 27.

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HOWARD, A., and PRATER, A. R. (1961).—Effect of pre-processing factors on the quality of air-dried mutton mince. C.S.I.R.O. Aust. Div. Food Pres. Tech. Pap. No. 23.

INGLES, D. L. (1961).—Reactions of reducing sugars with sulphite: the formation of β-sulphopropionic acid. *Chem. & Ind.* **1961**: 1312–13.

INGLES, D. L. (1962).—Formation of sulphonic acids from the reaction of reducing sugars with sulphite. *Aust. J. Chem.* **15**: 342–9.

KEYNAN, A.,* MURRELL, W. G., and HALVORSON, H. O.* (1961).—Dipicolinic acid content, heat inactivation and the concept of dormancy in the bacterial endospore. *Nature* **192**: 1211–12.

KEYNAN, A.,* MURRELL, W. G., and HALVORSON, H. O.* (1962).—Germination properties of spores with low dipicolinic acid content. *J. Bact.* **83**: 395–9.

MELLOR, J. D. (1962).—Vapour phase conditions in freeze-drying. 8th Vacuum Congr. Vol. 2. p. 1056.

MITCHELL, R. S., CASIMIR, D. J., and LYNCH, L. J. (1961).—Maturometer; instrumental test and redesign. *Food Tech., Champaign* **15**: 415–18.

PRATER, A. R., and COOTE, G. G.* (1961).—Influence of gas packing and flavouring additives on the storage life of dried mutton mince. C.S.I.R.O. Aust. Div. Food Pres. Tech. Pap. No. 24.

ROBERTSON, R. N., HIGHKIN, H. R.,* SMYDZUK, J., and WENT, F. W.* (1962).—The effect of environmental conditions on the development of pea seeds. *Aust. J. Biol. Sci.* **15**: 1–15.

SCHELTEMA, J. H., SYKES, S. M., and LAST, J. H. (1961).—Acceptability of frozen peas in relation to maturity and other factors. C.S.I.R.O. Aust. Div. Food Pres. Tech. Pap. No. 26.

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SMITH, M. B., and BACK, JOAN F. (1962).—Modification of ovalbumin in stored eggs detected by heat denaturation. *Nature* **193**: 878–9.

VICKERY, J. R., and HIRST, H. (1962).—Some Australian contributions to food science and technology. *Lab. Pract.* **11**: 261–6.

VICKERY, J. R., and SHENSTONE, F. S. (1961).—Nutritional factors affecting egg quality. Proc. Poult. Nutr. School, Univ. Sydney. pp. 34–7.

* Not an officer of the Division of Food Preservation.

Copies of most of these papers are available from The Librarian, Division of Food Preservation, C.S.I.R.O., Box 43, P.O., Ryde, N.S.W. (Telephone 88-0233.)

NEWS FROM THE DIVISION OF FOOD PRESERVATION

VISITORS

In July the C.S.I.R.O. Division of Food Preservation was honoured by a visit from Dr. V. Subrahmanyan, Director of the Central Food Technological Research Institute, Mysore, one of the laboratories of the Indian Council for Scientific and Industrial Research.

Dr. V. Subrahmanyan

Dr. Subrahmanyan, who recently received the Babcock-Hart Award of the Institute of Food Technologists for his efforts to improve the nutrition of the Indian people, made full use of his short stay in Australia to visit food processing plants and to study the research activities of the C.S.I.R.O. Divisions of Food Preservation, Protein Chemistry, and Dairy Research, the Bread Research Institute of Australia, the Department of Food Technology in the University of New South Wales, and the Food Preservation Research Laboratory of the Queensland Department of Agriculture and Stock, Brisbane.

Professor Harry Beevers, of the Department of Plant Physiology at Purdue University, Lafayette, Indiana, U.S.A., was a guest worker at the Division's Plant Physiology Unit at Sydney University from June to August. He delivered advanced lectures to University students, conducted seminars, and held discussions on research problems with plant physiologists and biochemists. Professor Beevers spent three weeks visiting universities and Divisions of C.S.I.R.O. in other capital cities.

