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Drying and Processing Tree Fruits

by D. McG. McBean

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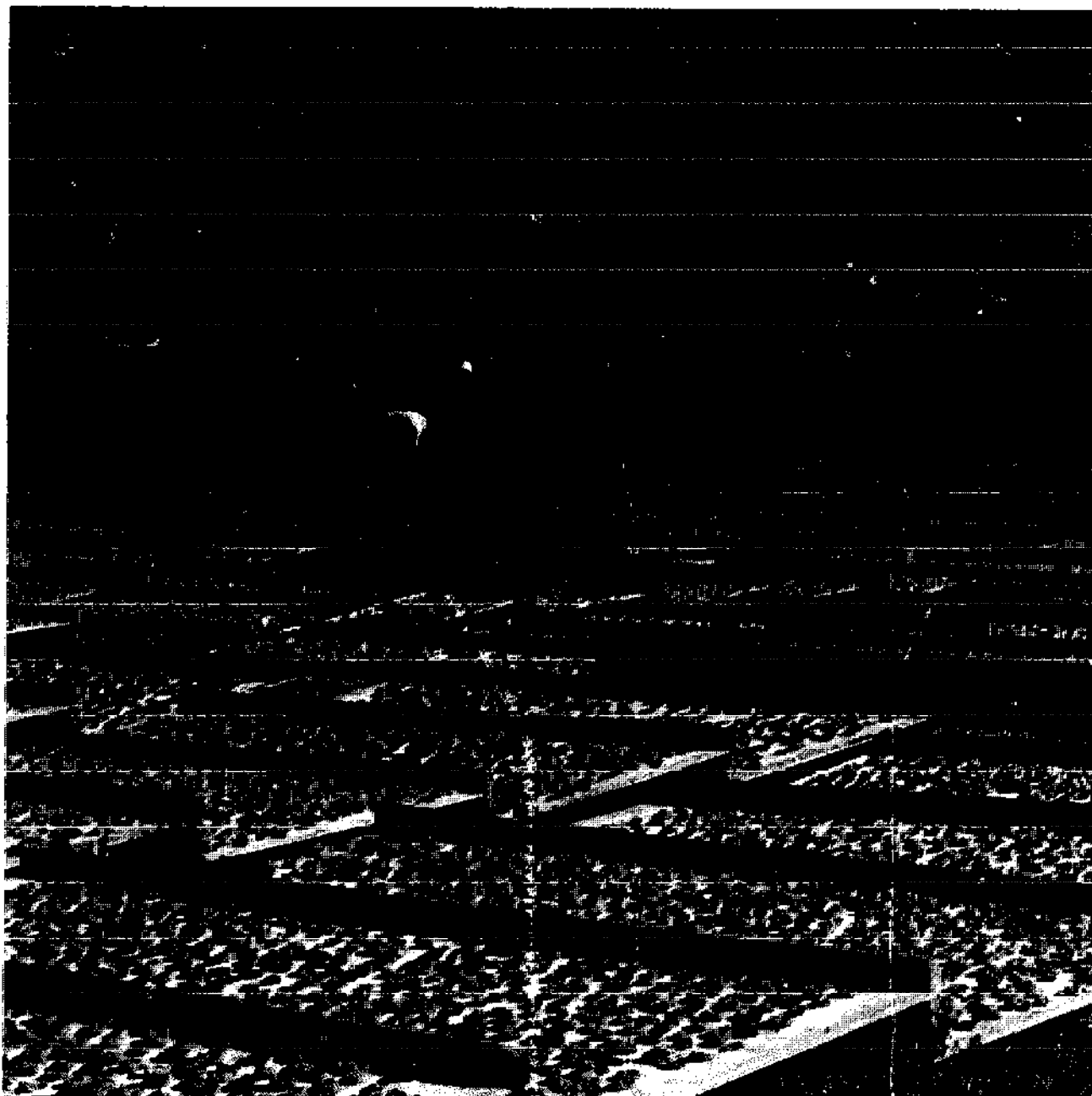
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Drying and Processing Tree Fruits

CSIRO Division of Food Research Circular No. 10



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By D. McG. McBean

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Foreword

Bulletins on the sun-drying and processing of tree fruits were published in 1942, 1954 and 1962. They were issued by various Commonwealth and State authorities and were widely used by growers and in packing-houses. These bulletins contained recommendations that were based mainly on the results of investigations reported to the Dried Fruits Processing Committee by officers of CSIRO and State Departments of Agriculture. Recent research findings indicated that a new and up-to-date bulletin dealing with sun-drying of tree fruits was necessary and the above Committee requested that this new Circular be prepared. It should be noted that this Circular is mainly concerned with sun-dried tree fruits; other publications give recommended procedures for dehydration of tree fruits and the drying and processing of vine fruits.

Drying and Processing Tree Fruits

Introduction

Most of Australia's sun-dried tree fruits are produced in the Upper Murray area of South Australia. This location has well-established irrigation settlements in which varieties of tree fruits suitable for drying are grown. In addition, hot dry weather, which is essential for sun-drying, usually prevails there during the summer months when the fruits ripen. Traditionally, drying is done by orchardists on their own farms but during the last five years significant tonnages have been processed in central drying yards which have been established in the area.

Recent production figures for the three most important sun-dried fruits – apricots, peaches and pears – are shown in the table below. Apricots are by far the most popular and most important sun-dried fruit, yet in the long term their production has declined. In the last three years dried apricots were imported because not enough were produced locally to fulfil Australia's market requirement (approx. 1200 tonnes per year) and to meet long-standing export commitments. Severe losses occurred in 1973 and 1974 due to persistent rains during

the drying seasons, while in 1975 the fresh crop was one of the smallest ever recorded. Production of dried nectarines seldom exceeds 30 tonnes per year although more could be sold on the local market. No separate figures are available for the small amount of sun-dried prunes. These are overshadowed by the 3000-4000 tonnes that are dehydrated in the Griffith and Young districts of New South Wales.

General Requirements

Fruit Quality

The production of uniformly high-quality dried fruit demands strict attention at many points along the line between tree and packing-house. The first requirement is high-grade fresh fruits produced by using good cultural methods in pruning, watering and manuring. Watering immediately before or during harvest causes a rise in moisture level in fruit and should be avoided where possible; it results in increased processing costs and lower yields of dried material. Fruit must be harvested at the correct stage of maturity and handled carefully to prevent damage.

Annual production of sun-dried tree fruits in Australia

Type of fruit	Annual production (tonnes)							
	1968	1969	1970	1971	1972	1973	1974	1975
Apricots	2803	2115	2821	2624	1807	2030	1270	704
Peaches	443	435	378	459	329	226	126	154
Pears	89	284	258	304	202	220	100	199

Picking-boxes should be kept clean; with soft fruits, shallow containers should be used to prevent bruising. Damaged or defective fruits must be rejected or segregated.

Rejections are made most conveniently while the fruits are being pitted or halved, and should include any that are bruised, over-ripe or under-ripe, and also windfalls and fruit damaged by hail, insect pests etc.

Different grades or varieties should not be mixed. Examination of commercial samples shows that there is decided depreciation in value when growers fail to grade fruit before processing.

Trays

Halved fruits are placed close together and one layer thick on self-stacking wooden trays 762 mm by 508 mm, 1524 mm by 762 mm or 1524 mm by 1016 mm. They should be made of relatively knot-free softwood which has been smooth sawn or dressed so as to prevent particles of wood from becoming embedded in the soft fruit tissue. The use of hardwood results in staining of the fruit. Metal trays may be used for prunes as this fruit is not exposed to sulphur dioxide (SO₂) which corrodes metal severely. The larger trays, when loaded, are so heavy that two people are needed to handle them. Most fruit is still cut and placed on trays manually. While this method is more precise than mechanical cutting, the latter has been introduced to the industry in an effort to reduce labour costs and increase throughput.

Delay between Cutting and Sulphuring

Halved fruits may be held between cutting and sulphuring for up to 10 hours in the shade without decreasing subsequent absorption of SO₂. It is good practice, however, to sulphur fruit as soon as possible after cutting.

Some growers spray the fruit with water before sulphuring in the belief that it increases gas uptake, but careful tests have shown that water spraying before sulphuring has no significant effect.

