

## TROPICAL FRUITS AND VEGETABLES. AN ACCOUNT OF THEIR STORAGE AND TRANSPORT\*

### NUTS

**N**UTS are often stored from one production season to the next. To prevent the development of rancidity and decay, and to control insect infestation, they are usually held at a low temperature; for the control of pests, a temperature of 50°F. is usually sufficiently low.

Pecan and Brazil nuts are more subject to deterioration than walnuts, almonds or filberts. Various reports indicate that walnuts, almonds and pecans can be held at 28°-30°F., 32°F. and 26°-38°F. for upwards of a year without deterioration. In storage trials with pecans, Medlock showed that a temperature of 40°F. was not low enough to maintain this commodity in sound condition for one year. According to Taylor, walnuts, almonds and pecans have been held, both shelled and unshelled, for periods of 4 years at 32°F. with only slight deterioration in flavour. At higher temperatures, moisture losses may become important. A temperature of 45°-50°F. is also considered satisfactory for walnuts, almonds and filberts. Shelled nuts, unless sealed in a vacuum, will not keep as long as unshelled ones. The most desirable moisture content results from storage at a humidity of approximately 65 to 70 per cent. As nuts readily take up undesirable flavours and odours, they should be kept away from apples, potatoes, &c.

### OCHRO

Ochro, or okra (*Hibiscus esculentus*) pods should be harvested when they are four or five days old, *i.e.*, when they are young, tender and crisp. Woodroof recommends that harvested pods should be placed under shade immediately and quickly handled to prevent shrivelling and toughening.

Half-bushel baskets are suitable as containers during harvesting, and four-peck hampers for transportation and marketing. Rough treatment is to be avoided. Gloves should be worn by workers to avoid the irritation setup by continuous contact with the stinging hairs.

Shill states that ochroes can be shipped successfully from West Indian Islands to the Canadian market, the storage conditions are not specified.

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\*By C. W. Wardlaw in *Tropical Agriculture*, Vol. XIV. No. 9, September, 1937

## ONIONS AND RELATED VEGETABLES

In this important group are included onions, leeks, chives, garlic and shallots or scallions, most of which can be grown successfully in tropical and sub-tropical regions.

### ONIONS

Although some varieties of onion (*Allium cepa*) can be kept for long periods in common storage, the use of refrigeration is essential for the satisfactory preservation of others; the modern view is that cold storage offers practical advantages in the handling of all varieties. Losses in onion storage are due to sprouting, root growth, fungal rotting, shrinkage and freezing.

### DRYING AND CURING

Onions should be well matured and thoroughly cured in the field, in drying sheds or on trays before being placed in storage. Experimental records show that the possibility of successful storage depends on the initial quality of the product; decay and deterioration tend to occur during the storage of immature, soft, 'thick-necked,' or imperfectly cured onions. Slatted crates or shallow bins are the most suitable storage receptacles. When cured in the field, bulbs are usually placed in slatted crates, stacked four or five tiers high. According to Wright, onions, after being pulled, are first of all dried in the windrows for 3 or 4 days; curing, *i.e.*, final drying out of the superficial scales, is then effected in slatted crates, stowed in open sheds or under tarpaulins; this operation may continue over several weeks.

The care with which handling, cleaning and drying operations are carried out has important effects on the subsequent storage life. Onions damaged during harvesting, packing or handling, if not thoroughly dried, soon begin to decay in storage.

### FACTORS GOVERNING KEEPING QUALITY

Jones and Bisson have observed that different varieties of onion show very considerable differences in respect of their moisture content. Thus dry weight determinations ranged from about 5 per cent. (of the fresh weight) in the Sweet Spanish variety, to about 16 per cent. in the Red and White Creole varieties. "Evidently those varieties which are considered mild and of rather poor storage quality have the highest moisture content, whereas those that are the most pungent and keep best in storage have the lowest moisture content." The moisture content in individual varieties is also subject to variation according to the growth conditions provided: onions grown on a peat soil were found to have a higher moisture content than those grown on a mineral soil. Similar observations on the relation between keeping quality and dry matter content have been made by Woodman and Barrell.

In a detailed study of the relation between keeping quality and rates of water loss during storage, Woodman and Barnell have shown that high relative rates of water loss, and high total water losses, are characteristic of non-keeping

varieties of onion. As differences in rates of water loss are particularly apparent during the period immediately after harvesting, they consider that actual storage trials may not be necessary in classifying new lines as keeping or non-keeping types.

### STOWAGE

Onions for storage should be packed in bags or crates and stacked so as to permit of good air circulation. When stowed in sacks, shelves or racks should be provided to avoid the bruising injury which might result from the weight of super-imposed sacks. Onion rooms should also be completely separated off from other storage rooms to avoid contamination of tainting.

