THE STORAGE OF TROPICAL FRUITS*

OF the large number of attractive fruits native to tropical and sub-tropical regions, only a few have yet attained to commercial importance. Relative to citrus and bananas, all other tropical fruits, though their production could be greatly extended, occupy a very minor place on temperate markets and for the most part are only retailed in small quantities and at high prices for the delectation of connoisseurs.

In addition to the tropical fruits occasionally offered on temperate markets there still remains a very considerable number of exotic fruits whose overseas transport has not yet been attempted, or been taken beyond the preliminary experimental stages. For this seeming neglect many reasons can be advanced, including demand (which must first be created by an extensive advertising campaign), competition with other fruits, chiefly temperate, difficulties of consistent production, the need for special packing, shipping and cold storage facilities, and lastly, the high degree of wastage inseparable from the handling of delicate tropical fruits. With a few notable exceptions, in fact, the transport of tropical fruits is still in its infancy. With the improvement of transport facilities it may be anticipated that this situation will to some extent be modified, and that, in time, an increased variety of properly ripened exotic fruits will regularly be offered on temperate markets. Accordingly a wide and interesting field of scientific inquiry still awaits appropriate investigation. Relevant aspects, on which a brief annotation will be attempted here, include (i.) horticultural relationships, (ii.) harvesting maturity, (iii.) pre-storage treatment, (iv.) cold storage requirements, (v.) post-storage and ripening treatments, and (vi.) wastage.

1.—HORTICULTURAL RELATIONSHIPS

Environmental factors, seasonal conditions, and plantation sanitation are important in determining quality, keeping quality in storage and wastage (*see* below). The selection of varieties adapted to particular environments, and acceptable on distant markets, is of first importance. Some examples, illustrating these several points may be cited ; avocados, which possess a high fat content when grown under dry Californian conditions, have a considerably diminished content when grown under humid conditions in Florida or the West Indies ; the Peter's mango, which grows well under Jamaica conditions, cannot be grown commercially in Trinidad because of excessive rotting during storage ; the Congo variety of banana, which is cultivated in the French Antilles and can be disposed of to advantage in French markets, is unacceptable on British or American markets.

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Standardization and conservation of desirable types have also important economic aspects. For example, in establishing grapefruit orchards, bud-wood should only be selected from trees, known to possess consistently the desired degree of seedlessness. In fruits such as the papaw in which seedling types show great variability and where no method of vegetative propagation is known, the resulting absence of standardization is a serious obstacle in the way of developing an export industry.

2.—HARVESTING MATURITY

The question of harvesting maturity is specific to each fruit, and criteria, not infrequently of an arbitrary nature, have to be employed. To allow for the progress of ripening during transport and distribution, tropical fruits, as a rule, are picked somewhat immature. Thus the banana is reaped when it is still quite immature and green, at stages described as three-quarters full, heavy three-quarters full, or full, according to the distance of the market for which it is intended. The necessity for harvesting fruits somewhat immature adds to the problems of the physiologist ; for whereas in some fruits the onset of ripening is indicated by well marked colour changes, in many others no colour change is apparent, and other means have to be devised in order that fruit shall be harvested at a constant maturity. With grapefruit and oranges, biochemical tests based on the percentage of total solids, and on the ratio of sugar to acid have of necessity been adopted, particularly where early season fruit is being handled. The ratios which have been found suitable in some countries, however, have not always proved rational or acceptable in others, and additional local criteria have had to be devised. In different varieties of mango, it has been found convenient to use a morphological criterion of maturity, the relationship between the stem insertion and the degree of development of the shoulders of the fruit (where growth is localized) being used for this purpose : otherwise, in many of the best commercial varieties, colour changes associated with ripening afford very little assistance indeed. Again, in green varieties of avocado, no good criterion of commercial harvesting maturity, other than a tentative ratio of fat content to the fresh weight, has so far been ascertained. In fruits such as the papaw, to illustrate another aspect of this problem, it has been found that unless fruits show some evidence of yellow (ripening) colour on harvesting, they will not ripen properly later. In tomatoes it is known that fruits picked when they show some pink coloration ripen to a product of superior quality than do those picked full grown but green.

3.—PRE-STORAGE TREATMENT

As a rule, in handling tropical fruits, it is desirable that the time between reaping and placing them in cold storage should be curtailed to the minimum, as it is during the period of exposure to tropical temperatures that wound fungi make a rapid initial penetration which markedly affects the subsequent progress of rotting. Again, in fruits harvested just before the onset of ripening, undue exposure to high temperatures tends to accelerate maturation processes, thereby curtailing the anticipated storage life. While quick handling is usually desirable there are circumstances in which some delay is advisable. Thus with

citrus fruits which have been picked in a highly turgid condition, it is sometimes advisable that a quailing or curing period should be allowed to minimize the tendency to superficial bruising and the concomitant fungal wastage.

In some industries, *e.g.*, citrus, fruits may be subjected to routine washing, disinfecting, ethylene ripening and machine grading before being packed. Each process requires critical examination in respect of its physiological or pathological effect on the fruit, such problems as desiccation, bruising and wastage being relevant to the case in point. Disinfectant treatments, for example, should only be used when the precise nature of the several rot-producing organisms has been clearly ascertained, since instances are known where the most important pathogens, being already present within the tissue as latent infections, or established as wound infections, are aggravated and not arrested or eliminated by the treatments applied.

