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Water Vapour Permeability of Food Packaging Materials

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Investigations on the protective properties of various types of flexible film for the packaging of food form part of the container research programme of the CSIRO Division of Food Preservation. The studies, over a wide range of conditions, have already led to the accumulation of many data on a number of factors that influence the water vapour transmission rates of such films, and these observations may be of interest to food packers and manufacturers of package material.

GASES and vapours may pass through membranes by two distinct mechanisms. One, a pore effect, is due to the presence of microscopic pores that enable the volatile material to pass through the membrane. The other is a solution–diffusion phenomenon, whereby the gases or vapours are actually dissolved in the membrane on one side, diffuse through the material, and escape from the other side. For either mechanism the rate of passage is influenced by the relative concentrations of the gases or vapours at each side of the membrane, i.e. the partial pressure gradient across the membrane.

Although aluminium foil can be permeable only through operation of the first mechanism, organic films, when sufficiently thin, may be permeable through both mechanisms. However, plastic films in thicknesses used commercially for food packaging are substantially pore-free, and therefore transmit volatiles by the second mechanism only, i.e. by solution and subsequent diffusion. Hence for such materials the gas and vapour permeability of the film may be truly regarded as a reflection of this process alone.

THEORY AND DEFINITIONS

The permeability of homogeneous films to gases under ideal conditions may be expressed in terms of the *Permeability Constant*, *P*. This has been defined by Barrer (1951) as

$$P = \frac{q.X}{A.t.p},$$

where, at a specified temperature, q is the quantity of gas diffusing through a film of area A and thickness X in time t, and p is the difference in gas partial pressure between the two surfaces. The practical significance of this relation is that values of permeability constants for specific film–gas systems are independent of area and thickness of the film sample, and of the test time and gas pressure gradient used in the tests. At the same temperature, therefore, permeability constants obtained by different test methods are directly comparable, provided that corresponding units are used (Taylor, Karel, and Proctor 1960).

The above relation does not hold for heterogeneous materials, such as coated or laminated films, or where there is interaction between the film and the test gas or vapour, such as occurs between hydrophilic materials and water vapour. The property is then defined, in the case of water vapour, as the *Water Vapour Transmission Rate* (WVTR) of the material, where

$$\text{WVTR} = \frac{q}{A.t},$$

and the relative humidity (R.H.), temperature, and material thickness and type must be specified.

A variety of units are used to express results on the WVTR or water vapour permeability of films. In this laboratory, WVTR values are expressed in the units g/100 in^2/24 hr at specified conditions of R.H.,

temperature, and material thickness, and permeability results as g/0·001 in./100 in²/24 hr/cmHg at specified temperature. Useful factors for the interconversion of the various permeability units used in the literature are available (Selby 1961; A.S.T.M. 1953).

EXPERIMENTAL METHODS

The WVTR of packaging film materials at temperatures above 20°C is determined in this laboratory by the British Standards Institution (1959) method, but the test atmosphere conditions are varied when necessary. There are other, similar methods (TAPPI 1945, 1949; A.S.T.M. 1953). In all of these methods, a circular sample of the material under test is sealed with wax across the opening of an aluminium dish containing a desiccant; the assembly is then stored under controlled conditions of temperature and R.H., and the uptake of moisture followed gravimetrically. Recently, Lelie (1964) described an apparatus which permits weight changes of test dishes to be followed without removing the dishes from the test atmosphere.

The WVTR of made-up packages is determined by the A.S.T.M. (1951*a*) method, with variations of the test atmosphere. In the work now described, test packages were made from the flexible film materials by fin sealing, using thermal-impulse sealers for homogeneous and polyethylene-laminated materials and hot-jaw sealers for coated viscose films. Paperboard cartons were fabricated and sealed on a commercial carton-forming and sealing machine.

At temperatures above 20°C, PATRA* cabinets (Fig. 1) were used to obtain required test atmospheres, temperature being controlled by electrically heated water jackets and thermostats, and R.H. by saturated salt solutions. Satisfactory results were also obtained with modified Labmaster Model D4† desiccator cabinets housed in constant-temperature rooms. The latter cabinets are fitted with an electric fan to promote air circulation, and shallow polyethylene trays are placed on each shelf to hold saturated salt solutions. The metal joints and sealing surfaces around the doors are gasketed to reduce changes in R.H. by diffusion. The use of laboratory desiccators containing saturated salt solutions with no provision for stirring the internal atmospheres is liable to give erroneous results, and cannot be recommended for WVTR estimations (Martin 1962).

Fig. 1.—PATRA cabinet for determining WVTR under known conditions of temperature and humidity.

For WVTR measurements at low temperatures, viz. −20°C, the TAPPI (1952*b*) method was used in this work. This method also involves circular samples of material sealed with wax* in aluminium dishes, but the made-up dishes are stored in a sealed metal box packed with ice and housed in a constant-temperature room (Fig. 2). The dishes are removed from the boxes at intervals for weighing.

The WVTR values reported in this article represent the arithmetic means of not less than triplicate estimations. In several instances more than one batch of a specific type of material was examined, and for these the values are recorded as a range. The mean thickness of test samples cut from the

*Designed by the Packaging and Allied Trades Research Association (PATRA) and available from Laboratory Thermal Equipment Ltd., Greenbridge Lane, Greenfield, England.

†Available from Drug Houses of Australia Ltd., Anax Division.

*A special wax blend, available from Technical Waxes (Aust.) Pty. Ltd., was necessary to give satisfactory seals at −20°C.

homogeneous materials was determined by the A.S.T.M. (1957) method using a dial-gauge micrometer graduated to 0·0001 in., and from such data the WVTR results were corrected to a unit thickness of 0·001 in.

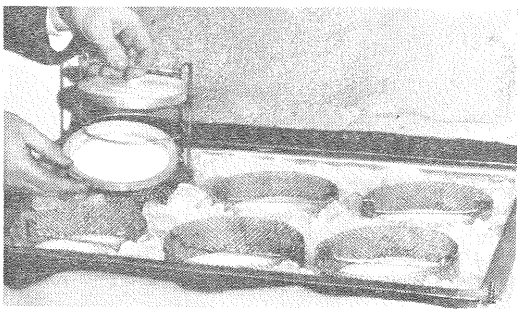

Fig. 2.—Apparatus for determining WVTR at −20°C.

RESULTS OF LABORATORY TESTS

WVTR of Film Samples

The WVTR value of a packaging material is a fundamental property to consider when selecting materials for the packaging of foods whose moisture content must be maintained within specified limits during distribution and storage. Most published information on WVTR values is determined by the test-dish method, described previously, and such data are widely used for the screening and selection of materials for specific applications.

Table 1 shows some of the WVTR data determined in this laboratory on a range of packaging materials by the test-dish method for the test conditions indicated. The relatively high values of WVTR for polyvinyl chloride and for vinyl-coated cardboard are particularly noteworthy.

WVTR of Packages

Some packaging materials are susceptible to damage during package fabrication and subsequent handling, and such damage usually results in higher water vapour transmission rates. Standard procedures (A.S.T.M. 1951*b*; British Standards Institution 1959; TAPPI 1952*a*) have been established for obtaining creased test samples, the WVTR values for which may be used for the prediction of package performance. The preferred procedure in this laboratory is to determine WVTR on made-up packages, since the efficiency of package seals as well as effects of fabrication damage are thereby measured also.

Some comparable results on the water vapour transmission rates of materials at several temperatures and R.H. levels, determined by both the test-dish and the package methods, are set out in Table 2. The two methods gave similar results with polyethylene, carton board waxed on one side and polyethylene-coated on the other side, MXXTA viscose film, MSADT viscose film laminated to polyethylene, and MXDT types of viscose film laminated to polyethylene. However, with MSAT viscose film, results by the package method were higher than those observed by the test-dish method. Cartons made from board waxed on both sides were more permeable to water vapour at 37·8°C and 90% R.H. than expected from the test-dish results, but the results at −20°C and 100% R.H. suggest that the effects of package fabrication are not important at very low temperatures with this type of material.