When large quantities have to be stored, the bags are piled in pairs laid crosswise in stacks about six bags high. The bottom pair of sacks should be laid on 2×4 inch dunnage strips to permit of air circulation ; the stacks should also be separated by 2 inch air spaces. According to Williams, storage in trays or in well ventilated boxes is better than storage in bags, wastage being consistently less.

### STORAGE TEMPERATURE AND HUMIDITY

There is a general consensus of opinion, that for successful storage, onions require good ventilation, low temperature and low relative humidity, low temperature being considered more important than low humidity. Not only is it necessary to control the growth of moulds, but sprouting and root development must also be prevented.

In storage trials at 32°, 40° and 50°F., with controlled R. H. varying from 65 to 90 per cent., Wright, Lauritzen and Whiteman have shown that the amount of sprouting—an important cause of loss—which occurs during storage is only slightly influenced by humidity but rather definitely by temperature : on the other hand, root formation is only slightly influenced by temperature, but is increased by increasing the humidity. In their experiments the amount of decay did not increase greatly with increased temperature and relative humidity. Onions sets showed an increase in sprouting, rooting and decay as the storage temperature was raised and as the relative humidity was increased at each storage temperature. The best storage environment for both onions and sets was found to be 32°F. with a relative humidity of about 65 per cent.

For onions grown in the United States the following general recommendations, ensuring successful storage up to 6 months with suitable varieties, have been given. At a temperature of 31°-32°F. there is the minimum of decay and no sprouting will occur ; low humidity is not essential but is desirable ; at higher temperatures onions should be kept as dry as possible. "Onions have been kept in good condition at as high a temperature as 40°-45°F. for several weeks when the humidity was kept low. Onions in storage should be kept dry enough to "rustle" like dry leaves when handled. In

cold storage at the higher range of temperatures it is usually impractical to keep the humidity sufficiently low, so it is the usual practice to store at 31° to 32°F. According to Platenius *et al* experimental lots of onions have remained in perfect condition at 30°-32°F., even when the R.H. was as high as 95 per cent.

A temperature of 32°-36°F. in well-ventilated chambers or cellars is advised by Corbett, Stewart and Thompson. Fricbe-Seupin records successful storage of onions at—3°C. (26·6°F.) and R.H. of 85-90 per cent. for 5-6 months. Rose, Wright and Whiteman recommend a temperature of 32°F. and R.H. of 70-75 per cent. for onions and onion sets, 5-6 months storage being assured. For onions grown in New Zealand, Sutherland cites 31°F. and R.H. of 78-81 per cent. as having given excellent results over a period of six to seven months, and considers that, by concentrating on the production of the more hardy varieties, it should be possible, with the help of refrigeration, to supply local markets throughout the greater part of the year.

Experimental work in Sweden has shown that at a temperature of 30·5°F., onion tissue may be altered by putrefaction, mould and germination. On the other hand, a very low temperature, *e.g.*, 19·5° to 23°F., kills the tissue and coagulates the albumen, which, after thawing, remains denatured. At 27°F., the tissue remains unaltered, and, on removal to higher temperatures, is similar to that of fresh onions, a view supported by chemical analyses. (See Undercooling).

Boswell studied the behaviour of onions during, and subsequent to, storage at 32°, 40° and 50°F., and found the lowest temperature most suitable. Onion plants from the lots stored for eight months at 32°F. showed extraordinarily vigorous leaf growth and a scarcity of flower stalk; storage for 6 months at 32°F., followed by 6 weeks at 50°F., resulted in a much more rapid growth than was obtained in bulbs held at 50°F. throughout. Other records also cite 32°F. as being best suited to the storage of onions.

Williams has reported satisfactory storage of Australian onions, held at temperatures ranging from 38°F., to below freezing point; bulbs held below the freezing point for onions (29°F.) had a particularly good appearance at the end of 3 months' storage. Some varieties, on being thawed out and held at ordinary temperatures gave a better storage life than others. Gradual thawing out (over a period of 2-3 days) was shown to be advantageous, as the onion tissues are very susceptible to rapid changes in temperature. Where this procedure was adopted, the full quality of the onion was retained, so much so that it compared favourably with that of fresh onions. Bulbs stored above freezing point also yielded good results, except that some sprouting took place. As a rule this commodity stored satisfactorily for a period of 6 months.

## HANDLING AFTER COLD STORAGE

When onions are removed from cold storage during warm or damp weather, the temperature should be allowed to rise gradually; this will prevent the condensation of moisture; otherwise the bulbs may be liable to severe rotting, particularly if they are loaded tightly into a car or other limited space where drying out is precluded. This danger can be avoided by moving them through a succession of intermediate temperatures till the outside temperature is reached.

