

SELECTED ARTICLE

Cold Storage and Transport of Tropical Fruits.

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Introduction. Steady and continued success in the important work of transporting tropical fruits to overseas markets calls for information on very diverse subjects, beginning with biological aspects in the plantation and not ceasing until the exotic commodity is finally gratifying the palate of the consumer. I shall indicate those aspects of the problem which appear to be of greatest importance to the worker at the tropical end of, what is, in fact, a very considerable chain of operations.

Of the large number of attractive fruits native to tropical and sub-tropical regions, only a few have yet attained to commercial importance as export crops. 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 shipping and cold storage facilities and the need for special picking, the high degree of wastage at present inseparable from the handling of these delicate commodities. 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 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.

It will be evident that by far the greater amount of information at our disposal is based on those fruits such as grape fruit, oranges, and bananas which might now be described as "standard" commodities. Pineapples, limes, mangoes and avocados also find their way to temperate markets, but in comparatively small quantities, leaving a host of others which are seldom or never exported.

Importance of Research on pre-storage aspects. It not infrequently happens that those who are responsible for the inspection of imported tropical plant produce find themselves faced with fruits exhibiting various pathological symptoms of the type described as "physiological" or functional diseases. In the absence of information from the tropical, i. e. producing, end, the correct diagnosis of such diseases may well prove a matter of considerable difficulty. Moreover, as it has been established that certain types of functional disease are a direct result of cold storage, or of improperly regulated conditions in the refrigerated holds, the inspector of imported produce may easily be led off on a false trail, to find in the end that a correct solution is not possible on the information at his disposal, having meanwhile incidentally incurred the enduring enmity of the ship's refrigerating engineer, the accuracy of whose records and depositions he may have had occasion to doubt. Such difficulties can be avoided but only if the effects of

all the pre-storage treatments to which the fruit has been subjected are known and understood. In illustration of this aspect, two instances may be cited. If Trinidad citrus fruits (grape fruit, oranges and limes) are picked while still covered with dew or after rain, the fruits are so turgid that the smallest amount of handling causes mechanical injuries and liberation of oil, which in turn gives rise to the type of superficial blemishing described as "oleocellosis". Again, in Trinidad grape fruit treated with borax solution before crating as a means of controlling blue and green moulds, the effect of the fungicide is to promote the activities of the fungus *Colletotrichum gloeosporioides* which is already present within the tissues as a latent infection. In its earlier stages the combination of borax injury and fungal activity yields blemishes whose appearance is suggestive of physiological injury. In both instances, the damage, which might easily be attributed to cold conditions during transport, are in no way caused by refrigeration. Bananas which have been cut too soon and held too long at tropical temperatures may become "stale" and tend to ripen during the overseas voyage. Here again a pre-storage and not a refrigeration factor is involved. Again, banana bunches which have hung too long on the tree because of poor growth conditions may appear suitable for harvesting, but may in fact have reached a maturity considerably beyond that which is desirable in fruit intended for overseas transport.

In general, pre-storage factors, environment, seasonal conditions, and plantation sanitation are important in determining intrinsic quality, keeping quality in storage, and wastage and must be given the same careful attention as those aspects which pertain directly to the subsequent refrigerated storage.

Harvesting Maturity. The question of harvesting maturity is specific to each kind of 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 standards which have been found suitable in some countries, however, have not always proved rational or acceptable in others, and different 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 papaya, 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. There is the further possibility that fruit harvested at different maturities may require different storage conditions.

Summarising these several points, it may be said that harvesting at the correct stage of maturity bears directly on the success with which subsequent refrigerated storage will be attended.

Rapid Cooling. 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 fungi make a rapid initial penetration which markedly affects the subsequent progress of rotting. As a rule the ripening of fully-grown fruits at tropical temperatures tends to be very rapid, after which senescence and fungal rotting quickly follow. Undue exposure prior to cold storage may therefore considerably shorten the anticipated storage life. This is particularly true of fruits such as the banana and mango. On the other hand, in grapefruit and oranges where changes take place more slowly the need is considerably less urgent from the point of view of preserving the quality of the fruit but still exists if fungal wastage is to be minimized.

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 as already indicated, that a quailing or curing period of suitable duration should be allowed to minimize the tendency to superficial bruising and the concomitant fungal wastage.