Because packages made from three batches of the MSAT viscose film were approximately three times more permeable than expected from the test-dish results (Table 2), the effect of heat seals on one batch was investigated by the dish method. In agreement with theory, the results (Table 3) show that for a double layer of film the WVTR was approximately half that of a single layer. However, a single heat seal across a double layer of film increased the WVTR of the double layer approximately four times; and even larger increases were observed with multiple heat seals. These increases in permeability of MSAT viscose film were observed with two types of hot-jaw heat sealers, both operated as recommended by the film suppliers. Hence in addition to the effects of creasing, which are known to increase the WVTR of MSAT viscose film (Paine 1955), it appears that heat sealing may also have an adverse effect on packages made from this material.

Effect of Relative Humidity Gradient

Under ideal conditions, the WVTR of film materials should be directly proportional to the R.H. gradient between the film surfaces; in other words, the permeability constant *P*

should be independent of the gradient. This has been demonstrated with hydrophobic films, such as polyethylene and polyethylene–terephthalate films; but with hydrophilic materials, such as plain viscose film and polyvinyl alcohol, the WVTR is not directly proportional to R.H. (Myers *et al.* 1961; Karel, Proctor, and Wiseman 1959).

The results of WVTR estimations on a range of films at various humidity levels up to 85% R.H. are plotted in Figure 3, which shows that for polyethylene and for MXDTA viscose film laminated to polyethylene the WVTR value is directly proportional to R.H. The WVTR values for MSAT viscose film and for MSADT viscose film laminated to polyethylene are also dependent on R.H., but these materials are relatively more permeable to water vapour per unit vapour pressure gradient at high than at low R.H. levels.

Results with MXXTA viscose film were similar to those observed on the MXDT viscose film–polyethylene laminate and are not plotted in Figure 3.

Table I

Water Vapour Transmission Rates of Some Food Packaging Materials

Material	WVTR (g/100 in²/24 hr)	
	37·8°C, 90% R.H.	25°C, 65% R.H.
Polyethylene, low density (0·001 in.)	1·0–1·2	0·26
Polyethylene, intermediate density (0·001 in.)	0·42	
Nylon 11 (0·001 in.)	2·2–2·8	
Polyvinyl chloride, unplasticized (0·001 in.)	3·5	
Polyvinyl chloride, plasticized (0·001 in.)	4·3–6·8	
Polyethylene–terephthalate (0·001 in.)	1·7	
Polypropylene (0·001 in.)	0·84	
MSAT 400 viscose film	0·28	0·05–0·14
MXXTA 300 viscose film	0·58	
MXXTA 400 viscose film (two lots)	0·18, 0·18	0·02–0·06
MXXTS 300 viscose film	0·52–0·61	
MXXTS 400 viscose film	0·54	
MXXTS 450 viscose film	0·36	
MSADT 300 viscose film/0·0006 in. polyethylene	1·8	
MSADT 300 viscose film/0·001 in. polyethylene	0·68–1·3	0·13–0·28
MSADT 300 viscose film/0·00175 in. polyethylene	0·45	
MXDTA 300 viscose film/0·001 in. polyethylene	0·25	0·03
MXDTS 300 viscose film/0·0015 in. polyethylene	0·29	
MXDTS 400 viscose film/0·00175 in. polyethylene	0·25	
MXDTS 400 viscose film/0·002 in. polyethylene	0·25	
Polyethylene–terephthalate/0·0015 in. polyethylene	0·52	
Bleached glassine, waxed (40 g/m²)		0·08
Superglazed, opaque paper, waxed (38 g/m²)		0·15
Superglazed, opaque paper, waxed (50 g/m²)		0·12
Glazed imitation parchment, waxed (65 g/m²)		0·12
Bleached glassine wax laminated to bleached glassine	0·53	
Opaque glassine wax laminated to opaque glassine	0·76	
Carton board (0·014 in.), waxed both sides	2·4	
Carton board (0·014 in.), waxed one side, polyethylene (0·0005 in.) coated other side	1·8	
Carton board (0·014 in.), Saran-coated both sides	1·9	
Carton board (0·014 in.), vinyl-coated both sides	6·4	
Carton board (0·014 in.), wax–polyethylene blend coat on both sides	1·1	

Table 2

Comparison of Water Vapour Transmission Rates of Packaging Materials by Test-dish and Package Methods

Material	Test Conditions	WVTR (g/100 in²/24 hr)	
		Dish Method	Package Method
Polyethylene, low density (0·001 in.)	37·8°C, 90% R.H.	1·0	0·89
	25°C, 65% R.H.	0·26	0·21
	−20°C, 100% R.H.	0·0040	0·0041
Carton board (0·014 in.) waxed both sides	37·8°C, 90% R.H.	2·4	7·1
	−20°C, 100% R.H.	0·23	0·26
Carton board (0·014 in.), waxed one side, polyethylene-coated (0·0005 in.) other side	37·8°C, 90% R.H.	1·7	1·5
	−20°C, 100% R.H.	0·02	0·02
MSAT 400 viscose film (batch 1)	25°C, 65% R.H.	0·07	0·23
MSAT 400 viscose film (batch 2)	25°C, 65% R.H.	0·14	0·46
MSAT 400 viscose film (batch 3)	25°C, 65% R.H.	0·05	0·15
MXXTA 400 viscose film	25°C, 65% R.H.	0·02	0·03
MSADT 300 viscose film/0·001 in. polyethylene	25°C, 65% R.H.	0·32	0·27
MXDTA 300 viscose film/0·001 in. polyethylene	25°C, 65% R.H.	0·04	0·03

Effect of Temperature

The effect of temperature on the permeability of film materials is complicated but, as suggested by Barrer (1951), may be represented mathematically by the equation

$$P = P_0 \exp(-E/\mathrm{R}T),$$

where

P_0 = a temperature-independent constant,
E = activation energy of permeability,
R = gas constant,
T = absolute temperature.

Thus, a plot of log P against $1/T$ at several temperatures should give a straight line from which the permeability at other temperatures may be predicted.

Figure 4 shows the effect of temperature over the range 25–37·8°C, at corresponding levels of 62–65% R.H., on the WVTR of packages made from several film materials. The results, corrected to unit vapour pressure gradient, are plotted on a logarithmic scale against the reciprocal of the absolute temperature.

Approximately straight-line relations appear to apply over the 20–37·8°C range with polyethylene, MXXTA viscose film, MXDTA viscose film laminated to polyethylene, and MSADT viscose film laminated to polyethylene. However, MSAT viscose film shows an appreciable departure from the ideal straight-line relation, and this material was more permeable to water vapour at 20°C than at 37·8°C.

Karel, Proctor, and Wiseman (1959) observed similar deviations from "ideal"

Table 3

Effect of Heat Seals on WVTR of MSAT Viscose Film

Sample Details	WVTR (g/100 in²/24 hr at 25°C, 65% R.H.)	
	Range	Mean
Single layer of film	0·07–0·09	0·08
Double layer of film	0·04–0·05	0·05
Double layer of film, 1 crimped-jaw heat seal across centre	0·18–0·19	0·18
Double layer of film, 4 crimped-jaw heat seals ¼ in. apart across sample	0·47–0·76	0·58
Double layer of film, 1 flat-jaw heat seal across centre	0·15–0·27	0·21
Double layer of film, 4 flat-jaw heat seals ¼ in. apart across sample	0·37–0·37	0·37

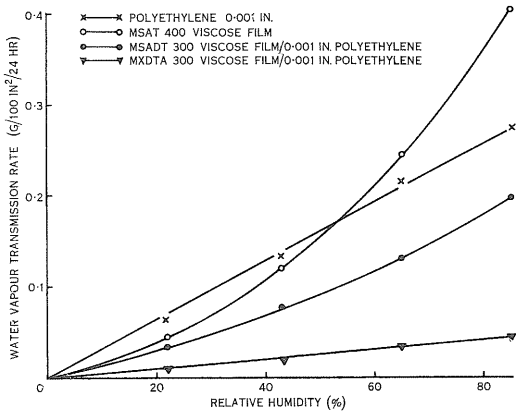

Fig. 3.—Effect of R.H. on WVTR of packages at 25°C.

behaviour with several types of film, particularly at temperatures approaching the freezing point of water. Extrapolation of data obtained at temperatures above 20°C for the prediction of WVTR for such materials at lower temperatures could therefore lead to seriously erroneous estimates.

Further work on the effect of temperature on the WVTR of materials over the temperature range 20° to −20°C is clearly required, and is to be undertaken in this laboratory.