## LOSS IN WEIGHT

Losses in weight in stored onions, due to rotting, evaporation, and metabolic processes, may in some instances assume considerable importance. In lots held in ordinary storage for 6 months at Pusa, Walton records losses of 58 per cent. by weight in bulbs stored on racks, and 46 per cent. in bulbs stored in baskets; rotting accounted for 5.5 and 13.1 per cent. respectively of the initial weight.

In onions stored at 29°F., Williams observed a loss in weight of only 4 per cent. in the course of six months, as compared with the 12 per cent. which is customary in common storage. Consignments of Sweet Spanish onions are reported as being subject to severe shrinkage through decay and rooting in storage.

In an earlier section attention was drawn to the important relation that exists between keeping quality and rates of moisture loss in different varieties. Woodman and Barnell have demonstrated that water losses take place mainly from the inner and not the outer surface of the scales, and therefore occur mainly through the neck of the bulb. Such losses are greatest immediately after harvesting; later, water loss proceeds at an approximately steady rate. Total losses, under comparable storage conditions, are always greater in non-keeping than in keeping varieties. Thus after 100 days whereas Unwin's Reliance, a keeping variety, had lost only 5-6 per cent. of its initial fresh weight, White Lisbon, a non-keeping variety, had lost approximately 30 per cent.

## UNDERCOOLING, FREEZING AND LOW TEMPERATURE INJURY

From storage data cited above it will be noted that onions may be held below their freezing point without sustaining injury, provided certain conditions are observed. Thus both Williams and Rasmusson indicate successful storage at temperatures below 29°-30°F., the freezing point for onions. The effect of freezing on onions has been the subject of some critical studies by Rasmusson and Wright. (A type of physiological breakdown comparable in symptoms to freezing injury has been described by Wright, Lauritzen and Whiteman. It was observed both in storage and under field conditions before any actual freezing had occurred; in yellow Globe onions stored at 32°F. a somewhat higher percentage of affected bulbs occurred in lots held

in the higher humidity chambers: this type of breakdown is characterised by a very limited amount of watery discoloration in the outer scales only).

In experiments with onions of the Globe type, Wright ascertained that while the average freezing point was in the neighbourhood of 30°F., it varied to some extent according to the temperature at which the onions had previously been stored: for example, bulbs which had been held at 32°F. had a consistently lower freezing point than those stored at 40° or 50°F.

*Undercooling.*—Although a temperature of 30°F. should be regarded as the minimum storage temperature, it has been observed that onions may be undercooled (*i.e.*, cooled below the freezing point without actual freezing of the sap taking place) without sustaining injury.

Undercooling in an onion may be terminated at any time and freezing (*i.e.*, crystallisation of the sap) begun by a sudden jarring or other disturbance.

“Therefore when onions are known to be cooled below their freezing point they should be handled with care, since a sudden jar, as when crates are roughly handled or onions are poured from crates or bags to be graded, is likely to start freezing in onions which otherwise would warm up without injury. Numerous tests conducted with undercooled onions have never shown injury caused by cooling below the freezing point, provided they were not permitted to freeze.”

The period during which onions may remain undercooled (and uninjured) varies according to internal and other factors. Wright has described experiments in which bulbs held at 22°F. for 2, 4 and 6 days showed 0, 15, and 25 per cent. freezing injury respectively. When onions have been allowed to freeze, the extent of freezing injury is greater if they are transferred to storage at a low temperature, *e.g.*, 32°F., than if they are removed to a higher temperature, say 40°F.; in such an experiment the 40°F. lot only showed 25 per cent. mild freezing injury as against 75 per cent. severely injured in the 32°F. lot; the more severe wastage at 32°F. was presumably in relation to the fact that ice still remained in the tissue, and that the bulbs remained below their freezing point for a considerable time before their temperature rose sufficiently to prevent freezing action.

*Freezing Injury.*—Freezing injury can readily be diagnosed by cutting open bulbs, when the affected tissues are seen to have a water-soaked, discoloured, transparent appearance, with indefinite scattered opaque areas. Wright states that “Symptoms of freezing injury are frequently and easily confused with those of physiological breakdown caused by excessive heat and other undetermined factors. When cut, such affected specimens show certain transparent, discoloured scales similar to those caused by freezing injury, but usually without the scattered opaque areas. Freezing usually includes an entire scale all or nearly all the way round the onion. Often one scale is found injured while the adjoining ones may be normal. Following light

freezing, usually the outer scale only is affected ; with more severe freezing the injury is found in the more inner scales, often skipping one or two scales as it penetrates toward the centre. The last portion to succumb is the heart or growing point, at the centre of the base of receptacle."