Preservation by Cold Storage. In the tropics, the past forty years have witnessed an increasing utilization of refrigeration for effecting the overseas transport of fruits and vegetables. Nor can it be doubted that there still remains a much wider field of usefulness for refrigeration. The very extensive and valuable industry in bananas from the West Indies, Central and South America has only been rendered possible through the provision of refrigerated shipping. The developing citrus industry, as also minor industries in mangoes, avocados, tomatoes, pineapples, passion fruits, and vegetables of different kinds, which can be produced abundantly and cheaply in the tropics, will in turn be largely, and in some instances, entirely, depend for their continued development and success on the provision of pre-cooling stations and of adequately equipped refrigerated ships. With regard to the latter it may be said that the absence of suitable transport facilities has been, and still is, the chief obstacle to the wider utilization of tropical produce on overseas markets.

It has been, that, if not held at suitably low temperature the ripening of tropical fruits and subsequent onset of wastage take place very rapidly. Accordingly, the problem is primarily one of arresting or retarding the progress of ripening without injuring the fruit. To do this to the best advantage it is essential that the physiological processes involved should be clearly understood. As the vegetable commodities under consideration are still alive, they require cold storage conditions which will permit of approximately normal though retarded maturation, so that the appearance, flavour, texture, aroma, and other qualities for which they are prized, will be preserved. The work of the investigator of fruit transport problems in the tropics, as elsewhere, is therefore principally physiological in nature, so that he may use to the best advantage the practical means which the refrigerating engineer has, or can, put at his disposal. In general, the equipment and design of refrigerated holds or cold stores for tropical fruits should be such as to permit of rapid cooling, the maintenance of steady temperature, humidity, and if necessary, gas concentrations optimal for the fruit in question.

Of recent years there has been a strong tendency to raise the storage temperatures recommended, this having been especially marked in the case of grapefruit where 'pitting' (chil blemishing) has in the past constituted a large proportion of

the wastage. Whereas formerly temperature below 40° F were frequently employed, the present tendency is to use 45° F. or higher. Such higher temperatures are important from the point of view of permitting two forms of wastage to occur at enhanced rates—blemishing due to desiccation and rotting by fungi. Further emphasis is thus put upon rapid cooling and higher humidity.

If an arbitrary and incomplete distinction may be drawn between 'cool storage' and 'cold storage', it will be found that the greater number of tropical fruits require to be carried in 'cool' storage (e. g. avocados, 45° F mangoes and tomatoes, 47.5° F. grapefruit oranges and limes, 45 to 50° F. Gros Michel bananas, 53° F. Congo and Lacatan bananas, 56 to 58° F. papaws, 60° F., etc.) if chilling injuries, are to be avoided. In that too low a temperature may give rise to specific types of physiological injury, to failure to ripen, and to loss of resistance to fungal pathogens already present in the tissues as latent or dormant infections, it will be apparent that the location of thermometers is of considerable importance, and the relationship which exists between the air delivery temperatures and those which are present in the vicinity of the fruit nearest the inlet must be known in order to avoid chilling. The constructional arrangements within holds or storage rooms must permit of uniform distribution of air and consequently of refrigeration. Provided fruit is charged into the holds in good condition, and at the correct stage of maturity its maintenance in good conditions is then the direct responsibility of the refrigerating engineer and indirectly of those responsible for the design and type of equipment installed.

In large fruit industries, with consistent all the year round production, as in the banana industry, whole fleets of ships are employed and refrigeration equipment, with minor variations, has become standardized, i. e., battery equipment permitting of rapid cooling and subsequently of a sufficiently rapid circulation of air at 53°F. in the holds. But with commodities where production is seasonal, adequately equipped shipping is not always available, and instances are known where, for example, grapefruit and oranges have had to be carried as non-refrigerated cargo or in grid-cooled holds, with concomitant danger of enhanced fungal wastage or the production of chilling injury. A major difficulty, where small consignments of fruits, e. g. mangoes, avocados, etc., have to be carried at special temperature, is that small refrigerated holds are seldom provided in the construction of the modern refrigerated ship.

From the purely commercial point of view, the smallness of the initial consignments offered, and the special temperature required by different commodities, present serious obstacles. Yet it is during those preliminary shipments when the fruit must be landed in such a state as to impress brokers and potential purchasers that special refrigeration service is most essential. The provision of some small refrigerated chambers, in addition to the larger refrigerated holds, would provide the ideal solution to this problem. In making this suggestion, it is realized that initial constructional costs would be considerably increased and that supervision of cargoes would also have to be extended.

Both in respect of the normal physiology of the fruit, and the biology of its pathogens, the maintenance of correct humidity relationships within the holds is of very considerable importance. This conclusion is drawn from a number of instances in which the questions of humidity and water-relations have presented themselves for consideration; it must be admitted, however, that no final statements of the exact conditions required in different instances can yet be made. But, in general, it may be said of relative humidity within holds or storage rooms: (a) that it should not be so low as to allow of serious loss in weight or modify the appearance and maturation of the fruit during the storage period; b) that it should not be so high as to promote the superficial growth of fungal hyphae; and (c) that localized condensation within the cargo sack must be

avoided. The question of the need for improved humidity control is now being urged on all sides by biologists; in its physical and manipulative aspects it is also being closely studied by physicists and engineers, and there seems little doubt that the future will be marked by interesting and valuable innovations.