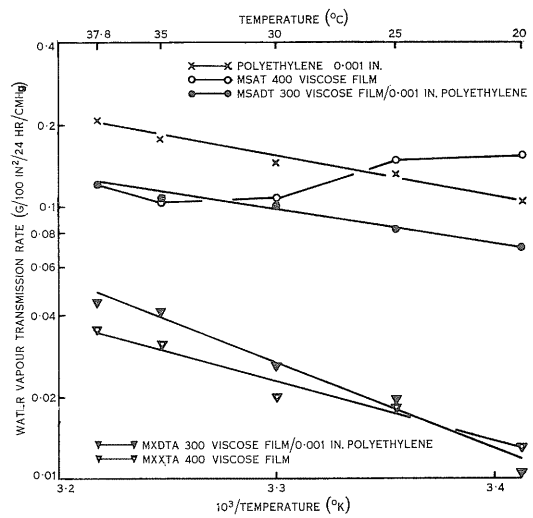

Fig. 4.—Effect of temperature on WVTR of packages at 62–65% R.H.

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*American Society for Testing Materials.

†Technical Association of the Pulp and Paper Industry.

Preservation of High-moisture Prunes in Plastic Pouches

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Prunes rehydrated to a moisture content of 30–40% are more convenient for dessert or cooking purposes than fully dried prunes. However, the packaging and storage of high-moisture prunes in containers of convenient size for retail sale at first presented many problems in Australia, chief of these being microbial spoilage. This article outlines investigations by the CSIRO Division of Food Preservation that pointed the way to commercially acceptable "hot fill" packaging procedures, and describes recent work that has led to modifications giving even better results.

UNTIL the late 1950s, Australian prunes of high moisture content (32–37%) were principally distributed in 7-lb cans, from which they were retailed in smaller lots (8–16 oz) as required. With the trend towards self-service merchandising, fewer retailers were prepared to repack the prunes. Sales began to fall off seriously, and it was necessary to consider alternatives to the 7-lb can. Smaller cans, being relatively more expensive, met with limited acceptance; but pouches made from transparent plastic film seemed to offer a suitable alternative. With pouches, however, the problem of preventing spoilage of the prunes through the development of moulds and yeasts during storage became acute. Microbial growth does not usually constitute a serious problem with canned prunes, because these are normally heat processed after sealing and the contents thereby sterilized.

The CSIRO Division of Food Preservation first considered the problem of controlling microbial growth on packaged prunes in 1955, and extensive investigations have since been carried out on this problem, with a view to establishing the nature of the micro-organisms responsible for the spoilage, the best types of packaging material to use, and the processing techniques most likely to lead to satisfactory results. An account of some of this work follows.

USE OF CHEMICAL INHIBITORS

One line of investigation early followed up in these laboratories was the use of certain chemical additives that overseas reports had indicated might prove suitable as fungistats on prunes. Of particular interest were the two epoxides, ethylene oxide and propylene oxide, and sorbic acid and its salts.

Epoxides

An account was given in a previous article (McBean and Johnson 1957) of the use of ethylene oxide and propylene oxide for preserving high-moisture prunes. Experiments showed that the addition of propylene oxide at the rate of 1 ml per litre of container space, immediately prior to heat sealing the pouches, inhibited microbial growth on prunes having moisture contents up to 33%. This method of control was easily adaptable to commercial use, utilizing either ethylene oxide or propylene oxide; it has indeed been widely used for many years in the United States of America for the preservation of prunes. However, the method has not been adopted commercially in Australia, because food regulations in the various States do not allow epoxides as food additives and prune processors have not sought permission to use propylene oxide on prunes.

Sorbic Acid and Sorbates

The fungistatic properties of sorbic acid are well known, because these chemicals have been used for many years as fungal inhibitors on pickles and cheese. Owing to its greater solubility in water, potassium sorbate is more commonly used.

Nury, Miller, and Brekke (1960) were the first to show the effectiveness of potassium sorbate in preventing the growth of yeasts and moulds on high-moisture prunes. They reported that sorbate-treated prunes sealed in plastic pouches did not develop mould during 60 days' storage at 25°C (77°F), and that mould was inhibited even when the pouches were opened and held a further 20 days at 25°C and 80% R.H. They observed that up to 50 lots of prunes could be dipped successively in the same solution of potassium sorbate without appreciable change in the rate of absorption of sorbate.

Table I

Uptake of Potassium Sorbate from Aqueous Solutions by High-moisture Prunes

Concentration of Potassium Sorbate expressed as Sorbic Acid (%)	
Dipping Solution	Absorbed by Fruit
1	0·01
2	0·02
5	0·03
10	0·05

Similar experiments later carried out by the Division on d'Agen prunes in Australia confirmed these findings. The prunes (34% moisture) were dipped for 2 min at 65°F (18·5°C) in aqueous solutions of potassium sorbate at various concentrations. Absorption of sorbate was determined by applying the method of Melnick and Luckmann (1954), modified to reduce errors caused by prune constituents. The results (Table I) showed that though in general the absorptions were lower than the values given by Nury, Miller, and Brekke (1960), they increased with the concentration of the dip. Other batches of similar prunes were immersed for 2 min in twice their weight of 3·1% potassium sorbate solution at 65°F, and after 40 successive batches had been dipped in the same solution, the sorbate concentration was 3·3%. Sorbic acid present in fruit from selected batches dipped in this way varied from 0·027 to 0·041%, with no consistent trend. Some of the dipped prunes were sealed in polyethylene pouches and stored at 25°C (77°F), but no microbial growth was macroscopically visible in any of the pouches within 15 months.

At about this time the Commonwealth Food Additives Committee recommended that sorbates be allowed in a limited range of foodstuffs, and some State Pure Foods Acts were amended accordingly. Sorbate-impregnated plastic film was, for example, allowed as wrapping for sliced processed cheese, but a maximum limit of 0·1% for sorbic acid in the cheese was specified, to guard against migration of sorbate from the wrapper to the cheese. Nevertheless, although potassium sorbate was being widely used as a fungistatic agent in high-moisture prunes in California (where it is classified as "Generally Regarded as Safe"), doubts remained whether the direct application of sorbates and similar additives to high-moisture prunes would be permitted in Australia. Preservation by some form of heat processing seemed therefore to be the only feasible alternative, but further investigation was necessary in order to develop suitable techniques if plastic pouches were to be used for packaging.

HEAT PROCESSING METHODS

Plastic pouches suitable for packaging prunes to be heat processed must possess three main characteristics:

- ability to withstand the action of steam or boiling water;
- low water-vapour permeability, to limit drying of the prunes in storage;
- an economic price.

Initially, no film fulfilled all three requirements and attempts to heat sterilize high-moisture prunes packed in pouches were consequently unsuccessful. In 1959, a method was tried wherein prunes were sealed into either nylon or Cryovac pouches and then processed in steam or boiling water. Nylon withstood the heat processes satisfactorily, but was too permeable to water vapour; while Cryovac (a Saran-type film) softened and sometimes burst at 212° F. Processing at 190°F (87·8°C) for 30 min was not sufficient to produce commercial sterility, i.e. a condition in which the number of viable micro-organisms in the prunes was reduced to a safe storage level.

Experiments were next conducted to ascertain whether adequate sterility would result

if the pouches were filled with hot, heat-processed prunes and then sealed, no subsequent heat treatment being given. The results of these tests indicated that, with care, spoilage due to microorganisms could be reduced to a low level by this procedure. Accordingly, in cooperation with prune processors and machinery manufacturers, suitable equipment was developed and a "hot fill" procedure devised, such that spoilage losses from all causes were sufficiently low to allow commercial application of the method.

Hot Fill Process

The hot fill process referred to above has been in general use in this country since 1961 and has proved quite successful. One processor, for instance, recorded only 1000 spoiled 12-oz pouches out of his total production of over a million in 1963. The type of equipment used is illustrated below.