In onions which have been lightly frozen, *i.e.*, where only the outer scales have been affected, serious losses can be avoided if care is taken to dry out the bulbs ; the water-soaked scales become dehydrated and the onions, though somewhat softer than before, remain in good condition : in damp storage on the other hand, decay soon becomes evident.

### BLEMISHING AND DISCOLORATION

Blemishing and discoloration, due to chemical injury, exposure to sunlight, and to fungal organisms have been considered in some detail by Ramsey and Butler and Ramsey. Freezing injury has been treated in detail above.

*Chemical Injury.*—Dark brown or black discolorations of onions, described as "scorched spot" and "bag print," are the result of chemical action by substances in the sack fabric, operating under conditions of damp storage ; as a rule the underlying fleshy scales are not injured in any way and eating quality remains unimpaired.

*Ammonia Injury.*—A uniform and severe type of discoloration caused by the accidental exposure of bulbs to ammonia fumes from the storage plant is occasionally found in onions that have come out of cold storage.

"The fumes cause an alkaline reaction with the colour pigments in the outer scales of the onions and often produce pronounced discoloration so that the marketability of the stock is greatly reduced. As a result of exposure to ammonia fumes yellow onions show brown blotches or a uniform brown colour over all the exposed surfaces ; red onions change to a deep greenish-black or metallic-black colour ; and white onions are discoloured greenish-yellow. If onions are exposed to strong fumes for several hours the fleshy, edible portion of the bulbs becomes watery, yellowish-green and worthless.

"Experiments have shown that ammonia injury will take place at a temperature as low as 31.5°F. and that the rate and severity of discoloration are approximately the same as at higher temperatures. The colour changes have been found to take place more rapidly in a humid atmosphere or when the onions are slightly moist. Less than 1 per cent. of ammonia in the air will cause marked discoloration if the onions are exposed for 24 hours or longer. With stronger concentrations the colour changes are noticeable almost immediately and large brownish-black blotches are produced within a few minutes.

"A similar type of discoloration in coloured onions has been observed in stock that had been covered with manure for protection against freezing. The ammonia fumes from the manure cause almost a complete blackening of the outer dry coloured scales, but generally do not discolour the fleshy scales."

*Sun Scald.*—Onions grown in regions of high temperature and bright sunlight frequently suffer from sun-scald during harvesting, immature and moist bulbs being most severely affected. The tissues of scalded areas are killed and become soft and slippery, but soon dry out, leaving bleached, white, sunken and leathery areas,  $\frac{1}{2}$ -1 $\frac{1}{2}$  inch in diameter. The blemished areas are also important as a means of ingress for fungi and bacteria. Another type of sun injury, described as sunburn or greening, is the result of exposure of bulbs during the growing period or after harvesting: green colouring matter develops in the exposed tissue but does not cause death or softening of the affected region. The tissues, however, tend to be bitter and unpalatable.

*Fungal Blemishing.*—Various fungal pathogens cause more or less severe blemishing, staining or wastage; typical infections have been described as Smudge, Black Mould, Purple Blotch and Soil Stain.

### ONION SETS

In general, onion sets require much the same storage conditions as do the mature bulbs. The sets are usually stored in shallow slat-bottom or wire-bottom trays, 4-6 inch deep, 2 by 3, 4 by 5, or 5 by 5 ft. in size, the trays being stacked so as to leave a space of one inch between the tiers. According to Platenius *et al* sets of more than one-half of an inch in diameter frequently develop seed stalks before time for bulbing. It has been shown that the temperature at which sets are held during the winter and spring affects the subsequent seed-stalk development, the percentage of seed stalks increasing as the temperature of storage is raised above 30°F.; at temperatures much higher than 32°F., the sets sprout before the time for planting and some decay may result. At 30° and at 32°F. sets keep well and remain dormant until planted; these temperatures are recommended when cold storage is employed.

### LEEKs, GARLIC, SHALLOTS

Green leeks are best stored at 32°F. with a R.H. of 85-90 per cent.; if properly handled they should keep satisfactorily for 1 to 3 months in storage.

Cultivated garlic may be kept at 21°F. without danger; 27°F. also gives satisfactory preservation. For dry garlic, Rose *et al* cite a temperature of 32°F. and a R.H. of 70-75 per cent., giving a storage life of 6-8 months.

For shallots, a temperature of 32°F. is considered suitable.