Influence on uptake of SO₂ of holding cut apricots for various times at 35–37°C before sulphuring

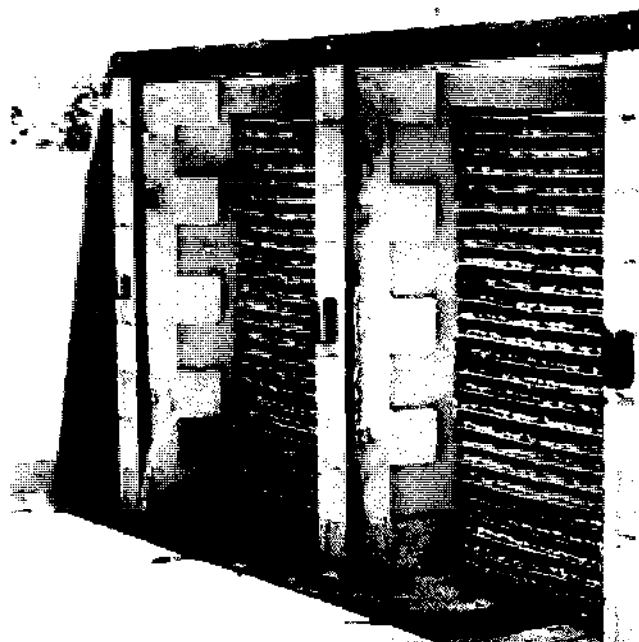
Holding time (h)	SO ₂ content (ppm wet basis)
0	6320
2	6270
4	6660
6	6690
8	7020
10	6900

Sulphuring

The exposure of cut fruits to the fumes from burning sulphur, or sulphuring, as the process is commonly called, is the most important technological operation the orchardist has to perform to ensure the production of high-grade dried fruits. The SO₂ taken up by the fruit displaces air from the tissue, softens cell walls so that drying occurs more easily, destroys enzymes that cause darkening of cut surfaces, shows fungicidal and insecticidal properties and enhances the bright attractive colour of dried fruit. It also inhibits darkening of the dried fruit during storage and during distribution to the consumer. The orchardist should consider carefully the many factors that influence the level of SO₂ in dried fruits such as how much sulphur is burnt, the rate of burning, time of exposure, fruit characteristics and weather conditions. Allowance for all of these factors is not easy and practical recommendations for sulphuring are given in later sections of this Circular.

Legal limits are prescribed for the level of SO₂ in dried fruits. For the Australian market 3000 mg SO₂ per kg (3000 ppm) is allowed in dried fruit but export markets commonly have levels lower than this, 2000 mg per kg (2000 ppm) being permitted in Britain and Canada and in most European countries. Fruit has sometimes been withheld from overseas markets because the SO₂ content was in excess of regulation maxima.

In order to comply with the different market requirements and to avoid financial losses it is essential that SO_2 content be determined both before and after processing the dried fruit. Batches of fruit should be segregated in the packing-house according to SO_2 level so that groups with similar contents can be treated together. This is particularly important where fruit is being packed for specific export markets. A 'workshop' method for the determination of SO_2 content is described later.



Halved apricots about to be sealed in sulphur houses made of concrete blocks. Sulphur will be burnt in the underground channel.

Operators drying cut fruits need one or more enclosures as free from leaks as possible for uniform controlled sulphuring. Permanent structures of brick or concrete can be built or a wooden frame covered with either asbestos cement sheeting or heavy-gauge plastic may be used. In the latter types, a mastic sealing compound should be used to prevent leakage at joints and the door should be made leak-proof by using clamps and a compressible gasket. Vent holes 25 mm in diameter should be provided in the roof or near the top of a wall.

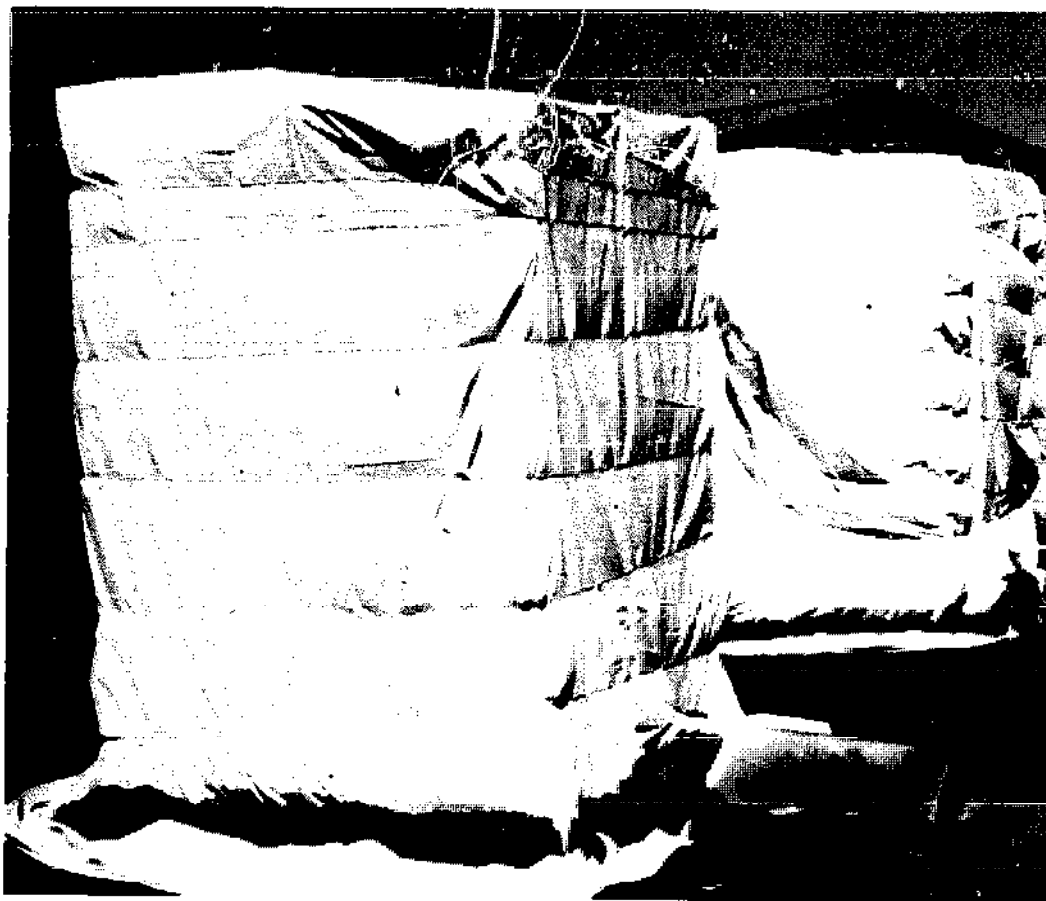
Tents made from plastic 0.2-0.25 mm thick may also be used. These have been made so that they can be slipped over a stack of trays holding fruit ready to be sulphured. The tent is easiest to use if the stack of trays rests on a concrete base; weights are put on the excess plastic sheet at the bottom to seal off the chamber. If free from rips and tears, tents can be sealed off better than most rigid structures; small rips may be repaired with patches and certain types of liquid cement. Eyelets are set into the top of the tent to allow ventilation.

Wooden frames covered with Malthoid-type material may be used but are difficult to manhandle over the trays and, being inflammable, are a greater fire risk.

A number of small sulphuring chambers is recommended in preference to one large one. This prevents fruit from being held for excessively long periods after cutting. A constant weight of fruit should be placed in the chamber for each sulphuring run, a height of 20 trays often being used. Staggered stacking of trays helps to improve distribution of SO_2 gas within the enclosure.

Burning the Sulphur

When sulphur burns it combines with oxygen in the air to produce SO_2 . Sulphur is weighed or measured by volume into a burning-pan which is placed in a small fire-proof box above ground or in a pit below ground. The box or pit is situated at one end of the sulphuring chamber and is connected to it by a passage. Alternatively, the pan may be placed within the sulphur house, making sure that the burning sulphur cannot ignite the wooden trays or the frame of the enclosure. With plastic tents, the pan of burning sulphur is situated in a short tunnel made of galvanized iron in the form of an inverted V. The outer end is solid and has a small flap for adjusting air supply to the burning sulphur. The open, inner end of the tunnel is inserted under one of the plastic side walls, care being taken to seal the



Plastic tents being used to sulphur pears. Ropes prevent tents from flapping and expelling SO_2 in windy conditions. Sulphur is burnt under the metal hood at the base of each tent.

junction and to prevent direct contact of the tent with the metal which may become hot enough to fuse the plastic. The pan of burning sulphur should be placed near the solid end of the tunnel in order to keep that part near the tent as cool as possible. The gas produced during burning circulates within the chamber and gradually fills it. Slight fumes should always be issuing from the vent holes during a run.