4.—COLD STORAGE

Although in some instances fruits may be shipped during comparatively long voyages without refrigeration, as a rule, particularly where delicate tropical fruits are concerned, cold storage is essential. Well-equipped refrigerated shipping is in fact the fundamental factor in the overseas transport of perishable tropical produce, refrigeration by the air blast system being now considered indispensable for the proper handling of fruit. For the major export commodities, such as bananas and citrus, considerable information on the required storage temperatures is now available, but for many others only fragmentary and inconclusive data have been obtained. In selecting a temperature for the overseas transport of fruits two factors are principally involved: (i.) the temperature must be sufficiently low adequately to control or arrest ripening and the growth of pathogens, but (ii.) it must be so low as to cause physiological injury or " chilling " to the fruit. Fruits which have been chilled in transit not only fail to ripen properly, with concomitant loss of flavour, but they are also subject to increased fungal wastage. The onset of chilling, in a number of fruits, is known to coincide with the onset of ripening—a critical phase in the life of fruits. Superficial chilling injury tends to be exaggerated where fruits are also subject to desiccation, whereas at high relative humidities, such injuries may be more or less completely masked. Once the precise storage temperature, *i.e.*, just above the critical temperature for chilling, has been ascertained, fruits may be cooled as quickly as possible by delivering cold air at that temperature, without danger of chilling. Where this information is available, pre-cooling may be used to advantage.

The storage temperatures required by different tropical fruits cover a considerable range, which is, however, more in the nature of " cool " storage than " cold " storage. Thus, for fruit grown under West Indian conditions, the following temperatures have been determined: Limes, grapefruit and oranges, 45°F.; tomatoes, 45°–47°F.; avocados, 45°F.; mangoes, 47·5°F.; Lacatan Congo, Giant Governor bananas, 58°F.; papaws, 60°F. In so far as chilling injury is in part a function of the duration of storage, fruits undergoing prolonged storage may require a modification in the upward direction, of the temperatures cited. The tomato may be cited as an example where fruits grown under different conditions may require considerably different storage

temperatures. The banana illustrates the fact that different varieties may show considerable differences in their tolerance of low temperatures. The range of temperatures required by different tropical fruits introduces additional difficulties in the matter of shipping, since, as a rule, even modern refrigerated ships are not provided with a number of small compartments in which small consignments can be accommodated each at its own special temperature.

The control of humidity, chiefly the maintenance of high humidities, is also important in the proper handling of fruits grown under moist tropical conditions. Instances are known (*e.g.* limes and grapefruit) where fruit may become unsightly and unmarketable, not because of the onset of fungal wastage, but on account of excessive desiccation. This aspect of the physiology of fruit in storage has so far received insufficient attention : with the advancement of special knowledge of the water-relations of fruit in storage considerable improvement in the technique of handling fruit should become a practical possibility.

5.—POST-STORAGE AND RIPENING

When tropical fruits are removed from cold storage to higher temperatures, ripening takes place rapidly, and serious wastage may soon be sustained. To a considerable extent the latter undesirable feature could be overcome by holding the fruit at a suitable temperature until required for actual consumption. In countries where refrigeration has been more or less thoroughly domesticated, such special post-transport treatment is feasible and is, in fact, a workable proposition. In many countries, however, refrigeration, whether in warehouses or small stores, is still regarded as an unwarranted and additional expense ; until some modification is made in this point of view considerable wastage must be expected during the retailing of delicate tropical fruits. In brief, the outlook for exotic fruits on distant markets will be determined, among other factors, by the extent to which the use of refrigeration becomes domesticated.

Some fruits, in particular the banana, undergo special ripening treatment, involving temperature and humidity control, on being removed from the ships' holds : the improvement of ripening technique opens up a wide and useful field for physiological work.

6.—WASTAGE

If tropical fruits are allowed to remain at high temperatures for any considerable time after harvesting, the onset of wastage tends to be rapid. Hence recommendations for the improvement of shipments stress the importance of good organization to permit of expeditious handling after harvesting and rapid cooling to the approved storage temperature. Wastage in most instances may be attributed to the activities of two major types of pathogenic fungi : (i.) wound parasites which enter through the numerous wounds and abrasions sustained during handling ; and (ii.) those which are established as latent or dormant infections during the earlier stages of development of the fruit, and which do not become evident until a certain stage in senescence has been reached. Knowledge of the precise behaviour of the several organisms involved is essential in formulating rational measures of

disease control. Thus where wastage is due to the development of latent infections, it is evident that control measures must be applied in the field (*i.e.* by protecting the young fruits from infection), and that questions of environment and plantation sanitation must be given careful consideration.

SUMMARY

With a few notable exceptions, the overseas transport of tropical fruits is still comparatively undeveloped. The many factors involved in creating an export industry based on the production and handling of delicate fruits notoriously subject to wastage are briefly dicussed and illustrated by reference to bananas, citrus, avocados, mangoes and papaws.