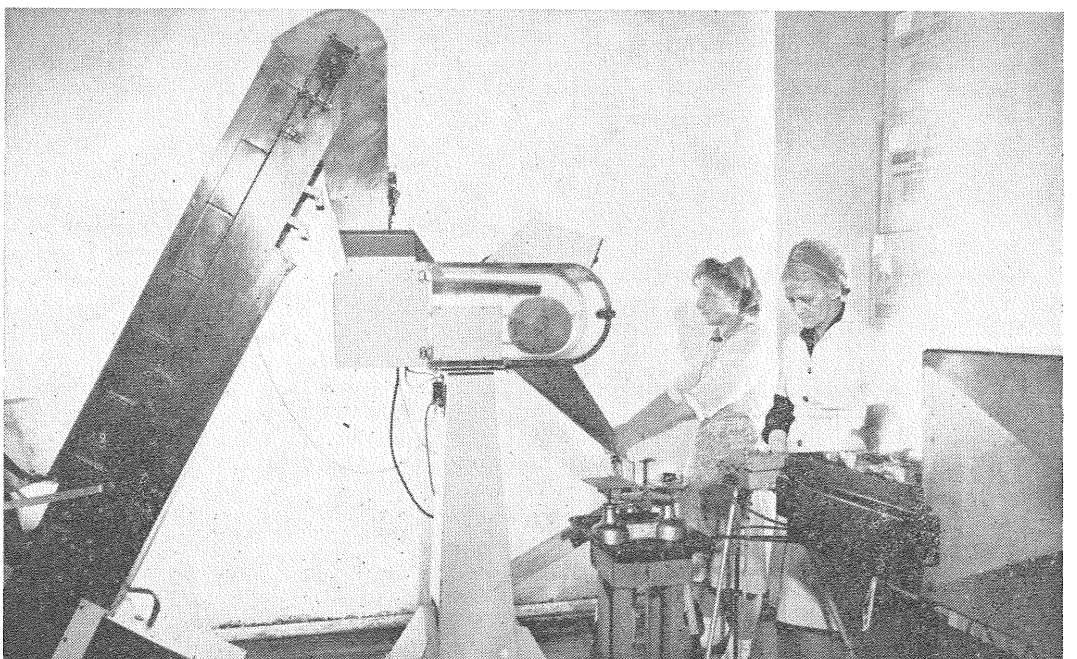
Procedure.—Dried prunes (15–18% moisture) are rehydrated in boiling water for 15–25 min to a moisture content of 32–37%. The moist, hot prunes are tipped into an insulated hopper (see photograph), from which they are conveyed by belt past an inspection section to an elevator, which feeds them to an automatic weighing machine. The hopper, conveyor system, and weighing machine are all enclosed, and the conveyor system is filled with live steam during its operation. Weighing, filling, and sealing are carried out as quickly as possible and, after sealing, the pouches of prunes are packaged in cardboard cartons.

The above procedure depends for its effectiveness on several factors. The rehydration in boiling water renders the prunes commercially sterile (Pitt 1965). Hence spoilage in storage is unlikely unless subsequent contamination occurs during or after packaging. Enclosure of the conveying and weighing systems minimizes the risk of contamination before the pouches are sealed, and steam in the conveyor system ensures that the prunes are packed hot. As the residual heat in the pouches after they have been sealed is sufficient to inactivate many types of microorganism, the risk of subsequent spoilage of the packaged prunes is further reduced. Procedures requiring handling of processed prunes by operators, such as check-weighing, should be avoided, as they may cause contamination.

CHARACTERIZATION OF SPOILAGE FUNGI

Although the hot fill process described has proved to be an effective method of reducing spoilage to a very low level under commercial conditions, a small proportion of pouches (about 0·1% of total production) may still be affected. Even this proportion

Machine for packaging prunes. Hot prunes are packaged by the machine on left, heat sealed by the operator on the right; the packages are sterilized in the tunnel shown on the extreme right.



of spoiled pouches could impose a severe limitation on export trade in packaged prunes. Further work was considered desirable, therefore, in order to type the spoilage microorganisms capable of growth on hot-filled prunes after the pouches had been sealed and, if possible, to develop a processing technique that would eliminate them altogether.

Measurements of pH and water sorption isotherms for Australian d'Agen prunes suggested that the types of microorganism able to grow on high-moisture prunes would be limited to a few genera of yeasts and moulds (Pitt 1965), and examination of a number of types of microorganism isolated from spoiled pouches confirmed this prediction. A preliminary trial on pouches of high-moisture prunes that had been inoculated with six strains of these isolated microorganisms showed that hot filling inactivated all yeast cells up to inoculation dosages of 10^6 yeast cells per pouch. Yeasts, therefore, were not a problem in the hot filling process if it was carried out as recommended above. However, enough viable spores consistently survived from inocula of 10^4 mould spores per pouch to cause spoilage.

Specific Spoilage Types

To ascertain which mould species were likely to be of greatest importance in prune spoilage, the physiological water relations of the species isolated from prunes were examined on a substrate similar to prunes. Various other drought-tolerant species were also examined. The water activities studied ranged from 0·90 to 0·71, corresponding to equilibrium relative humidities of 90 to 71% and prune moisture contents of 48 to 23%. The moulds best adapted to growth on high-moisture prunes were the members of the *Aspergillus glaucus* group (long recognized as a common spoilage microorganism of dried or concentrated foods) and the rare mould *Xeromyces bisporus*. Two species belonging to *Chrysosporium* Corda, and *Sporendonema sebi*, *Eremascus fertilis*, and some other aspergilli and a few penicillia were also capable of growth, but less readily.

Heat Resistance.—A study of the heat resistances of some of these microorganisms on a medium prepared from fresh d'Agen plums showed that ascospores of the *A. glaucus* group were more heat resistant than their conidia, while some other aspergilli, *Chrysosporium* spp., and *S. sebi* possessed relatively low heat resistances. The most heat-resistant mould was found to be *A. chevalieri*, whose ascospores were somewhat more resistant than those of *A. mangini* and *X. bisporus*. It was found that to induce a reduction of 10^5 in the number of viable ascospores of *A. chevalieri*, 18·2 min at 175°F, or 11·6 min at 180°F, was required.

Lethal Effect of Hot Filling

The cooling rates of prunes hot filled at various temperatures were measured by means of thermocouples passing through the pouch walls and sealed through glands made of brass and Neoprene rubber. From these data, the lethal effects on *A. chevalieri* ascospores of the various heat treatments applied were estimated. The results were startling, in that it was found that, unless filling temperatures were higher than 188°F, hot filling was not lethal to *A. chevalieri* ascospores at any part of the pouch. Prunes cool rapidly in air, and even when the filling temperature was 200°F, the prune surfaces near the pouch edges did not reach 160°F, at which temperature the lethal effect would be slight. Pouch extremities near the heat seal often failed to reach even 120°F, which temperature would have no lethal effect at all on *A. chevalieri* ascospores. As hot filling temperatures in commercial practice seldom exceed 180°F, it was clear that the hot fill process could not guarantee commercial sterility of high-moisture prunes contaminated with the spores of such heat-resistant species.

These findings were confirmed in experiments using pouches inoculated with 10, 100, or 1000 viable ascospores of *A. chevalieri*. The pouches were filled with prunes at 170, 180, 190, and 200°F, sealed, and allowed to cool in still air. On one pouch from each heat treatment, counts of viable organisms were made. The rest were stored at 25°C for 4 months and examined regularly for macroscopic evidence of spoilage.

Table 2 shows the percentage of spores viable after the hot-filling process, and indicates that hot filling at 200°F will not inactivate even 10 spores per pouch. Among the stored pouches, at least one from each treatment showed macroscopic evidence of mould growth within 2 weeks. After 6 weeks, over 75% of the pouches had spoiled.

Table 2

Percentage Recovery from Hot-filled Pouches with Various Inocula of Initially Viable *Aspergillus chevalieri* Ascospores

Filling Temperature (°F)	Survivors (%)		
	Initial Inoculum Viable Spores/Pouch		
	10	100	1000
170	20	28	33
180	10	56	47
190	0	23	19
200	30	11	16

The effectiveness of the hot-filling process in commercial practice, then, must depend on asepsis, i.e. the almost complete exclusion of potential spoilage microorganisms from the packaging line, and packers using the process must exercise the utmost vigilance, so as to minimize microbial contamination of the prunes at all stages of packing.