FORTHCOMING VISIT

Dr. J. C. Fidler of the Ditton Laboratory of the United Kingdom Agricultural Research Council is visiting Australia for three weeks from September 20, 1962. Dr. Fidler is a leading authority on the storage of fruit and vegetables and is at present Chairman of the Technical Board of the International Institute of Refrigeration. Dr. Fidler will visit fruit-growing areas in most States of the Commonwealth and will discuss research on fruit storage with officers of C.S.I.R.O. and the State Departments of Agriculture.

OVERSEAS VISITS

Mr. E. G. Hall, Principal Research Officer, left by air for the United Kingdom on May 25 to inspect a number of experimental shipments of apples and pears carried out with the cooperation of the Shipowners' Refrigerated Cargo Research Association and the several State Departments of Agriculture. Financial support for Mr. Hall's overseas visit was given by the Apple and Pear Board, the Fibreboard Development Council, and the Fruit Shippers' Committee. The shipments were made to obtain information on the conditions obtaining on shipboard when fruit in various types of fibreboard containers and bulk bins was stowed in different types of cargo space. Temperature records during shipment were kept by means of equipment read by the ships' engineers, and in the case of one ship more detailed data were obtained by Mr. R. Scrine of the Shipowners' Refrigerated Cargo Research Association. Out-turn on arrival was examined by Mr. Hall, with the assistance of officers of the Australian Department of Primary Industry and from

the Covent Garden Laboratory of the United Kingdom Agricultural Research Council.

Four members of the Division who attended the first International Congress on Food Science and Technology held at the Imperial College of Science and Technology, London, England, from September 18 to 21, 1962, presented papers, some on behalf of their colleagues in the Division. The staff members were Dr. J. R. Vickery, Mr. J. F. Kefford, Dr. J. H. B. Christian, and Dr. D. L. Ingles.

Dr. J. R. Vickery, Chief of Division, attended the meeting of European Meat Research Workers in Moscow, U.S.S.R., from August 20 to 27, and subsequently visited food research laboratories in Europe to study current work on meat and fish. While in the United Kingdom for the International Congress on Food Science and Technology, Dr. Vickery also attended an international symposium on Food Regulations in relation to International Trade, where problems associated with food additives came under discussion. Dr. Vickery will return to Australia at the beginning of November after visiting en route many food research centres in the United Kingdom, Canada, and the United States.

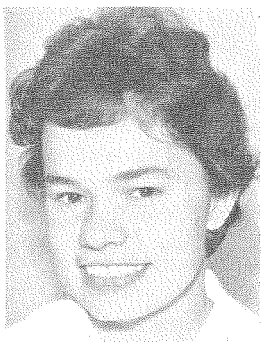
Mr. J. F. Kefford, Senior Principal Research Officer, left Sydney on June 7, 1962, to attend the 22nd Annual Meeting of the Institute of Food Technologists at Miami Beach, Florida, U.S.A., from June 10 to 14, where he took part by invitation in a symposium on citrus products. Mr. Kefford visited research laboratories in various parts of the United States until the end of July when he continued his studies of canning and fruit juices on the continent of Europe and in the United Kingdom. Mr. Kefford returns to Australia at the end of September after attending the International Congress on Food Science and Technology.

Dr. J. H. B. Christian, Principal Research Officer, left Sydney on August 15 to attend the Eighth International Congress of Microbiology at Montreal, Canada, from August 20 to 24. In the following week he led a symposium at a Conference on the Microbiological Quality of Foods at Franconia, New Hampshire, U.S.A. Dr. Christian is to visit microbiology laboratories in the United States, Canada, and the United Kingdom, and in addition to attending the International Congress on Food Science and Technology in London, he will deliver lectures at an Advanced Course on Biochemistry and Biophysics in Food Research at Cambridge, England. Dr. Christian will revisit the U.S.A. in the course of his return to Australia, where he is expected to arrive at the end of October.