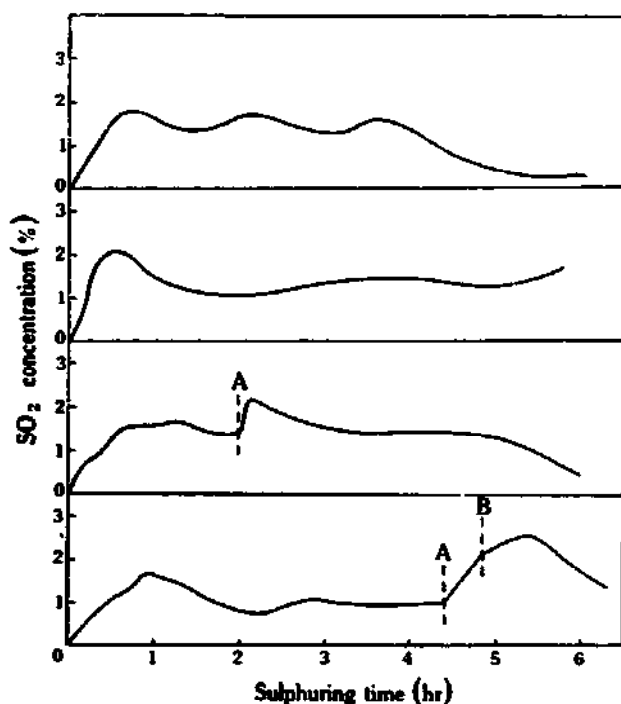
Sulphur should burn steadily during the complete sulphuring period and this is best controlled by an adjustable air inlet to the burning sulphur. If fumes cease to issue from vent holes in the sulphuring chamber, all sulphur has been burnt or else the flame has been extinguished by slag. Too rapid burning of sulphur indicates excessive draught which can be reduced by decreasing the inlet and outlet vents. This is necessary if windy conditions prevail during a run.

In the past, difficulty has been experienced with the burning of some types of sulphur, particularly the powdered types, but this has been generally overcome by requiring suppliers of sulphur to provide packing-houses with the results of test burns before purchase. Sulphur that is hard to burn can be improved by the addition of 1-2% powdered sodium nitrate thoroughly mixed through the sulphur. If hessian wicks are used to start burning, they should be clean and free from impurities which may cause slagging and resultant slow burning or complete extinction. A better way to start is to pour a few millilitres of methylated spirit onto the surface of the sulphur and apply a flame.

Gas Concentration during a Run

During commercial sulphuring under calm conditions SO_2 concentration rises slowly in

the first hour and then settles to a level of between 1 and 2%. If windy conditions prevail the burning rate is faster and the gas concentration rises to as much as 3.5%. Concentration of gas in the chamber is greater near the entrance to the burning area, close to the bottom. Differences within the enclosure are not great enough, however, to produce large variations in absorption.



Variation in average concentration of SO_2 during four tests using a sulphuring chamber of concrete blocks. Molten sulphur was stirred at point A to remove surface slag. Additional air to increase rate of burning of sulphur was admitted at B.

In general, gas concentration is more uniform in plastic tents than in rigid chambers. This is due to leakage around door joints in the latter and wind blowing in through wall cracks. Under windy conditions plastic tents tend to flap, acting as bellows and blowing SO_2 out through the vents. This can be overcome by tying the tent securely to the stack of trays inside so that the plastic sheet cannot move appreciably.

At the conclusion of sulphuring fruit should not be left in the chamber, as the gas concentration falls quickly within the

enclosure as soon as the sulphur ceases to burn and then fruit loses gas rapidly. Fruit should be put out on the drying-ground as soon as possible after sulphuring is completed even if the run ends late at night.

Temperature during Sulphuring

The temperature in the sulphuring chamber rises 5-10 degC above outside air temperature as a result of the heat emanating from the burning sulphur. Apricots absorb slightly more gas at lower temperatures so fruit sulphured at night would absorb more preservative than fruit sulphured during the day, but the effect is small and has no practical significance.

Influence of sulphuring temperature on absorption of SO_2 by pear tissue (1 h at 1% SO_2)

Sulphuring temperature (°C)	Absorption of SO_2 (ppm)
26.6	1080
32.2	1000
37.7	1030
43.3	1020
48.9	1070
54.4	1010

Amount of Sulphur to be Burnt

It is impossible to state precisely how much sulphur must be burnt per tonne of fruit. It is worth repeating, however, that sulphur should burn steadily throughout the time that fruit is in the sulphur enclosure. In general, pans in which sulphur is burnt contain about 3 kg initially and under gentle breeze conditions this quantity burns for about 6 h or at the rate of 0.5 kg/h. Times for sulphuring will be given for different fruits later in this Circular.

Two different experimental sulphur burners have been designed and tested by CSIRO. They control the burning rate independently of wind conditions but their estimated cost of about \$200 rules them out for small-scale operation. They are more suitable for larger centralized drying operations.

Determination of Adequacy of Sulphuring

The filling of cups (the pit or core cavity) with juice is not a reliable indication of adequacy of sulphuring because this 'bleeding' is dependent upon ripeness. With firm ripe fruit, cups filled with juice would indicate over-sulphuring. An easily detachable skin serves as a rough indication of adequate sulphuring. Standardization of rate of burning of sulphur combined with uniform weight of fruit and a fixed duration of sulphuring are the most reliable means of obtaining uniform gas uptake.

Resulphuring after Wet Weather

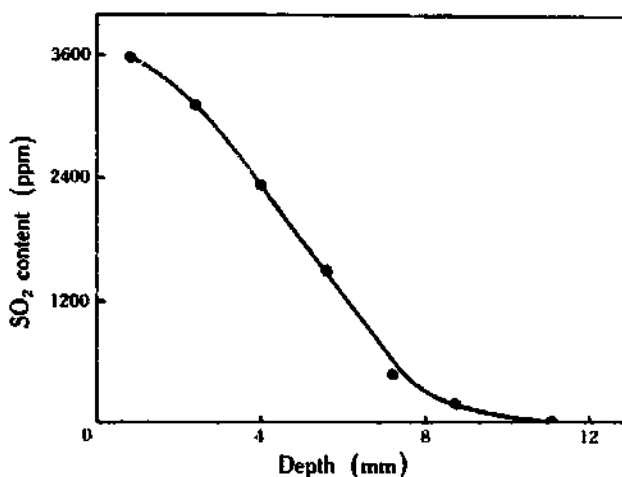
Weather changes sometimes make it impossible to put fruit out to dry immediately after sulphuring. Under these circumstances it is necessary to hold it in stacks under shelter to prevent wetting by rain. The SO_2 is lost very rapidly under such conditions, and when the weather begins to clear resulphuring must be carried out. The length of time for resulphuring depends upon how long fruit has been held in stacks. If the holding time is only overnight a further 2 h is recommended. If the holding time is 24 h, 4 h resulphuring should be done.

Effect of Weather Conditions on Retention of SO_2

Although the grower has no control over drying conditions he can make allowance for certain conditions in his sulphuring routine. If weather is very hot and dry sulphuring times are shortened, since a high proportion of the preservative will be retained during drying. If conditions are humid or showery much less SO_2 will be retained and longer exposure times must be used.

Slightly more sulphur is retained if fruit is put out to dry in the heat of the day rather than late at night but the differences here are not important.

Under good drying conditions fruit may retain about 15-20% of SO_2 but under slow drying conditions retention can be reduced to less than 5%.



Variation in sulphur dioxide level with depth in peaches which were sulphured for 1 h at 1% SO_2 concentration. The high level near the surface results in rapid desorption at the start of drying.