HEAT PROCESSING AFTER SEALING

From the evidence reported above it was clear that the hot fill process, even if carried out with the greatest care, could not be relied upon to inactivate certain species of mould with which the prunes might be infected. Accordingly, to eliminate spoilage entirely from preservative-free high-moisture prunes packaged in pouches, further heat sterilizing treatments might be required after sealing. Progress in this direction also clearly depended upon the commercial availability of suitable plastic film.

Davis (1962) had reported that of the film materials then commercially available, those most likely to withstand exacting heat-processing conditions and fulfil other essential requirements for pouches for high-moisture prunes were medium-density polyethylene, polypropylene, heavy-gauge nylon, and an extruded laminate of 300 MSAT viscose film and polyethylene. Unfortunately, pouches made from any of these films required printing on the exterior, and tests showed that, even after lacquer coating, the printing inks would not always withstand much heat treatment. However, about this time a laminated film became available which possessed all necessary characteristics, including interlaminate printing. It was made from viscose film (0·0012 in.) coated with polyvinylidine chloride and laminated to polyethylene (0·00175 in.) by means of a thermosetting resin. Accordingly, pouches were made from this film and tested as described below.

The pouches, fitted with thermocouples, were filled with prunes at various temperatures, sealed, heated in steam at 212°F, and cooled in ambient air. In parallel trials, identical pouches were inoculated with 1000 ascospores of *A. chevalieri* and, after filling with either cold (80°F) or hot (140–160°F) prunes containing 37% moisture, were steamed for periods of up to 30 min and then cooled in ambient air. Counts of viable organisms were made on one pouch from each treatment, the rest being stored at 25°C for 4 months and examined regularly for macroscopic evidence of mould growth.

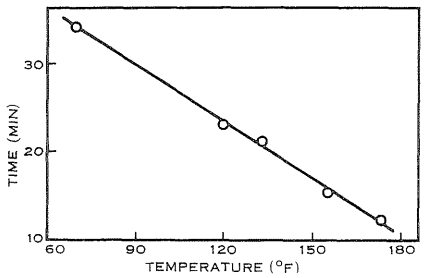
The results of both sets of experiments showed that prunes in pouches require substantial heat treatment to ensure that they become commercially sterile. Temperature distribution data obtained in these experiments showed that heat penetration into cold packaged prunes was very slow. As shown by Tables 3 and 4, even after the packages had been steamed for 30 min the cold-packed prunes contained enough viable organisms to induce spoilage; but hot filling did result in a useful shortening of the processing time required to produce sterility.

Table 3

Average Viable Counts per Prune of *Aspergillus chevalieri* Ascospores after Various Heat Processes*

Time in Steam (min)	Viable Count per Prune	
	Filling Temperature Cold (80°F)	Filling Temperature Hot (140°–160°F)
0	23·3	3·9
5	18·9	7·4
10	22·4	1·3
15	24·3	0·4
20	18·3	0
30	2·4	0

*Initial viable count 1000 ascospores per pouch, equivalent to about 25 per prune.



Effect of filling temperature on heating time required in steam to commercially sterilize high-moisture prunes in 12-oz pouches.

The graph on this page shows the relation between filling temperature and subsequent time in steam at 212°F required to produce commercial sterility. It indicates that at a filling temperature of 140°F, the process time required in steam is 20 min; but if a filling temperature of 180°F can be attained, only 10 min is required.

CONCLUSION

The post-sealing process outlined above is designed to supplement rather than replace the hot-fill procedure. Where high-moisture prunes in pouches are intended for local sale, with rapid turnover, hot filling is the simplest and most economical process. Where returns through spoilage cannot be tolerated, however, as for export markets or where pouches might be held for a long period under adverse conditions, processing in steam after hot filling is indicated. This procedure is the most effective way of producing commercially sterile high-moisture prunes without the use of chemical preservatives.

If a process using a heat treatment after sealing were adopted commercially, processors should note the following points.

- Times shown in the graph at left have been determined for d'Agen prunes of 35 to 37% moisture content. Similar times should be required for d'Agens, and other varieties, of 32 to 40% moisture content.
- The graph relates to the standard commercial pouch, which holds 12 oz of prunes and is approximately 8 in. by 6 in. overall when empty. Pouches should be uniformly filled, to no more than 1 in. thickness at any point.
- Filling temperature as shown on the graph is defined as the maximum indicated by a thermometer whose bulb is placed at the estimated centre of the pouch immediately after filling.

Lethalities of the process times were calculated for a 10,000-fold reduction in viable numbers of *A. chevalieri* ascospores. If the conditions recommended for hot filling are observed, processing for the times shown in the graph should reduce spoilage to no more than 1 pouch per 100,000.

A steam-heated tunnel situated adjacent to the packaging and sealing units (see photograph on page 29) provides a convenient means of sterilizing the packages after sealing.

Table 4

Spoilage of Pouches of Prunes Inoculated with *Aspergillus chevalieri* Ascospores after Various Heat Processes*

Time in Steam (min)	Pouches Spoiled (out of 12)	
	Filling Temperature Cold (80°F)	Filling Temperature Hot (140°–160°F)
0	12	12
5	12	8
10	12	4
15	12	2
20	12	0
30	11	0

*Viable inoculum 1000 spores, stored 4 months at 25°C, 12 pouches each treatment.

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The Drying of Fruits in Australia and California

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Preservation by drying is probably the oldest method employed by man to keep supplies of foodstuffs for long periods, but methods have evolved differently in different parts of the world, according to local conditions and traditions. Dr. Miller was attached to the CSIRO Division of Food Preservation as a Fulbright Scholar from December 1964 to June 1965 and in this article compares techniques used by the fruit drying industries of Australia and California.

FOR most purposes, dried fruits can be grouped into two categories. In the first category are dried vine-fruits, comprising mainly raisins and sultanas produced from grapes, seedless or otherwise.*

In the second category are dried tree-fruits, which can be further grouped into those usually dried whole (prunes, plums, figs, etc.) and those normally cut into halves or smaller pieces before drying (apples, apricots, peaches, nectarines, and pears), which are referred to as "cut" tree-fruits.

VINE-FRUITS

With an average annual total approximating 90,000 and 225,000 tons for Australia and California respectively, the production of dried vine-fruits constitutes the largest segment of the dried fruit industries in each of these two areas. The production of sultanas from the Sultana (Australia) or Thompson Seedless (California) variety of grape accounts for the greater part of total production (65–70% and 90% respectively). The remainder includes raisins produced from the "raisin" and Lexia grape (Australia) and the Muscat (California), and currants from the Zante Currant (Black Corinth) grape.

While both the Australian and Californian methods are dependent upon hot, dry weather for their success, vineyard rows in California are orientated east–west to obtain maximum sunlight on the grapes while they are drying on trays laid between the rows. In this way colour development is enhanced. In Australia, however, the grapes are dried on racks customarily built with the long axis north–south for minimum exposure to the sun, thus assuring the light colour desired in Australian sultanas.

*In the U.S.A., dried grapes of the Thompson Seedless variety are called raisins, not sultanas as in Australia. Muscats (U.S.A.) correspond to the "raisin" of Australia.

Raisin Production Methods

The raisin-producing areas in both Australia and California generally have a favourable climate, although unfavourable conditions are more frequently encountered by Australian producers, who may have to contend with high humidity or even rain towards the end of the drying season, these conditions necessitating the use of auxiliary drying equipment. Methods for drying the Thompson Seedless variety of grape in California differ appreciably from those used in Australia for the (identical) Sultana variety, and the dried products are also different.

The simpler procedure is used in California. Bunches of Thompson Seedless grapes are hand picked when fully ripe (18–26° Brix), and spread to dry in the sun on clean paper trays (about 2 ft by 3 ft) laid between the rows of vines. When nearly dry, they are rolled into bundles and left in the field to cure completely. The grower then places the dried fruit in boxes for delivery to the raisin packer, who places the fruit under fumigation until it is processed. This type of raisin is dark brown in colour, with the waxy bloom of the grape remaining on the berries, and contains 12–14% moisture.

Golden Bleach Raisins

In California the "golden bleach" type of raisin, corresponding roughly to the sultana of Australia, is produced from the Thompson Seedless variety grape. The grapes are dipped in caustic soda, to remove the waxy bloom and check the skin, rinsed in water, and loaded onto wooden trays (3 ft by 6 ft), which are placed on low trucks or trolleys. They are then exposed to the fumes of burning sulphur for a short time, after which they are dehydrated at a moderate temperature. This type of raisin, of a light golden colour, is produced to the extent of about 15,000 tons annually in the San Joaquin Valley, central California.