### PAPAW

The papaw or papaya (*Carica papaya*) indigenous to tropical America, has become a food of some importance for local consumption in various parts of the tropics and sub-tropics. It is well known as the source of the digestive substance papain, obtained by coagulating the latex exuded from green fruits on wounding. During recent years some attention has been paid to the papaw as a possible export crop notably in South Africa and the West Indies,

while as early as 1907 Higgins was considering the possibility of exporting the fruit from Hawaii. An attempt has also been made to extend papaw cultivation in California and to breed varieties adapted to prolonged storage or transport. From the information available on the production and cold storage behaviour of papaws, it may be predicted that the organisation and standardisation of an export industry will be attended with serious difficulties.

### SELECTION OF DESIRABLE TYPES

The papaw shows great variety in its fruiting characters, some types producing small fruits, spherical and no longer than an orange, and others elongated fruits as large as water-melon and weighing up to 25 lb. The immature fruit is firm and green with a thin waxy cuticle, the flesh being of a whitish or greenish-white colour. On ripening, the flesh becomes soft, and of a pale-yellowish to dark reddish-orange colour according to the variety; externally the fruit has a yellowish or orange colour. Flavour varies from varieties which are insipid and tasteless to those which are sweet and spicy. According to Barrett the fruit, even when immature, contains no starch.

Fruits for export should be of smallish or intermediate size and of a shape suitable for packing side by side in a standard crate. They should possess a reasonably tough skin to minimise the effect of bruising and should show some degree of resistance to the normal storage pathogens. Lastly, in addition to obvious, essential requirements in the matter of attractive appearance and colour, flavour and thickness of flesh, the constitution of varieties selected should be such as to make for good keeping quality in storage. In all of these respects great variability is the rule.

In working towards an export trade, standardised production under plantation or orchard conditions is a first essential. The difficulties attendant on the field aspect cannot be over-emphasised. The outstanding problem is to select and perpetuate good types from material which is notoriously variable. Again, most varieties are dioecious so that, in establishing an orchard the liability to a low standard of production is accentuated by the number of male plants present in a sowing. Hoffmeyr has indicated the possibility of improving stocks by selection, the main points in a selection programme being (*a*) keeping and shipping quality, (*b*) suitable shape and size for packing, (*c*) colour when ripe, (*d*) eating quality, (*e*) thickness of flesh, (*f*) length of fruit stalk, (*g*) disease resistance, (*h*) yield and vigour. Some hermaphrodite varieties are known and it has also been shown that cutting back male plants frequently, though not invariably, causes a change of sex. According to Hoffmeyr, there are no true-breeding papaw varieties, and observations in any grove will reveal great variability in shape, size and quality of fruit and vigour of plants.

Attempts have been made in Hawaii to breed a hermaphrodite strain and it has been demonstrated that it is possible to increase the percentage of

fruit-bearing plants. Unfortunately no means of early sex-diagnosis has yet been discovered. As a rule no difficulty has been experienced in crossing the various types: the trouble lies in the fact that it has not yet been possible to fix the desirable types obtained by crossing. Some papaw varieties are seedless. According to Cheema and Dani this is due entirely to the absence of pollination, the size and weight of a fruit being related to the number of seeds it contains.

Up-to-date accounts of general cultivation and marketing requirements are given by Pope, Nyenhuis, Hoffmeyr, Cheema and Dani. In the West Indies, orchard difficulties are accentuated by the presence of a widespread virus disease which completely destroys the crown of foliage with concomitant loss of crop.

### MATURITY, STORAGE TEMPERATURE AND CHILLING

One of the earliest accounts of papaw storage is that given by Higgins, working in Hawaii. Fruits for local consumption, according to Higgins, should be picked when they show the first trace of colour. When fruits of this maturity were wrapped in paper surrounded by a sleeve or cylinder of crimped strawboard, placed side by side in a single layer in a flat crate, and shipped to San Francisco—a voyage of 7 days in cold storage (temperature not specified)—fairly satisfactory results are said to have been obtained. The wastage recorded ranged from 7 to 44 per cent. It is stated that the fruit did not deteriorate in flavour. Wilcox and Hunn have also given some account of six Hawaiian varieties stored in cold chambers maintained at 32° and 36°F. The results were generally successful: these temperatures are now known to induce chilling, with concomitant excessive wastage later. Nearly ripe fruits, *i.e.*, yellow coloured but firm, washed with 3 per cent. formalin to prevent or curtail the growth of moulds, are stated to have kept in good condition at either temperature for one month to six weeks.

McGuire records that an experimental shipment of a few cases of papaws was made from South Africa to London—a transit period of approximately 24 days at 38°-40°F.—but no marketing data are available.