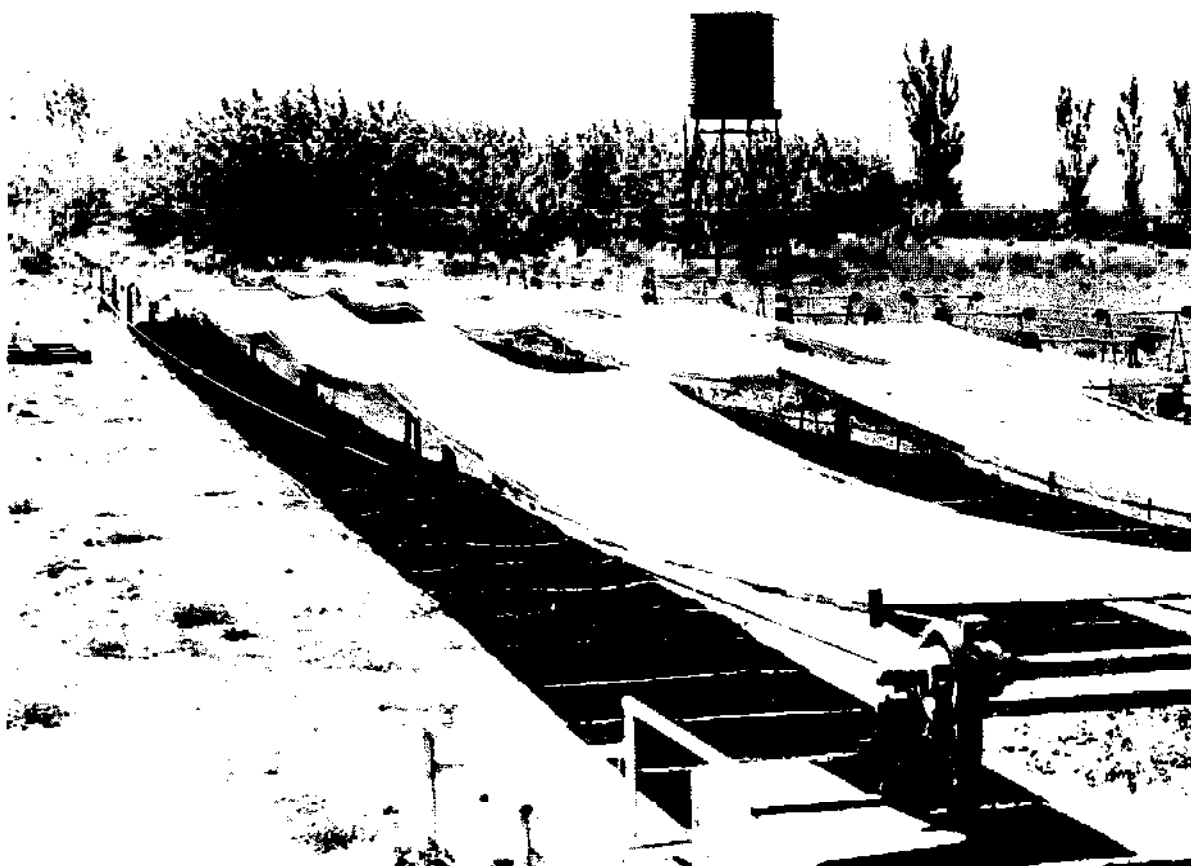
Drying

As mentioned above, sulphured fruit should be placed on the drying area as soon as possible after sulphuring is completed. Drying times depend on the type and size of fruits and on weather conditions. The grower should make sure that fruit is well dried before it is delivered to the packing-house: it should be able to accept all treatments applied at the packing-house without additional drying. In general, this means that the moisture content should be about 15%.

The Drying-yard

The drying-yard should be established where fruit is exposed to direct sunlight for as long as possible during the day and where prevailing winds blow directly across the trays. It should not be near roads or pathways used by wheeled vehicles as this will result in dusty and dirty dried fruit.

There are many different types of surfaces on which trays of fruit are placed to dry; these include lawn, earth, gravel and bitumen areas. Recent experiments show that drying rates are similar on each of these surfaces. However, fruit dried on lawn usually contains dried grass cuttings and fruit dried on earthen areas consistently picks up dust and dirt.



Drying apricots with trays suspended on steel ropes about 1 m above ground. The ropes are motor-driven, either forward or reverse, allowing rapid loading and unloading.

Placing of the Trays

Trays of fruit are generally placed directly on the ground but it has been shown that fruit dries a little faster if it is suspended up to one metre above ground level. This slightly quicker drying rate is probably due to convective wind currents carrying moisture away from the drying surface of the fruit. Elevation of trays results in cleaner dried fruit and also appreciably reduces back-breaking labour during spreading and picking up. Suspended wire ropes bearing trays of fruit have been motor-driven, introducing mechanization into the labour-intensive operation of placing and stacking trays.

Tilting the Trays

The common practice of tilting trays to the north does not result in faster drying than if the trays were placed flat but it does

allow easier and more rapid pick-up by workmen; moreover, less dirt adheres to the side runners of the trays on pick-up.

Removing the Fruit from the Trays

Removing the dried fruits, particularly apricots, from trays is laborious and time-consuming. Removal is easier if trays are washed after each drying run, and this practice could well be more commonly followed as some growers have devised excellent tray-washing machines. Preliminary trials using tray liners of transparent or black plastic showed no increase in the drying rate nor easier removal of the dried fruit from the trays, hence their adoption is not recommended.

Finish Dehydration

The cost of trays is a major capital item in drying fruit and in order to keep the number needed to a minimum, rapid turnover is

important. This Circular is restricted to sun-drying, but enough growers now complete the drying process in a dehydrator for this procedure to be mentioned. Initial exposure of fruit to the sun is essential if the dried product is to conform with the grading system which is based on sun-dried fruit. Exposure to the sun for one day is enough to impart a typical sun-dried appearance to apricots, and dehydration for about 12 h at 55–60°C will complete drying. This procedure greatly reduces the overall drying time for apricots which results in a significant reduction in the number of trays required. Offset against this is the capital cost of the dehydrator and its power and fuel costs. Most producers with a dehydrator have installed it for use primarily with other dried products such as vine fruits and as an insurance against wet seasons.

The Different Types of Cut Fruits

Apricots

Commercially, apricots are the most important dried cut fruits and more attention will be given to them than to peaches, nectarines and pears.

Satisfactory dried apricots can be produced from most varieties including Trevatt, Moorpark, Tilton, Royal and Story. Fruit should be picked 'eating ripe'. Sugar accumulates rapidly in apricots during the two weeks before they ripen and this not only improves quality but increases yield of dried fruit. Immature fruit should be put aside to ripen fully, while over-ripe or damaged apricots should be processed separately or discarded. Further selection should be made while apricots are being cut. Fruit showing 'yeasty' or severely discoloured centres should be discarded as these often dry black. Such fruits have frequently been infested with *Carpophilus* beetle and the presence of these insects is often an indicator of likely discoloration. At present, raw fruit is not always carefully sorted and a mixed pack with lower

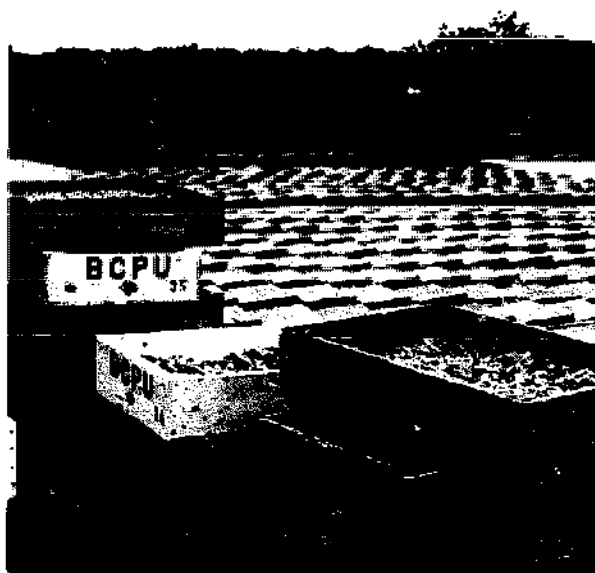
value results. Each sulphuring run must contain as uniform fruit as the grower can provide and he must impress upon his cutters the need to use only sound uniformly ripe fruit. An increasing tendency recently to dry apricots which are not fully coloured has resulted in a proportion of production with poorer colour and flavour. On the other hand, over-ripe fruit 'bleeds' badly during sulphuring and produces mis-shapen flat halves known as 'slabs' which are difficult to scrape from trays.

Small and large fruit should not be mixed on the one drying tray because either over-drying of the small or under-drying of the large apricots will result: grading into two or more sizes is highly recommended.

During hot dry weather, i.e. when temperatures are higher than 35°C (95°F) and humidity is low, apricots should be sulphured for 4–5 h. If conditions are cooler, cloudy or humid, the sulphuring time should be extended to 7–8 h. Many growers commence a run late in the afternoon and use sufficient sulphur to burn overnight; recharging is often done about 10 p.m. This practice is not recommended for apricots as it will result in over-sulphured fruit. However, there is no reason why sulphuring should not start about 10 p.m., allowing fruit to be placed on the drying-green early next morning.

It is general practice to scrape dried apricots from trays into sweat-boxes in which they are held until delivery to the packing-house. While in the boxes, equilibration of moisture occurs amongst the halved apricots. Sweat-boxes should be held in as cool an area as possible at the orchard and delivery to the packing-house should be prompt. Colour deterioration and loss of SO₂ are both rapid at high temperatures, more than doubling for each 10 degC rise in temperature. Thus deterioration at 40°C is about five times greater than at 20°C. At the packing-house dried fruit should also be held in a cool area at all times. Two weeks of extremely high temperatures soon after

drying equals a shortening of the life of dried fruit by months in temperate zones.



Apricots drying in the sun in background while dry fruit is equalizing in moisture content in sweat-boxes in foreground.