Sultanas

In Australia the Sultana is harvested as in California, but the harvested grapes are placed in "dip tins" (14 in. by 11 in., and 4 in. deep) made of perforated galvanized iron; these are loaded onto steel frames, which on the average hold about 75 tins. The tins are taken from the field to a central location, where they are immersed in a dip consisting of an alkaline emulsion of a vegetable oil with alkali salts of fatty acids and sulphonates. This treatment, which has evolved from the traditional Greek practice of dipping the grapes in an emulsion of potash (wood ash) and olive oil, reduces the time required to dry the grapes from about 20–30 days to 7–14 days.

The dipped fruit is spread on drying racks consisting of tiers of wire netting tightly stretched in a timber or metal framework. About 15 tons of fresh, dipped grapes can be accommodated in each rack. Usually the racks are 50 yd long and 4 ft wide, and have 9 or 10 tiers of wire netting, the tiers being spaced 9 in. apart. Some racks are roofed with corrugated metal, laid flat. These racks can also be converted to temporary drying tunnels during inclement weather by attaching curtains to the sides and passing warm air through the tiers of drying fruit, using an oil-fired heater and a fan for this purpose.

When nearly dry, the sultanas are shaken from the wire netting onto hessian cloth, placed in the sun for a short period for colouring, and then rolled up in the hessian to finish curing before being placed in boxes for delivery to the packer.

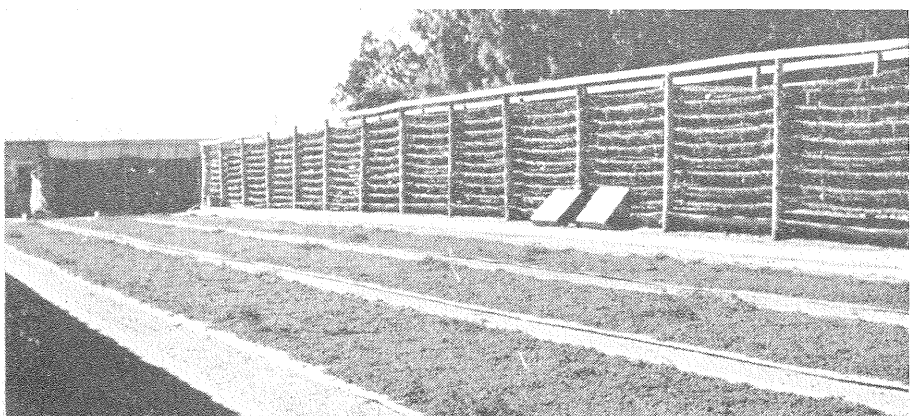
Australian sultanas have a light golden tan colour, and lack the waxy bloom of the fresh grape, as this is removed in the alkaline dipping treatment. Production is centred in the Sunraysia district around Mildura, Vic.

Muscats

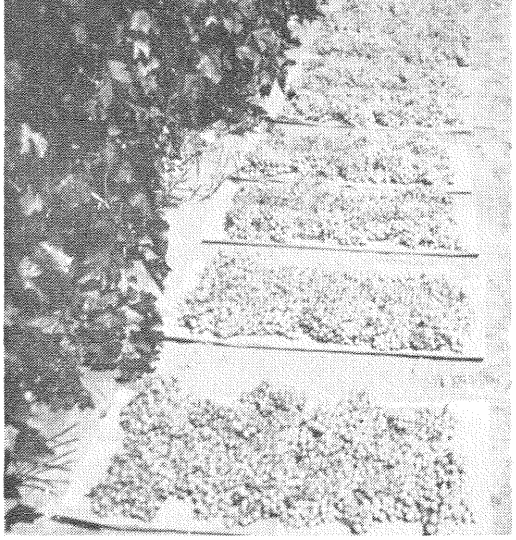
In California, Muscat (Gordo) grapes are dried in the field in a similar way to Thompson Seedless, but are turned on the trays when half dry; this is to ensure uniform drying, as the grapes are larger than the Thompson Seedless variety. Muscat raisins are produced in Australia in a manner similar to the sultanas, although cluster-type muscatels, produced from the Waltham Cross variety, are not dipped but are dehydrated in bunches, or clusters, at a moderate temperature (135–140°F) and high humidity for 75–80 hr.

Post-drying Processes

Processing of the dried fruit for the consumer is much the same in California and Australia. Stalks, berry or cap stems, leaves, other debris, and the small, light-weight berries resulting from immature fruit, are separated from the fully mature raisins (except the cluster-type muscatels) by shaker screens and various types of stemmers and air streams. Since in California the waxy bloom is left intact and extraneous material rarely adheres to the berries, final cleansing is accomplished simply by carrying the raisins over a "riffle" in a stream of water to remove relatively heavy debris. This treatment is followed by the removal of excess water, and packaging. As a result



Sultana drying in Australia. In the background is a rack on which dipped grapes are spread for initial drying. In the foreground partly dried sultanas are spread on hessian where drying is finished in direct sunlight.



Sultana drying in California. The harvested grapes, which are not dipped, are dried in direct sunlight on heavy paper trays set down between the rows of vines.

of the dipping practised in Australia there is a greater tendency for extraneous material to adhere to the drying berries, and more thorough cleansing is required. This is followed by an application of a thin film of an emulsion of paraffin oil and oleic acid, to prevent the berries from sticking together when packaged.

CUT TREE-FRUITS

Annual production figures for dried, cut fruits are quite modest compared with those of the dried vine-fruits. In Australia approximately 1800 tons of dried apricots, 800 tons of dried peaches, and 200 tons of dried pears are produced each year. In the same period California produces 9000, 8000, and 1800 tons respectively. In both production areas the actual annual tonnages are markedly influenced by the demands of the fresh fruit markets and by canners' requirements.

Cut fruits used for drying range from "orchard run" fruit, picked from the trees, to fruit picked for the fresh markets or canneries but surplus to their requirements. Most cut fruits are picked ripe, but pears are picked hard and green and ripened before use.

Sulphuring Equipment

Preparatory to drying, the fruit is brought to a cutting shed, where workers cut the fruits in halves and place them cut side upwards on wooden trays. Although cutting machines are used by some Californian driers, hand cutting is usual. Filled trays (generally 2 ft by 3 ft in Australia, 3 ft by 6 ft in California) are stacked on pallets or low trucks for sulphuring.

In Australia, two types of sulphuring enclosures are in use, permanent or temporary. The permanent type is constructed of concrete, concrete blocks, or lumber. It is from 5 ft to 6 ft in height and about 4 ft by 5 ft in area, and will accommodate a double stack of trays (2×25 trays) on pallet or truck. The sulphur-burning chamber may be a shallow trench in the floor, or attached to the rear of the sulphuring house. One permanent type observed was in the form of a tunnel that could hold up to four trolleys. The trolleys entered in succession, with a sulphuring period between, thus making operations semi-continuous.

The temporary chambers consist of plastic tents made from PVC sheeting 0·008–0·010 in. thick. These are used for supplementing sulphuring capacity, or by some driers who have only small tonnages of fruit to handle. The tent is slipped over a double stack of trays, and its bottom edges sealed by heaping dirt or placing timbers on them. The chamber in which the sulphur is burnt is an inverted V-shaped sheet metal form, which attaches to the tent.

The plastic tent is not used in California, and the permanent sulphuring houses there are built to accommodate 3 ft by 6 ft trays but vary in total capacity. In California, single-car houses are not as common as two- and three-car enclosures, and sulphuring chambers attached to the rear of the house are uncommon.