Nyenhuis, referring to papaws grown in Northern Transvaal, stated that fruits, after careful washing, were wrapped in tissue paper and placed in cases, 4 fruits to the case, with a plentiful packing of woodwool. The cases were sent in refrigerated trucks to the Capetown Low Temperature Research Station for further observation, where they were stored for 3 weeks at 36°, 40° and 45°F. and a R.H. of approximately 90 per cent. Two stages of maturity were selected for investigation: (a) fruits full-grown, dark green but showing the first trace of yellow; such fruits were considered sufficiently mature to ripen after long storage; and (b) riper fruits of pale green colour, the yellow colour being distributed fairly evenly over the surface.

On removing fruits from cold-storage after 3 weeks very little advance in ripening could be detected ; those at 40° and 45°F. were becoming mouldy, particularly on the lower side. After 5 days' exposure at room temperature no appreciable ripening had taken place but wastage due to fungal activity was conspicuous. Further exposure at the higher temperature failed to induce normal ripening. After 14 days, the greener fruit grade (*a*) had failed to ripen and the more mature grade (*b*), though ripe, was wasty and of poor flavour.

Storage trials carried out in Trinidad in 1933 and subsequently have shown that relatively immature papaws will not ripen after cold storage, and further, that most of the varieties tested show evidence of chilling if held at temperatures lower than 55°-60°F. Fruits at three stages of maturity (*a*) full-grown green, (*b*) with first traces of yellowing and (*c*) more or less completely yellow but still firm, were held for periods of 15 and 20 days at 45° and 50°F. approximately, for comparison. The following observations were made. Wastage was serious at both cold storage temperatures, but was noticeably worse in fruit held at 50°F. It was evident that some types of papaw possess greater resistance to pathogenic fungi than others. In the course of 20 days at 45°F. and 50°F. respectively, apart from the onset of wastage, there was no evidence, as judged by external criteria, that maturation had advanced significantly in any of the three classes of fruit. Even the yellow fruits were still quite firm, and apparently unaltered from the time of reaping. Green fruits, on transference to the ripening room at 70°F., failed to ripen and were soon overrun by various fungi or partly shrivelled before any trace of colour appeared. It is evident that fruit reaped at this stage of maturity is quite unsuitable for export. Slightly coloured fruits were little better as regards external appearance, but became soft and were quite palatable. The almost fully coloured fruits, on the other hand, were normal in behaviour. In some types, in which storage pathogens had become established, degeneration at the higher temperature was rapid and within two days the fruits were unsightly and unfit for use. A few of the yellow fruits, however, undoubtedly possessed a better keeping quality and were still in good condition after three to four or five days at 70°F. The inference is that fruit for export should be reaped when yellow but quite firm, and held at 45°F. There was also definite evidence that some varieties on transference to the ripening room or if held at tropical temperatures ripen more rapidly than others. In attempts to secure a partial ripening of green or slightly yellow fruits by holding them for a few days at tropical temperatures prior to cold storage, the subsequent wastage was excessive.

The results indicate that the overseas transport and distribution of papaws is by no means impossible provided suitable types can be selected. It is also evident that fruits should be well coloured but still firm at the time of reaping. As these remain practically unchanged during 20 days

storage at 45°F., they should, if carefully packed, be available for retailing on distant markets. In handling a delicate fruit like the papaw, it would be an advantage if some refrigeration could be given during the distribution period. The handling of green or slightly coloured fruits at a higher storage temperature, say 55°F. to 60°F., to permit of partial ripening during the voyage period, is precluded by the onset of fungal wastage at temperatures above 50°F.

### ETHYLENE RIPENING

According to Harvey papaws picked sufficiently green to withstand shipment can be ripened to a product of agreeable flavour, comparable to that of fruits ripened in the tropics, by the use of ethylene gas.

It has been found that papaws are very susceptible to low temperature injury: chilled fruits fail to ripen and acquire a smoky or sooty greenish-yellow colour and are particularly subject to fungal attack.

### FUNGI CAUSING WASTAGE

The wastage which develops when papaws are held in storage is principally due to *Colletotrichum gloeosporioides* (anthracnose spots), established as latent infections during the development of the fruit in the field. Normally these only become apparent when the fruit is approaching final maturity in storage but they may also occur in less mature fruits which have been held at chilling temperatures. So far, spraying with fungicides in the field and steeping fruits in disinfectant solutions have not yielded the desired reduction in rotting.

### PARSNIPS

Boswell studying the parsnip from the point of view of changes in quality and chemical composition during storage, found that roots may be rapidly brought to a state of high table quality by storage at 32° to 34°F.: the hydrolysis of starch and other polysaccharides proceeds much more rapidly than at ordinary temperatures, with concomitant accumulation of sucrose. The commercial value of this vegetable is enhanced by holding it at a temperature of 32° to 34°F. for three weeks. A temperature of 32°F., and R.H. of 90-95 per cent. should ensure a storage life of 2-4 months. Platenius *et al* state that when stored at 45°F., parsnips lose moisture and deteriorate rapidly.