'White Centres' in Dried Apricots. During certain seasons a large proportion of the apricot crop dries with a white appearance in the pit cavity. While the consumer might believe this to be mould – such complaints have been received – under a microscope it appears as dried material from the cell wall. It is thought that an extended spell of hot weather just before picking may increase the incidence of 'white centres'. If so, it could be caused by desiccation of cells in the pit cavity due to general heat stress of the tree and water loss from the fruits.

The defect may be overcome in practice by spraying sulphured fruit with clean water as soon as the trays are spread on the drying-ground; the spray should be sufficient to fill all pit cavities. If cavities fill with juice during sulphuring, 'white centres' will not be a serious defect. The condition appears to be more prevalent in slightly immature fruit than in fully ripe apricots. This spraying procedure has little effect upon the SO_2 content of the dried fruit.

Whole Dried Apricots. Small quantities of apricots are dried as either whole unpitted or whole pitted fruits. These are slow drying and require sulphuring for 12-18 h.

Peaches and Nectarines

Satisfactory dried freestone peaches can be prepared from Elberta, Blackburn Elberta, J. H. Hale and Halehaven varieties. It is not usual to dry clingstone varieties. Goldmine is the main variety of nectarine which is dried. These fruits should be picked when they are well coloured but require a further 1-2 days to ripen fully. If they are picked too green, additional sorting is necessary which results in bruising and higher costs.

Peaches and nectarines absorb SO_2 more slowly than apricots and also retain less during drying; over-sulphured peaches and



'White centre' in a halved dried apricot. The whitened area in the pit cavity is desiccated cellular tissue and shows no microbial growth.

nectarines are seldom seen in packing-houses. For hot drying conditions sulphuring for 8 h is recommended for nectarines and 15 h for peaches. If drying conditions are poor as a result of high humidity the time should be increased to 12 h for nectarines and 20 h for peaches.

Many growers expose peaches to direct sunlight for only 2-3 days; after this trays are stacked until fruit is dry. Drying under shaded conditions such as this reduces bleaching of the cut surfaces. It is important that the stacks of trays are placed so that prevailing winds can blow across the fruit and carry away the slowly evaporating water. Sulphur dioxide losses are high during shade-drying, so if this procedure is employed sulphuring time should be maintained at 20 h.

Pears

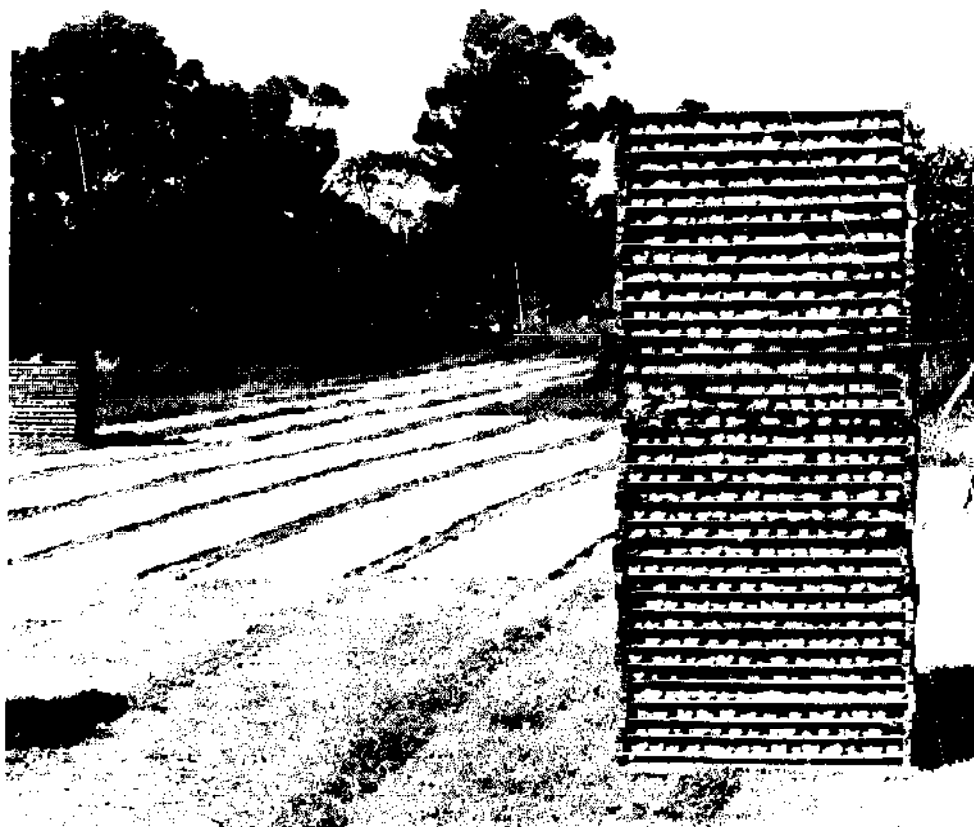
Sun-drying of pears is limited to the William Bon Chrétien variety because it is

the only type which matures when natural drying conditions are favourable.

Pears are picked while still hard and ripened in boxes covered to exclude light. Cool storage for 14 days before ripening hastens the rate of maturation and improves the degree of uniformity, avoiding the need for picking over. Ethylene may also be used to improve uniformity of ripening. Pears are ready for cutting when the stem can be pulled easily from the flesh; colour is then usually yellow.

Pears are halved, and until recently the core, calyx and skin were left intact. It is now usual to remove the calyx, while a few growers further improve their product by removing the core as well. Present production of sun-dried pears is low at between 200 and 300 tonnes annually.

Pears should be sulphured for 24-36 h since heavy losses of SO_2 occur as the fruit slowly dries. Sulphuring should be continued



Trays of halved pears spread on the grass for initial sun-drying and partly dried fruit stacked for shade-drying.

until pear halves are so soft that they cannot be lifted from trays without disintegrating. The flesh of adequately sulphured pears has a jelly-like consistency.

As with peaches, pears are frequently exposed to the sun for only 1-3 days. It is general practice to pick up the fruit and finish drying in the shade when the outside cut edges of the halved pears show the first hint of darkening.

Prunes

Most prunes produced in Australia are dehydrated but, as there are still some growers who have too few trees to warrant the installation of tunnel-drying equipment, details of sun-drying of prunes are given.

The varieties d'Agen and Robe de Sargeant are the most suitable for making into prunes, although reasonably good prunes can be obtained with such varieties as Splendour, French, Fellenberg (Italian), Imperial and Sugar; other varieties of European plums are generally unsuitable for drying.

Cultural methods play an important part in prune quality. Although such operations are not directly connected with processing, they obviously have a very important bearing on the quality of the fresh fruit and this is the first essential in the production of high-grade prunes. The adoption of suitable soil management practices is also very important. In addition, careful attention should be given to regular pruning and to the control of pests and diseases. It is particularly important in all districts to spray for the control of rust in plum trees, as this disease may cause serious losses in both quantity and quality of the crop through early defoliation.

Harvesting. For best results fruit should be fully ripe before harvesting. Immature fruit when dried is of poor quality and flavour and is more subject to deterioration. Fruit that has fallen before harvest is usually immature, and should be picked up and handled separately.

Just before harvest the ground should be cultivated and brought to a state of fairly

fine tilth. As irrigation causes the moisture content of fruits to rise, water should not be applied to trees within 3 weeks of harvest, and certainly not during the time when fruit is being picked.

Harvesting is best done by placing sheets under the trees, and fruit drop is generally assisted by very light shaking of the branches. Mechanical shaking of trees is now accepted practice in important prune-growing areas but is not usually applied where sun-drying is used.

Picking-up should be done at frequent intervals since dropped fruit may deteriorate rapidly. This is particularly so with Robe plums, which must be picked up at least every 2 days. In good weather d'Agen plums may be left for 4-5 days. Should unfavourable weather prevail, harvesting must be done at very short intervals to avoid spoilage.

Dipping. The practice of caustic dipping of plums before dehydration has almost ceased because it does not reduce dehydrating rates significantly, but it is still usual to dip fruit in a near-boiling caustic solution to increase the rate of sun-drying. The strength of the dipping solution will vary according to variety and maturity of the fruit and must be determined by trial, but generally 0.25 to 0.5 kg of caustic soda to 100 l of water is sufficient. Dipping produces very fine cracking or 'checking' of the skin and should be just sufficient to 'cut the bloom' from the fruit. It is important that the quantity of caustic soda used in the dip should be the minimum amount required to check the skin of the fruit. Excessive checking results in sticky prunes which, in addition to being difficult to handle during drying and subsequent processing, make an inferior processed product. Robe plums cannot stand, and do not need, as strong or as long a dip as d'Agens to achieve the required degree of cracking. In some districts Robe plums can be satisfactorily checked in boiling water only. If cracking is excessive the three factors involved - time, temperature and strength of dip - may need to be adjusted.