Dr. D. L. Ingles, Senior Research Officer, is leaving Purdue University, Lafayette, Indiana, U.S.A., where he has held a post-doctoral fellowship, on September 1, to visit laboratories in the United States, the United Kingdom, and Europe, and to attend the International Food Science Conference in London. He will return to Australia by ship.

HICKS MEMORIAL PRIZE

Miss Jeanette Barr, who became an Associate of the Sydney Technical College in June 1962 on completion of a Diploma Course in Applied Biology, has been awarded the Hicks Memorial Prize for 1962. The award is given annually to the Technical Assistant in the Division who obtains the most outstanding results on graduation.



Miss Jeannette Barr

Miss Barr, who is proceeding to an Honours B.Sc. degree at the University of New South Wales, obtained a credit in experimental biology and distinctions in microbiology and biochemistry.

Sources of Finance, 1961-62

IN 1961–62, the Commonwealth Treasury financed the activities of the Division of Food Preservation to the extent of £363,000, made up as follows:

	£
Salaries, and payments in the nature of salary	256,862
Equipment (including special grant of £7400 for 1961–62)	33,718
Consumable supplies, food supplies, services, travel, general maintenance, etc.	72,420

Considerable amounts were contributed also by Government Departments, statutory bodies, and private industry in support of specific investigations. In 1961–62, the following such contributions were received:

	£
Australian Meat Board	
Meat investigations at Cannon Hill, Qld.	500
Metropolitan Meat Industry Board, Sydney	
Muscle biochemistry investigations	500
Queensland Meat Industry Board	
Investigations at Meat Research Laboratory, Cannon Hill, Qld.	1275
Department of Primary Industry	
Fruit fly sterilization investigations on citrus fruits, and investigation on removal of spray residues from fruit	5200
N.S.W. Department of Agriculture	
Fruit storage investigations	2200
Australian Apple and Pear Board	
Apple and pear storage investigations	500
Australian Dried Fruits Association	
Investigations on dried tree fruits and on mould attack on prunes	500
Australian Egg Board	
Investigations on storage disorders in eggs	750
Council of Egg Marketing Authorities of Australia	
Survey on egg quality during marketing	1500
Broken Hill Pty. Co. Ltd.	
Tinplate corrosion investigations	6000
	£18,925

Three Australian organizations—the Apple and Pear Board, the Fibreboard Development Council, and the Fruit Shippers' Committee—combined to make a contribution which enabled the Division to send a senior officer to England to report on the ship transport of apples and pears in fibreboard containers and bulk bins.

Substantial contributions towards the cost of overseas travel by other officers accompanied invitations to participate in scientific conferences and lecture courses.

In addition to donations for specific purposes, the Division has received many general donations from the Australian food industry. These donations, first solicited in 1956, had amounted to £25,000 by June 30, 1962, of which amount nearly £4000 was obtained in 1961–62. It is with great pleasure that the Division places on record its sincere appreciation of the generous support afforded its activities during the financial year 1961–62 by the following donors:

A. Boake, Roberts & Co. (Australia) Pty. Ltd.
Committee of Direction of Fruit Marketing
Corona Essence Pty. Ltd.
Dewey and Almy Pty. Ltd.
F. J. Walker Ltd.
Gordon Edgell & Sons Ltd.
Green's Products Limited
Harry Peck & Co. (Aust.) Pty. Limited
Holbrooks Pty. Limited
James Barnes Pty. Limited
John Darling & Sons Pty. Ltd.
Matthews Thompson Co. Ltd.
Orange Fruitgrowers' Co-operative Cool Stores Ltd.
P. Methven & Sons Pty. Ltd.
Port Huon Fruitgrowers' Co-operative Association Ltd.
Port Huon Juices Pty. Ltd.
Raleigh Preserving Co. Pty. Ltd.
Rosella Preserving & Manufacturing Co. Ltd.
Sardik Engineering Pty. Ltd.
Taubmans Industrial Coatings Pty. Ltd.
Unilever Australia Pty. Ltd.