Sulphuring Techniques

While in both countries the sulphuring practice of individual operators is fairly consistent, there is a wide variation of techniques within the industry as a whole. This is more apparent in Australia, since in California both the structures and operations are somewhat more standardized. The quantity of sulphur burned for each charge of fruit, and the time of exposure to the fumes of sulphur dioxide, vary with the variety of fruit being sulphured and the individual operator. The rate of burning is influenced by how well the house is sealed, by the size of inlet and outlet vents, and by the strength and direction of the wind. Attempts are made to control the rate of burning by adjusting inlet and outlet vents while keeping

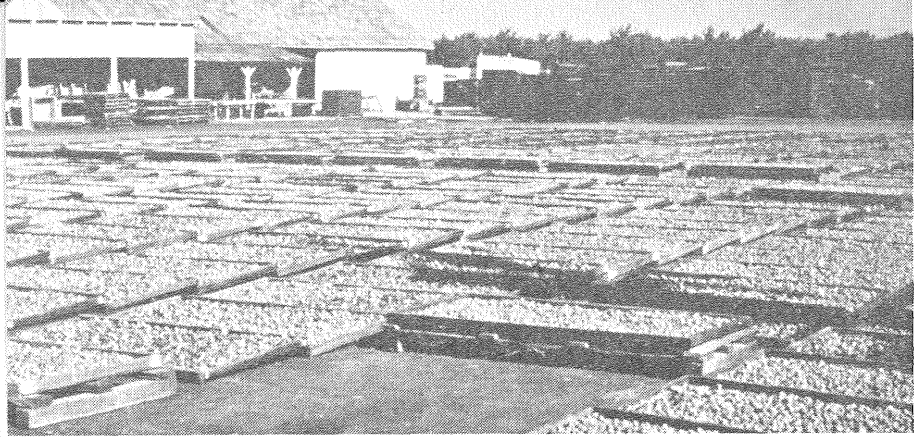


Fig drying in California. The figs are in wooden trays in a drying yard, which is sealed to reduce dust, and the trays are arranged to receive as much sunlight as possible.

the amount of sulphur relatively constant. More uniformity in respect of sulphur dioxide treatment of the fruit would be of benefit to the industry, as the amount of sulphur dioxide absorbed during this operation is reflected in the keeping qualities of the dried product and in its acceptability to the purchaser.

Drying of Sulphured Cut Fruits

The sulphured trays of fruit are spread in a drying yard on the earth, on straw, couch grass, or mown lucerne (Californian drying yards are generally earth-surfaced or paved). Here the sunlight and wind start the drying process, and give the various cut fruits their characteristic translucency and colour. After one to several days, depending upon the fruit and the weather, the trays are again stacked, an empty tray placed on top, and the drying completed without further exposure to the sun.

The dried fruit is removed from the trays when the moisture content has reached the desired level (14–16%), and placed in boxes where "sweating" or moisture equilibration occurs before delivery to the packer.

Some operators expose the sulphured fruit to the sun for 1–2 days, and finish drying in a counter-flow dehydrator using a moderate temperature (120–140°F). Thus the final moisture level desired is obtained in 10–16 hr rather than in 5–15 days as in stack drying.

After-processing

Final processing of dried cut fruits consists of washing the dried fruit after sizing and grading, removing excess water, and placing the washed fruit on trays for a brief resulphuring treatment. The latter is generally done with fumes from burning sulphur, although a dip in a metabisulphite solution is used for some products. Finally the product is packaged.

WHOLE TREE-FRUITS

Prunes

The prune is virtually the only tree-fruit grown exclusively for drying, and very small amounts are sold fresh or otherwise processed. Prunes are the main tree-fruit dried whole in Australia: approximately 4000 tons are produced annually. California produces about 165,000 tons and, in addition, dries about 22,000 tons of figs each year. Australia recorded a production of 23 tons of figs in 1963–64.

The d'Agen is the principal prune variety grown in both Australia and California. Robe de Sargeant prunes are decreasing in tonnage within Australia and are a minor variety in California, as also are the Imperial and Sugar varieties.

The prune-growing areas are concentrated in the Young and Griffith districts of New South Wales, and in the Santa Clara–Gilroy, Napa–Sonoma, and Sacramento Valley areas of California. With the exception of the Sacramento Valley, where all the fruit is removed from the tree in a single harvest, ripe, mature fruit is harvested 2–4 times during the season by lightly shaking the trees, or by hand picking each harvest.

In Australia, mechanization in harvesting is just starting, whereas in California mechanical development in shakers, various harvesters (catching frames and pick-up machines), and bulk-handling equipment have reached a high degree of sophistication. This is particularly true in the Sacramento Valley where, because the prunes do not form an abscission layer and do not drop preferentially when ripe, single harvests are customary. A great deal of research and development has been devoted in America to mechanization and to indices of fruit maturity in the prune industry, and the findings

have been commercially applied there on a wide scale.

In Australia the fresh fruit is generally harvested in field boxes containing 45–50 lb of fruit, although smaller lug boxes and 5-gallon tins are also used. In California, in addition to the field box, bulk bins (4 ft by 4 ft by 2 ft), which hold approximately half a ton, are used.

Drying Methods for Prunes

In California the prunes, when received from the grower, are washed free of orchard dust with water and then spread in a single layer on 3 ft by 6 ft wooden slatted trays; the loaded trays are stacked about $6\frac{1}{2}$ ft high (25–26 trays) on low trolleys, which are in turn placed one at a time in one end of the dehydrator tunnel, whose cross section is just large enough to accommodate the loaded trolleys.

Australian practices differ in that the fresh fruit is dipped in or sprayed with a hot (170–200°F) caustic soda solution (about 0·2% NaOH). This removes some of the waxy bloom on the surface of the skin, and may cause a slight checking or cracking of the skin. This treatment has the tendency to accelerate drying. Tray sizes vary from 2 ft by 3 ft to 3 ft by 6 ft, depending on the dehydrator dimensions. The trolleys generally carry a double stack of trays so that a car may be 4 ft by 3 ft or 6 ft by 6 ft, the height again depending on that of the tunnel.

In both countries the dehydrators are operated in a counter-flow manner, i.e. drying air is introduced into one end of the tunnel and its movement is opposite in direction to that of the trolleys of fruit. Counter-current operation is conducive to the establishment of the most rapid drying conditions at the end of the tunnel, where the prunes are relatively dry. The maximum permissible air temperature, therefore, is that which the nearly dry prunes will withstand for a period of some hours without incurring incipient heat damage.

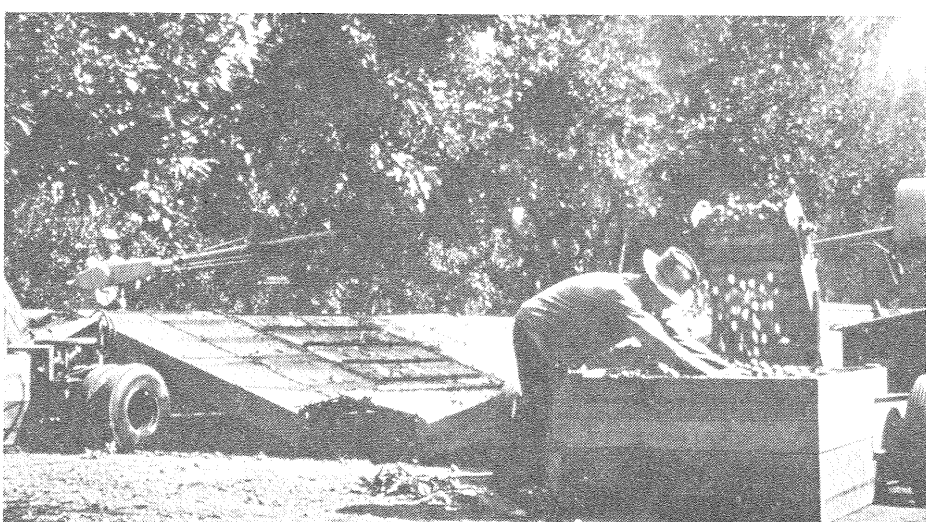
Parallel-flow tunnel operation, where fruit and air pass through the dehydrator in the same direction, has recently been applied in some plants in California. This procedure is characterized by very fast drying conditions in a portion of the tunnel where the product to be dried is still very wet. Because of evaporative cooling effects, it is possible to use a high initial temperature without causing heat damage to the product, and greater drying efficiency is thereby attained. Tunnels so operated can therefore have a higher drying capacity than when operated on the counter-flow principle. Tests conducted with an Australian dehydrator plant have shown the method is applicable to Australian fruit.

After-processing

Processing of the sized and graded fruit consists of washing and rehydrating in hot water prior to packaging. In Australia prunes are heat processed: the containers are filled at temperatures not less than 180°F and may be followed by an additional processing in steam. In California, additives are used instead of heat for preserving the prunes.