The caustic dip will gradually become contaminated with dirt from the fruit and must be renewed at intervals. Dirty fruit should first be dipped in water to remove adhering soil and so prevent rapid contamination of the caustic dip.

Following dipping, fruit is allowed to drain and is then spread in a single layer on drying-trays.

Drying. In hot weather, before exposure to the direct rays of the sun, trays of fruit are stacked until wilting occurs. Failure to wilt fruit before exposing it to hot drying conditions will result in the loss of much juice by 'boiling'; Robe plums are particularly subject to this trouble. In cool or cloudy weather this preliminary drying period in the stack is dispensed with and the trays of fruit are spread directly on the drying-ground.

When putting out trays, the tray sides should be placed in a north-south direction. If this is not done the end-pieces of the trays cast a shadow which prevents a band of fruit at the end of the tray from drying as rapidly as the rest.

Should rain threaten during drying, trays must be stacked and protected from the weather. If heavy dews are likely (particularly if associated with poor drying conditions during the day) trays should be stacked at night. Mould and fermentation develop rapidly in prunes subjected to wet conditions and with a very slow drying rate.

When fruit is sufficiently dry to handle (i.e. approximately two-thirds dry), it is spread in a more compact layer, one fruit deep, on sheets of Sisalkraft until drying is completed. Each night, and also if rain threatens, one side of the Sisalkraft sheet is folded over the other half. This protects the fruit from moisture and, in addition, the fruit is turned and redistributed when re-spread, thus ensuring more even drying. If Sisalkraft is not available, fruit can be re-spread on trays in a compact layer, thus releasing some trays for future use.

Sweating. Fruit is ready for sweating when the flesh is dry enough to be tough but pliable and does not exude juice when squeezed. Prunes should not be allowed to dry out and become hard. When the bulk of the fruit is ready for sweating it is removed from the Sisalkraft sheets or the trays and placed in sweat-boxes under cover; any fruit that is not sufficiently dry should be sorted out and allowed to dry for a further period before sweating. Sweating normally takes 5 or 6 weeks during which the moisture content of the fruit evens up, the drier fruit absorbing moisture from the wetter material. At 2-week intervals, fruit should be poured from one box to another to redistribute the prunes. This is particularly important if there are any moist specimens amongst the bulk. It is essential to remove any prunes that show signs of microbial growth as evidenced by faint white or yellowish discoloration on the skin.

If sweat-boxes are not available prunes may be sweated in clean wheat bags. However, bags must not be stacked more than three deep when placed on their sides. They should be turned at intervals, the top bag being lifted off and the underside turned uppermost on the floor. The middle bag is then lifted off and the bottom bag placed on top of the bag first removed, and the middle bag is then placed on top of this. This operation should be carried out every 2 weeks.

After sweating, prunes are ready for delivery to the packing-house and are usually bagged for this purpose. If fruit is retained for any length of time bags should be re-stacked as above, so that fruit in the outer layer of bags will not become too dry. Where large-scale handling of prunes is involved the feasibility of bulk bins should be considered.

Mould on Trays. A problem that causes big losses in years of unfavourable drying weather is the development of mould on the trays of fruit. This condition can be greatly

alleviated if trays are thoroughly scrubbed each year before use and dipped in a sterilizing solution. The best dip for this purpose consists of 0.5 kg of Shirlan W.S. in 100 l of water; care must be taken to keep the dip well agitated.

Packing-house Practice

It is the responsibility of packing-houses to hold dried tree fruits after receiving them from growers, to grade, clean, adjust moisture and/or SO₂ levels and pack for local and export markets. Dried fruits for local sale

kept to a minimum and insect infestation is prevented.

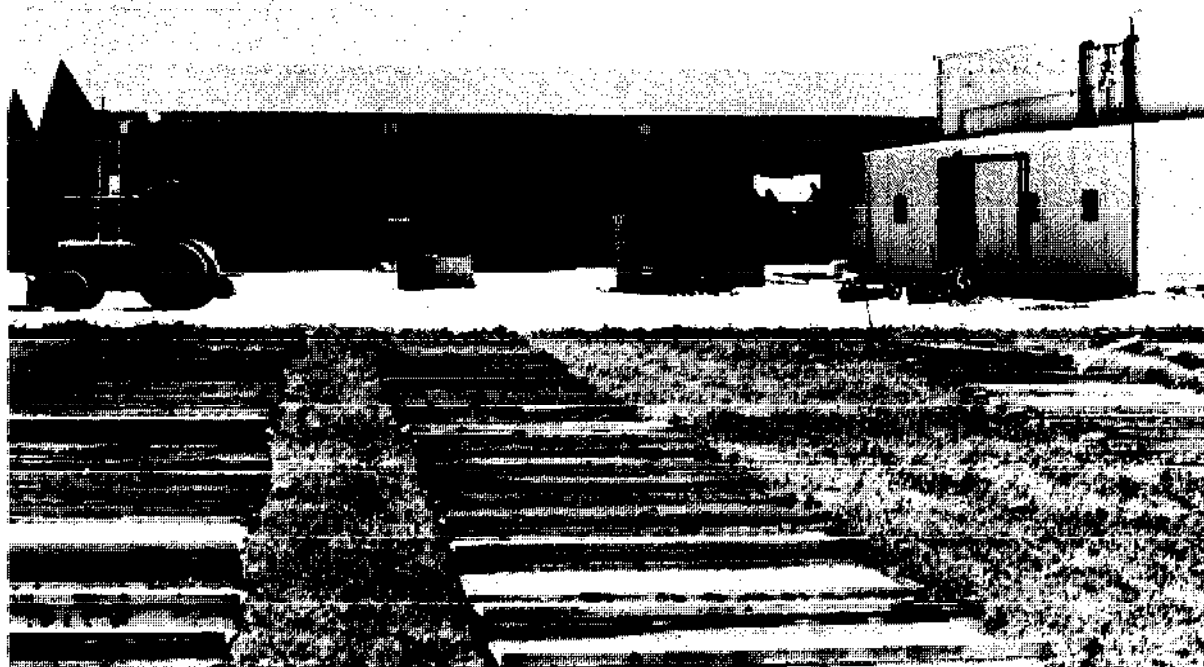
Cut Tree Fruits

Grading

In addition to grading for size it is essential to remove darkened, dirty or other faulty pieces to obtain an attractive and uniform product.

Packing

Whereas some years ago all tree fruits were packed in a sun-dried condition and



Plant for the centralized drying of fruits. Cool stores are on the right, cutting and spreading on trays are done under cover and fruit is drying in the foreground.

must meet the requirements of the Pure Food Act for the State in which they are marketed. Dried fruits for export must meet the requirements of the Export (Dried Fruits) Regulations, draft amendments to which have recently been approved by the industry as a preliminary step in the setting up of Statutory Rules.

At all times the packing-house must store the fruit so that deterioration in quality is

thus with a low moisture content, it is now common practice to market a moist pack in which the fruit is conditioned by further treatment in the packing-house. Apricots are almost entirely moist-packed and the treatment is also used to some extent on peaches and nectarines. The production of a moist pack involves certain processing problems and attention is drawn to the following points.

The statutory limit to which moisture content can be raised is now 25% for apricots and 22% for other fruits. Not only does this leave the processor leeway in which to handle the fruit efficiently but the softer product has gained a high consumer acceptance. In the United States, moisture levels up to 30% are often used and this may ultimately be permitted within Australia. In any case, if the permissible moisture limit is not to be exceeded, determination of the moisture content of processed fruit must be a regular procedure in the packing-house. Methods of determining moisture are discussed later.

There are various procedures by which processors increase the moisture content of farm-dried fruit. However, brief washing in cold water to remove surface dirt is common as a first step. Vigorous and lengthy washing at this stage, which may be needed for very dirty fruit, results in dehydration becoming essential as a final stage.

Most of the water is taken up by the fruit during a second stage which may consist of dipping for 10 s in water at 70°C, or a longer dip in cold water or steaming for 10–20 min. Sorbitol at 1.6 l in 50 l of water is commonly added to the dip as it reduces the drying out of the fruit later and improves appearance and texture. Some processors think that sorbitol reduces the loss of SO₂ from fruit, but no evidence exists for or against this view.

Adjusting SO₂ Levels

If necessary, SO₂ content in moist fruit may be adjusted during or after the increase in water content. Some processors add sodium metabisulphite to the dip while others spray with such a solution immediately after increasing the moisture content. A short exposure to burning sulphur may also be employed but excessive labour costs are gradually ruling this out. These treatments vary depending upon the initial SO₂ level but are meant to be applied to good-quality fruit which requires an increase in SO₂ level of

500 to 1000 ppm. Preservative added at this stage has been shown to be as effective as that applied before drying. Dips and sprays of sodium metabisulphite usually contain 1–5% sodium metabisulphite by weight and dipping times range from 10 s to 3 min depending upon the additional amount needed.