### PASSION FRUITS

The Passifloras to which attention has been directed in storage literature include the purple granadilla or passion fruit (*Passiflora edulis*), the sweet granadilla or water-lemon (*P. ligularis*) and the giant granadilla (*P. macrocarpa*):

## PASSION FRUIT

The purple granadilla or passion fruit, native to Brazil, is now grown throughout the tropical and sub-tropical belt, reaching its greatest economic importance in Australia. The commonly grown species, *P. edulis*, is very prolific and when fully matured has a dark purple skin, sub-acid flavour and a distinct agreeable odour.

### HARVESTING, GRADING AND PACKING

Pope states that gathering and handling should be done while the fruit is cool, and that Hawaiian fruit intended for shipment should be cut from the plants when it is just approaching the full colour of ripeness. The best flavour is obtained in fruit fully ripened on the vines. According to Krone, Australian fruit should not be harvested at the beginning of the season until it has completely changed to its darker colour but before any sign of shrivelling has appeared. As the season advances picking at a less mature stage is desirable; the correct picking maturity is indicated when fruits have become more than three parts coloured; this allows for the completion of ripening during transport, storage and marketing. In hot weather fruits should be harvested just colouring. Fruits harvested immature fail to ripen properly; instead of the normal dark purple colour developing, such fruits assume a reddish colour and may shrivel before becoming fully coloured.

Fruits should be collected daily, windfalls being picked up first as they are quickly ruined by exposure to hot sunlight.

The view has been expressed that fruit from correctly pruned vines is superior in quality to that from badly pruned or unpruned vines; the pulp is more luscious and of finer quality and the skin of harder texture. The fruit should be collected in padded field boxes. Careful handling is particularly important in consignments intended for export.

Krone and Gregory direct attention to the importance of careful grading and packing. "Dummy," *i.e.*, light weight fruits, should never be packed along with fresh fruits. Three grades, "special," "standard" and "plain" have been suggested for Australian produce, according to size, succulence, woodiness and shrivelling exhibited by fruits. Desirable types of cases and systems of packing have been described in detail by Krone and others.

### STORAGE TEMPERATURE

The passion fruit has long been considered unsuitable for prolonged storage; fermentation of the pulp, shrivelling and fungal decay all militate against the preservation of this delicate fruit. In an early reference, Benson, 1893, states that passion fruit cannot be held in cold storage in good condition for more than 2 weeks.

In storage trials at 36°F. with Australian passion fruit, commenced in 1929, Savage and Ramsay record only moderately good results. By the end of the second week in storage, the fruits, whether packed with or without

peat moss, had acquired "papery" skins. By the end of 6 weeks, apart from the development of moulds, the skins had become very thin and there was a general depreciation in flavour. At this stage, moss-packed fruits had a slightly better appearance than the others.

It is considered that harvesting at the correct stage of maturity, trimming the stem-ends close to the fruit, and quick cooling will contribute materially to the successful transport of this commodity.

Recent investigations, conducted under the auspices of the Australian Council for Scientific and Industrial Research indicate that passion fruit will not stand low temperatures. In storage experiments at 36°, 43° and 50°F., it was found that a storage life of only 4-5 weeks could be anticipated and that low temperature breakdown, in the form of a blood-red discoloration of the skin quickly followed by mould attack, occurred at temperatures below 50°F. Some gas-storage experiments, using 5 to 15 per cent. carbon dioxide at a storage temperature of 45°F. have been carried out, but further investigations are required.

### WATER-LEMON OR SWEET GRANADILLA

According to Wilcox and Hunn consignments of this fruit, grown in Hawaii, kept in good condition for periods of 2-3 months at storage temperatures of 32° and 36°F. "At the end of the time, the appearance of the rind, the fibrous bag inside the rind, and the pulp of the fruit were the same in all respects as when the fruit was put in cold storage." Wilcox and Hunn comment on the difference between results with Hawaiian fruit and those obtained with passion fruits by Benson in Australia.

### THE GIANT GRANADILLA

This species has the largest fruit among the Passifloras; its quality, however, is inferior to that of other edible species. While it is widely distributed in the tropics, it is nowhere cultivated on a commercial scale.

Some experiments on the storage behaviour of granadillas have been carried out in Trinidad. Fruits picked green, turning, and yellow were stored in small quantities at 50°F. for 17 days, then transferred to the ripening room at 70°F. After 7 days at 50°F. the yellow fruits, which were already almost ripe on reaping, had become over-ripe, soft and leaky. Green fruits showed little change during the entire period in cold storage, but turning fruits showed a slight increase in colour. In the course of 7 days at 70°F., turning fruits became quite ripe and soft and green fruits became slightly coloured, soft and ready for use. In a second experiment, green and turning fruits were held at 45°F. for 15 days and subsequently ripened at 70°F. in the course of 7 to 10 days.