CONCLUSION

In many respects the differences between the Australian and Californian prune industries are small. But the Californian industry is much larger and has to face the problem of handling very large quantities of fruit in a short harvesting season. Consequently it has been obliged to make greater use of automation and mechanization.



Mechanical harvesting and transport of fresh prunes in California. The shaker (left) is connected to the tree. When the shaker vibrates, the fruit drops from the tree onto the catching frames below. The prunes are elevated from the frames to the bulk bins (right) for transport to the dehydrator.

Alfred Ronald Prater, 1919-65

ALFRED RONALD PRATER, who died suddenly on March 23, 1965, was one of the group of young scientists who joined the Division of Food Preservation during the rapid expansion of its activities occasioned by World War II. He was assigned to investigations on dehydrated foods, in particular to problems related to dehydrated meat and eggs, and studies in these fields occupied much of his time for nearly 20 years.

A. R. Prater was born on May 29, 1919, in Subiaco, a suburb of Perth. He was educated at Wesley College, and graduated in 1942 from the University of Western Australia with the degree of Bachelor of Agricultural Science. After graduation he spent some 12 months in the Institute of Agriculture at the same university studying the relationship between nutrition and wool growth in sheep. He accepted an appointment with CSIR (now CSIRO) in March 1943, and was posted to the Food Preservation laboratories at Homebush, N.S.W. At this time Australia was faced with the major task of victualling the Allied Forces in the South-West Pacific Area. Among the food stuffs required were substantial quantities of dehydrated vegetables, meat, and eggs—products novel to the Australian food industry. It became the responsibility of the Division of Food Preservation to acquire and supply technical information essential to the production of these foodstuffs and Prater at once applied himself to the tasks assigned to him.

Prater's major contributions were on meat dehydration, but he also worked on dried egg technology and later published a paper on this subject. When he began his work both dehydrated meat and eggs had earned a very unsavoury reputation among service personnel. This is not surprising when one recalls the processing methods used in their production and the prevailing paucity of technical knowledge. There was an acute shortage of meat-boners, and mutton carcasses were pressure-cooked to a degree that permitted the bones to be shaken out. The bone-free residue, after mincing, was dried in primitive through-draught driers, which had no effective control of drying conditions. In the circumstances it was not unexpected that dehydrated meat was removed from the services' rations.

The end of World War II was the signal for an almost total cessation of dehydration investigations, dictated partly by the need to resume research programmes suspended during the war, partly by the conviction that dehydrated foods were a necessary wartime evil. Their past reputation certainly did not engender confidence in their peacetime market potential. However, Prater and a few enthusiastic colleagues were convinced that dehydration had a commercial future. Their confidence has been vindicated by the resurgence of interest in dehydrated foods in recent years.

Prater's post-war investigations were carried out for many years in a laboratory at Auburn, N.S.W. With a few laboratory assistants, he faced the twin frustrations of uncertainty as to how long the meat dehydration studies would continue, and of working in virtual scientific isolation. The work was intended on two occasions to meet defence interests. Initially it was prolonged for three years at the request of the British Ministry of Food; for a number of years thereafter it was financed by the Commonwealth Department of Commerce and Agriculture as part of its defence food research programme. During this period Prater conducted comprehensive studies of factors influencing the quality of dehydrated minced meats. For this purpose he devised an excellent experimental dehydrator, which permitted precise control and measurement of the physical factors important in dehydration.

Prater published many papers on dried meat and his work made it possible to produce dehydrated mutton mince of excellent quality. Although the process has not yet

been used in large-scale production, defence authorities and commercial organizations have shown much interest in it.

He collaborated closely with fellow workers in Britain and New Zealand, and twice visited the latter country. On the basis of his experimental results Prater was able to recommend a method for producing a greatly improved dehydrated mince meat.

At the conclusion of his meat dehydration investigations, Prater assumed responsibility for the Division's fish processing research. Once again, he was confronted by serious difficulties, because in the planning of the new North Ryde laboratories inadequate provision had been made for this work. While attempting to have this deficiency remedied, Prater occupied himself with work on fresh egg quality and with preparing a series of technical pamphlets and articles on common fish processing problems. These articles were published in *Fisheries Newsletter*.

In all his scientific work Prater displayed a scrupulous regard for detail and this was one of his outstanding characteristics, as was his friendly interest in other people. Within the Division, frequent recipients of his kindness were his own laboratory assistants and only they would know and appreciate the full extent of his efforts on their behalf. Recently one of his former assistants was constrained to write that "to me he was more like a father than a boss".

In 1946, Prater married Margaret Elsie Woodley, an Honours graduate of the University of Sydney. They were a devoted couple who derived great satisfaction from their home life and from their two charming daughters, to whose problems Prater applied himself with unlimited patience and good humour.

Ron Prater's untimely death, at the early age of 45, is not only a great loss to food research, but a tremendous personal loss to his family and countless friends. To me his most appropriate epitaph is found in the words of Leigh Hunt, "Write me as one that loved his fellow men".

J. SHIPTON

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NEWS FROM THE DIVISION OF FOOD PRESERVATION

MODERN TECHNIQUES FOR FOOD LABORATORIES

The CSIRO Divisions of Food Preservation and Dairy Research have arranged for a series of talks and demonstrations on modern techniques for food laboratories to be delivered at the CSIRO Division of Dairy Research, Graham Road, Highett, Vic., on Wednesday and Thursday, November 10 and 11, 1965. The demonstrations—on gas chromatography, thin layer chromatography, measurement of temperature and humidity, and microbiological techniques—attracted a large following in Sydney in 1964 and they are being repeated for the convenience of food technologists in southern States. Programmes and enrolment forms may be obtained from the Technical Secretary, CSIRO Division of Food Preservation, Box 43, P.O., Ryde, N.S.W.

OVERSEAS TRAVEL

Mr. J. F. Kefford was guest speaker at a Food Technology Conference organized by the Massey University of Manawatu at Hamilton North, New Zealand, in May. He delivered a paper on "Science in Packaging", and was one of a panel of speakers who addressed the conference on food research in New Zealand and Australia. Mr. Kefford also had discussions with officers of the New Zealand DSIR, the Cawthron Institute, and the N.Z. Apple and Pear Marketing Board.

Miss E. M. Christie, who is in charge of the Taste Test Unit in the Division's North Ryde laboratories, attended the 25th annual meeting of the Institute of Food Technologists at Kansas City, Missouri, U.S.A., and a meeting of the committee of the American Society for Testing Materials in May. This Society is concerned with setting up standard methods for the sensory evaluation of foods. Miss Christie also visited laboratories in the United States where tasting tests are a feature of the work. She returned to Australia via Europe and Asia.

Mr. M. B. Smith, Senior Research Scientist, Physical Chemistry Section, Division of Food Preservation, was overseas from May 1 to June 24, 1965, when he attended the 25th annual meeting of the Institute of Food Technologists at Kansas City, and visited research institutions in the U.S.A., Great Britain, and Europe. Mr. Smith's field of research is concerned with the proteins of eggs and meat and with changes in their properties during storage. The main purpose of his visit was to discuss his research on the structural differences and transformation of ovalbumen and S-ovalbumen with scientists of the U.S. Department of Agriculture, which contributes to the cost of the investigation as part of its agricultural research programme. Mr. Smith also visited a number of laboratories engaged on other aspects of the physical chemistry of proteins.

OBITUARY

Mr. Norman E. Holmes, a former research officer of the Division of Food Preservation, died suddenly in London in April 1965.

Mr. Holmes, a graduate in engineering of the University of Melbourne, joined the CSIR Section of Food Preservation in 1931, and conducted a series of investigations on refrigerated transport of meat and fruit by rail and sea. Subsequently he was stationed in London, where he was responsible for examining the out-turn of a number of experimental shipments of beef, apples, pears, and plums.

During and for some years after World War II Mr. Holmes was seconded to the British Scientific Civil Service, working principally at the Ministry of Agriculture, Fisheries, and Food. For the past 12 years he held the position of food technologist in the Nutrition Division of the Food and Agriculture Organization of the United Nations, helping many under-developed countries to initiate programmes for the improvement of food handling, storage, transport, and processing.

He will be greatly missed by his former colleagues in Australia and many friends throughout the world.