Attempts have been made to improve the appearance of dried fruits that are dark and unattractive. This defect is usually due to low SO₂ levels which may have been caused by poor drying conditions or overlong storage of the dried product. Some bleaching of dark colour can be achieved by moistening, resulphuring and further drying but any improvement is very limited.

Efforts to reduce the SO₂ level of dried over-sulphured fruit have also met with only slight success. Immersion in hydrogen peroxide will reduce the level slowly but this method leaves the fruit with an objectionable off-flavour and surface colour seems to darken rapidly following treatment.

If only a slight reduction of SO₂ level is required, this can be achieved by holding fruit in storage for a month or two before packing.

Problems of excessive SO₂ content occur chiefly in dried apricots. A proportion of the dried peaches and nectarines are also moist-packed but, since they normally have a lower SO₂ content, the main problem here is to ensure adequate SO₂ levels to prevent darkening during storage.

Storing

The desirability of avoiding holding dried fruits at elevated temperatures at any stage was mentioned earlier and packing-houses should consider the provision of cool storage for some of their intake, particularly fruit with SO₂ levels below 2000 ppm. Temperatures down to freezing point are not necessary because the rate of darkening of dried fruit is very slow below 15°C; 10°C would be an excellent practical holding temperature.

Moist-pack fruit tends to deteriorate more quickly than dry-pack and should not be stored unnecessarily. It is preferable to moist-pack throughout the year as demand requires, and fruit intended for export markets with their lower permissible SO₂ levels should only be packed as shipment is required. Deterioration of moist-pack fruit is rapid in tropical areas and the advantages of the drier product for those markets should be made clear to distributors and consumers.

Dried pears are normally packed without further conditioning and improvements that can be effected in the packing-house are limited. Hot water treatment and addition of sorbitol have been tried on pears but with little effect, and are not warranted.

Attention to size-grading and hand-picking for good or attractive appearance are the chief requirements. Over-sulphuring of pears during drying is very rare, and if the dried fruit is satisfactory at the time of delivery to the packing-house it usually keeps its condition without further treatment.

Prunes

Prunes when dried are dark in colour and while further darkening occurs slowly during storage this is generally not sufficient to be damaging. Cool storage is not necessary but prunes should not be stored in areas where they are subjected to high temperatures for long periods, such as next to a boiler house.

At packing-houses, prunes are size-graded and culled for broken or faulty fruit and then washed. It is usual to increase the moisture content to some extent before they are marketed. This is done principally by dipping in near-boiling water. How long the fruit is dipped depends on the initial moisture content and the level required in the processed article.

Bulk Prunes in Cartons

The common fibreboard pack is used for export and moisture content is limited to 22%.

Moulds are likely to develop if moisture level is even 1-2% higher. If prunes are shipped in containers it is advisable to keep moisture levels below 20%, as water migration which may occur under certain conditions of transit can result in serious microbial spoilage.

Prunes are first washed, dipped in boiling water for 2-5 min, drained to remove surface moisture and then packed.

Dessert Prunes in Cans

Dessert prunes are processed to a condition where the finished article contains more moisture and is much more tender than prunes in cartons. Usually only the larger sizes are used and the product is packed in No. 10 cans containing about 3 kg of fruit.



Hot, high-moisture prunes being hand-filled into cans ready for sealing.

The prunes are thoroughly washed and then processed in hot water for from 15 to 30 min to render the skin tender and the flesh soft. The time required for this depends on the variety and condition of the dried prunes and can be determined only by continually testing the fruit as it is being processed. This operation requires considerable experience so that different batches of prunes, with some variation in dryness and texture, will be processed to the correct point of uniformity in moisture content and tenderness required in dessert prunes. The prunes are packed hot into cans which are lidded and sealed. Some processors finish by placing the cans in boiling water for 30 min;

others retort for the same time at 35 kPa steam pressure; while still others, who ensure that the filling temperature of the fruit is not below 82°C, merely invert the cans to heat up the lids; the last process is adequate.

The moisture content of Fancy-grade dessert prunes packed in No. 10 cans must not exceed 37% for d'Agen and 35% for Robe de Sargeant. For Choice-grade dessert prunes of all varieties the moisture content should not exceed 33%.

Dessert Prunes in Plastic Pouches

Packing of dessert prunes in small (250-500 g) cans is expensive; a cheaper alternative pack using plastic pouches, suitable for sale through modern supermarkets and self-service stores, was devised and today accounts for more than 50% of prunes sold on the local market.

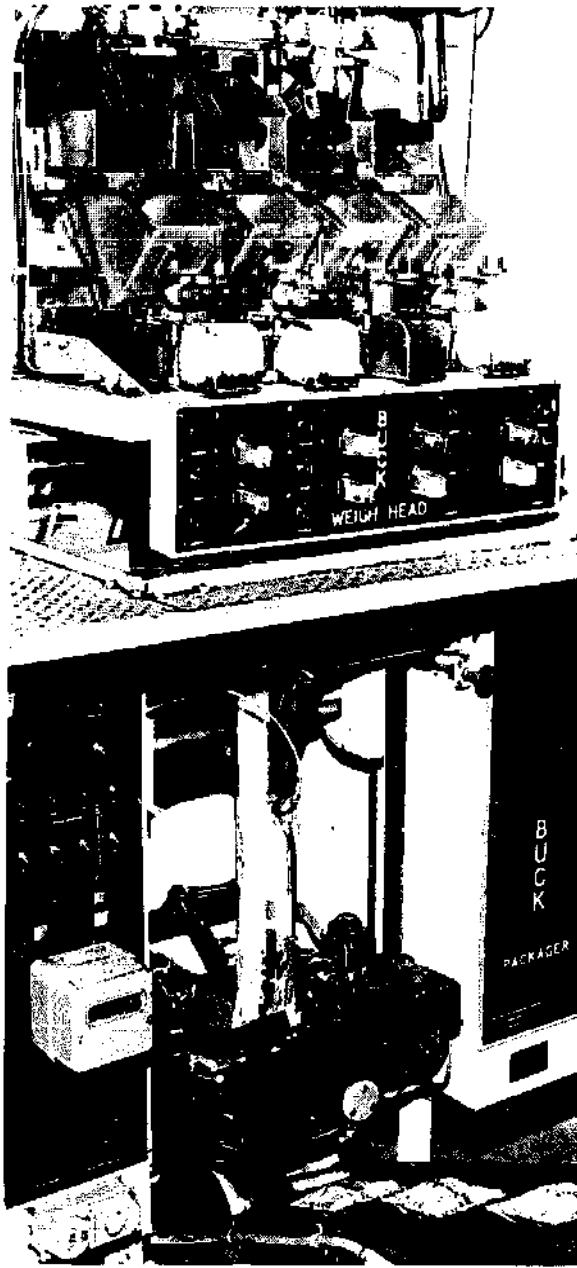
Moisture content is increased by immersing prunes in boiling water after grading and washing, as described above. The fruit is then packed at a temperature not below 82°C into pouches which are sealed immediately. This minimum temperature is most important to ensure that inoculation by viable yeasts and moulds cannot occur before the package is sealed. The hot pouches are then usually packed into cartons where they slowly cool.

The most usual type of package is a laminate of Cellophane and polyethylene with printing sandwiched between the two layers. Automatic packing and weighing machines are available which will deal with hot moist prunes and have a daily throughput of about 2 tonnes.

There is a tendency for processors to increase the moisture content of prunes in plastic pouches beyond 40%, even to the extent of free liquid being visible, but this procedure is dangerous because it increases the possibility of microbial spoilage.

A recent decision to permit the addition of a fungistat, potassium sorbate, to moist-pack prunes will allow lower temperatures to

be used when filling pouches and will avoid the necessity of keeping the pack under refrigeration after it has been opened.



An automatic weighing and packaging machine for sealing moist-pack prunes in plastic pouches.

Pest Control

Dried fruit is subject to attack by a range of insect pests, the most common of which are species of moths and beetles. Repeated insecticidal treatments can still control infestation but this is not enough for export

markets which are becoming more discriminating, particularly about the presence of insect remains and pesticidal residues. General hygiene must be such as to limit infestation as far as possible in both the orchards and the packing-houses. Packing-houses are subject to inspection under the authority of Exports (Dried Fruits) Regulations.