If required for export, this fruit should not prove difficult to handle. Although prized locally for the preparation of ices and drinks—the pulp has a pleasant sub-acid flavour—the cost of crating and freight for such large fruits

(some are nine inches long) would seriously militate against its economic disposal on distant markets.

Smith has recorded that very large granadillas, when reaped mature, can be stored at 47°F. for a considerable time without deterioration; fruit reaped less mature was unpalatable after cold storage.

### PEPPERS

Peppers and chillies (*Capsicum* spp.) are represented by many varieties in the tropics. Sweet peppers for export are usually reaped when full grown but green; Smith records that mixed lots of red and green fruit make an attractive pack and have been favourably received by the trade.

### PACKING

Peppers, from which over-ripe and sun-scalded fruits have been eliminated, are graded for size, packed in what is known as the American pepper crate, or in smaller slatted cases lined with glazed tissue paper. Jamaica exporters have found a hinged crate measuring  $16 \times 11\frac{1}{2} \times 9$  inch to be satisfactory and acceptable. Wrapping of fruits has not been found necessary.

### STORAGE TEMPERATURE

The most comprehensive consideration of the effect of storage temperature and humidity on the keeping quality of peppers is that of Lauritzen and Wright. Fruits were held at four temperatures, 0°C. (32°F.), 4.5°C. (40.1°F.), 10°C. (50°F.) and 13°C. (55.4°F.) several different humidities being provided at each temperature. The chief causes of wastage were infection and rotting by *Botrytis cinerea* and anthracnose.

Ripening continued at all four temperatures, but was very slow at 32°F. In green fruits ripening was sufficiently slow at both 32° and 40°F. to permit of storage for upwards of three, or four weeks. Indeed little advance in maturation took place at 32 and 40°F. in the course of 39 days. The higher the temperature and the lower the relative humidity the greater was the extent of shrivelling: a temperature of 40°F. and R.H. of 95 per cent., or a temperature of 32°F. and R.H. of 90 per cent. provided conditions favourable to the storage of peppers. Of the two storage conditions the latter was to be preferred: the limiting factor at the high relative humidity employed was infection and rotting by *Botrytis cinerea*, but as the earliest infections were only observed after 32 days, and the amount of wastage remained small until after 46 days, a reasonable storage life is assured. The time required for the initial growth of *Botrytis* at 40°F. and 50°F. was about 18 days. From data submitted by investigators it is evident that the anthracnose fungus is already present in fruits prior to storage in the form of latent infections: hence, although their development is influenced by the temperature factor, it is little affected by humidity.

For American produce it has been stated that green peppers can be kept from one to three weeks at 32°F. with a humidity of 90 to 95 per cent.; at this temperature will be found the minimum of decay, shrivelling and ripening. A more prolonged storage life has been cited by other workers. Thus from experimental trials, Platenius *et al* states that peppers remained in good conditions for 10 days at 70°F. (breakdown being caused by softening, wilting and shrivelling), 16 days at 50°F., 28 days at 40°F., and 40 days at 32°F. At the lower temperatures the peppers remained firm and smooth until they became spoilt by the inroads of fungi. Platenius *et al* consider that if mould growth could be curtailed, a storage life of two months should be possible.

Peppers held at 30°F. did not show signs of freezing injury, and kept as well as those at 32°F. As compared with other vegetables, the rate of water loss is low, only 4 per cent. being recorded in 40 days.

Smith states that small quantities of sweet peppers have been successfully shipped from Jamaica to Canada, and that trial shipments are now being made to England. For dry Chile peppers Rose *et al* cite a storage temperature of 50°-80°F.

### FREEZING INJURY

Freezing injury is characterised by the development of a soft, watery, flabby texture in affected tissues, accompanied by the production of a deadened darker colour; small areas only, or the entire fruit, may be involved according to the severity of the exposure. These changes are in marked contrast to the normal firm, brittle tissues of uninjured fruits.

When a frozen fruit is cut open the soft tissues ooze water freely. The seeds, normally white, also acquire a darker colour. Such freezing injury was induced experimentally by exposing fruits to an average temperature of—1.06°C. (approximately 30°F.). Chilling injury, produced at higher temperatures than those required to freeze tissues, may be expected to be considerably less serious.

### CARBON DIOXIDE TREATMENT

Brooks *et al* have observed that peppers are injured by medium and high concentrations of carbon dioxide, the superficial tissues of the fruits becoming pitted, scalded and discoloured.