Three main measures for insect control are recommended for use in Australian packing-houses. The first is fumigation with methyl bromide using gas-tight sheets. It is most effective in killing insects which are infesting stacks of fruit because of its exceptional penetrating ability. Standard dosage is 24 g of methyl bromide per cu m per day of exposure time. Operators using this pesticide should use safety procedures in a code of practice approved by the National Health and Medical Research Council. In some States operators must be registered. Methyl bromide does not confer lasting protection on a treated product; fruit can be reinfested within a few days of fumigation. Thus its use should form part of a wider integrated system of insect control. A Californian procedure which could well be adopted is fumigation of all dried fruits entering a packing-house. This would ensure that no live insects would enter processing and storage areas via the fruit.

Dried fruits transported in containers may be treated with methyl bromide within the container, as long as appropriate safety measures are taken and the importing country permits this practice.

The second type of treatment is the application of insecticides with residual effect such as lindane (8-12 weeks), malathion (6-8 weeks), fenitrothion (6-8 weeks), dichlorvos (2-3 weeks) and pyrethrum. These are applied to structural parts of the packing-house. They should not come in contact with the food so are best applied before the start of delivery of dried fruit to the packing-house.

The third form of treatment is space-spraying or fogging with pyrethrum,

dichlorvos or lindane. Pyrethrum is preferred because of its relatively low toxicity; the minimum concentration in the insecticide should be 0.8%, and it is frequently used in conjunction with a synergist such as piperonyl butoxide (3%). Pyrethrum has a short residual life of 2-3 days and regular applications are needed.

Apart from general pest control, all cartons of dried fruit must, by regulation, be fumigated at the point of packing to ensure the destruction of any insect pests that may be present. This is most conveniently done by treatment of each individual container with ethyl formate, a volatile liquid sold under the trade name Eranol Z3. Dispensers in common use apply a dose of the liquid on the top of the fruit immediately before the carton is sealed. The dosage employed is 6 ml for a 16-kg carton. This treatment does not harm the fruit or affect its flavour. The ethyl formate evaporates and disappears in a few hours, leaving the fruit subject to reinfestation at any time during storage.

The increasing resistance of many species of insects to pesticides has not yet reached serious proportions in the dried fruit industry but it should not be ignored. An alternative control measure that should be studied is cool storage: insects that attack dried fruits cannot develop into major infestations at temperatures below 15°C.

Factors Essential to Produce a High-grade Pack

Processing details already outlined have indicated the various points that require strict attention to ensure a uniform and high-grade pack. Some of these warrant reiteration with stress on the influence they exert on keeping qualities.

Hand-picking and sorting, commenced in the field and completed in the factory, should be sufficiently thorough to ensure uniformity in colour. Export standards for shape, size, quality and allowable defects are defined by the Australian Department of

Agriculture and are judged by inspectors.

Sun-dried fruits that have a bright colour at the end of their drying period usually maintain their quality well at ambient temperatures, especially if their moisture levels are between 12 and 15%. Even for these, however, cool storage is a distinct advantage. Extremely dry fruits should be avoided because they are objectionably hard.

Moist-pack fruits as now commonly processed in Australia require particular attention to maintain good keeping quality. This fruit is packed in paper-lined boxes and the loss of SO₂ under storage conditions is at such a rate that values above the prescribed maximum would not often be experienced, taking into account the delay before the fruit is marketed. Cool storage of this fruit is strongly recommended if the aim is to hold

it for more than a few weeks at the packing-house.

The special requirements of some export markets in relation to SO₂ content must be carefully considered. Dried fruits for the armed forces must comply with Commonwealth Food Specification 4-3-2 which specifies moisture and SO₂ levels.

Consumers should be able to purchase high-quality dried fruits the year round. This can be achieved only if orchardists and packing-houses perform their respective operations properly. The orchardist must prepare uniformly good-quality dried fruit, while packing-house personnel are responsible for storing, grading and packaging the material for distribution as well as adjusting moisture and SO₂ levels so that the fruit meets all prescribed specifications.

APPENDIX

Methods of Analysis

Determinations of SO₂ and moisture in dried fruits must be done in packing-houses if quality control is to be practised. The procedures commonly in use are given below.

Determination of SO₂ in Dried Fruit

The method usually recommended in the food industry is that of Monier-Williams (1927), but for packing-house control purposes a rapid workshop method in general use in the dried fruit industry and considered to be sufficiently accurate is as follows.

Reagents

0.1 N iodine solution, accurately standardized
10% Sodium bicarbonate solution
1% Starch solution
Concentrated hydrochloric acid
Distilled water

Apparatus

B.A.R. distillation apparatus, comprising distillation flask, condenser, still head and absorption adapter
Glass beakers, 600 ml, 100 ml
1 Bunsen burner, hot-plate or other suitable source of heat
1 25-ml Burette, graduated in 0.1 ml

- 1 Balance accurate to 0.1 g
- 11.0-cm Filter papers
- Clamps and bosses for setting up apparatus
- 1 Stirring rod approx. 25 cm long with a rubber 'policeman' on stirring end
- Measuring cylinders of 250 ml, 25 ml and 10 ml capacity
- Asbestos wire gauze
- 1 Sheet of asbestos to protect condenser and receiver from heat of burner or hot-plate

Preparation of Sample

Pass 3 times through a mincing machine.

Method

(a) Place approx. 250 ml of water in distillation flask, bring to boiling point and boil 5 min. Add 5 ml of sodium bicarbonate solution. Weigh exactly 10 g of prepared sample on a filter paper, roll up sample in filter paper and place in distillation flask. Connect apparatus so that the outlets of the B.A.R. adapter are all below the surface of 200 ml of ice-cold distilled water contained in a 600-ml beaker and so that the bottom of the adapter is not less than 10 mm from the bottom of the beaker.

(b) To the distilled water in the beaker, add 2 ml of starch solution. Fill burette with 0.1 N iodine solution and add 1 drop of 0.1 N iodine solution from the burette. Zero burette reading, i.e. before starting the test make sure burette reading is 0.00 ml. Add 25 ml of concentrated hydrochloric acid solution to distillation flask through the thistle funnel and close tap immediately.

(c) Turn on heat so that the content of the flask boils within 2 min. Note time of the first sign of decolorization of the starch-iodine solution in the receiver. Slowly add 0.1 N iodine solution at such a rate that there is always a slight excess of iodine solution present. Stir contents of beaker continuously with stirring rod. As the speed of decolorization slows down, add the iodine solution 1 drop at a time, stirring after each

addition. The end point is reached when more than 1 min is required to decolorize the colour produced by 1 drop of 0.1 N iodine.

(d) In any case, distillation should be completed in 15 min and, if the rate of distillation after this time is slightly faster than that which could be taken as the end point, the burette reading after exactly 15 min of distillation is to be taken as the end point.

(e) A blank determination must be carried out in the same manner, but without the sample, in order to check whether the hydrochloric acid or other reagents have substances which interfere with the test.

Calculations

On a 10.0-g sample, each 1.0 ml of 0.1 N iodine solution is equivalent to 320 ppm SO_2 and each 0.1 ml is equivalent to 32 ppm SO_2 .

0.1 N Iodine (ml)	SO_2 (ppm)
1.0	320
2.0	640
3.0	960
4.0	1280
5.0	1600
6.0	1920
7.0	2240
8.0	2560
9.0	2880
10.0	3200

Determination of Moisture

Moisture determination should be made on the edible portion of the fruit, with the stone discarded.

The vacuum oven-drying method is considered the most accurate for determining moisture in dried fruit as, when the necessary precautions are taken, it usually gives an end point that is slightly more definite than that produced by other methods, while causing only slight caramelization or other visible chemical changes. The official method of the

Association of Official Agricultural Chemists (1970a, b) for dried fruits which stipulates drying for 6 h at 70°C in flat metal dishes, with special precautions regarding spreading, oven ventilation and pressure, has therefore been chosen as the standard method. Strict adherence to every particular of the prescribed method is essential. All other methods such as toluene distillation or the electrical conductivity methods must be calibrated against this vacuum-oven method.

For control purposes in packing-houses, the conductivity (moisture meter) method is the most convenient to use and, when properly calibrated and provided with suitable tables, the results obtainable with dried fruit should be sufficiently accurate for practical purposes. The degree of accuracy varies with each variety of fruit. For all dried tree fruits the appropriate U.S. conversion tables to convert meter readings to moisture percentage may be used with sufficient accuracy for packing and control; copies of these tables are available from the Commonwealth Research Station, Merbein. Copies of tables

for apricots and prunes, standardized for Australian conditions, may also be obtained from this source.

If a moisture meter is not available, toluene distillation for 2½ hours is recommended as reasonably satisfactory if a correction factor is applied. For dried apricots, 2.5% should be subtracted from the moisture content obtained to give a figure approaching that which would be obtained by the vacuum-oven method; for prunes, 1% should be subtracted.

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