Special methods of packing may call for modifications in the internal arrangements of holds and in methods of stowage. Thus, whereas the 'naked' stowage of Gros Michel bananas permits of easy access of cold air to the individual fingers a very different situation arises in the case of the Congo (Poyo) banana as presently exported in large quantities from French West Indian colonies. This variety, having a more delicate and easily bruised skin than the Gros Michel is carefully padded and packed in a double envelope of paper with an intermediate layer of straw. On being stowed, these packages, particularly when subjected to the weight of the superimposed fruit, tend to form a compact mass of cargo, with the result that the interstices by which air can pass may be greatly diminished. To compensate for this the present tendency is to deliver air to the holds at undesirably low temperatures, with the result that whereas centrally placed bunches may still remain inadequately refrigerated, marginal bunches tend to be chilled. It is open to doubt whether a vertical distribution of air would effect a sufficiently good penetration of each closely packed cargo.

With particular reference to delicate exotic fruits, very considerable possibilities lie in improved overseas transport through the use of (a) small, specially equipped ships plying frequently, and (b) transport by fast ships whereby higher storage temperatures could be employed, with the desirable result that the pristine qualities of the fruit would tend to be less modified than during more prolonged storage at lower temperatures.

Tropical Pre-cooling Stations and Cold Stores. In any agricultural scheme involving the handling of fruits and vegetables in large quantities, the rational application of refrigeration should not be neglected. So far, both as a means of conserving locally produced supplies for home consumption and to facilitate export industries, comparatively little use has been made of refrigeration in the tropics; with some notable exceptions, one cannot escape the impression that the possibilities of refrigeration have to a large extent been overlooked or neglected through lack of knowledge, or, in some instances, fear of the expenditure involved. Still, the ideas are gaining a foothold and the need for local pre-cooling and holding stations is beginning to be appreciated to an increasing extent. The special problems arising in relation to the planning, construction and equipment of cold storage accommodation adapted to different tropical conditions, and to local agricultural and social requirements, will undoubtedly provide great opportunities for refrigerating engineers in the not distant future. Here it should be emphasized that although the basic scientific principles are the same throughout, the special conditions prevailing in different tropical regions present problems that cannot be satisfactorily solved by experience in temperate countries alone. Indeed, it would appear that there is ample scope for a commission to visit the tropics and to consider the special refrigeration requirements in respect of site, construction, insulation and equipment of the ideal pre-cooling and holding station. In this respect the Union of South Africa is giving a valuable lead which, one would like to see followed elsewhere.

In the humid tropics fruit that has been held in pre-cooling station is liable to 'sweating' (i. e., condensation of moisture) during the period of transference to the ship's hold. In some instances, where ships are unable to come alongside, the commodity may have to be exposed for several hours. So far there is no definite evidence that fruit suffers to any marked degree as a result of the changes involved, e. g., sharp rise in temperature and deposition of moisture on the wrappers, provided such moisture is allowed to evaporate fairly rapidly on

shipboard, but it is evident that from the standpoint of the refrigerating engineer such arrangements are very unsatisfactory. These conditions are by no means uncommon in tropical ports. Although there is considerable scope for refrigerating engineers to devise ways and means of solving these special problems, it is probable that the expenditure involved would tend to be disproportionately high.

For the most part, ideas regarding the advantages of local cold stores are only now beginning to be appreciated in the tropics. As a rule the initial capital expenditure and high running costs, and the absence of refrigerating engineers to give the necessary supervision, are the factors which limit schemes whose operation would eventually benefit the whole community to an extent that would be difficult to assess. In this way the value of the short but highly productive cropping period, characteristic of many tropical crops, can be greatly increased, in that "glut" periods and their attendant low prices, can be eliminated, and produce of good quality can be made available over a very considerably extended period. The most economical use of local cold stores, where the harvest period for any one crop is short, is a matter for careful consideration by the authorities involved, departments of agriculture and planters in particular via co-operative marketing.

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, an established scheme. 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 become domesticated. The recent development in the United Kingdom of the retailing of frozen fruit and vegetables also points to the need for investigation of this method on tropical fruits.

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

Concluding Observations. To those who are occupied with questions pertaining to the storage and transport of tropical fruits it becomes increasingly evident how extensive is the field that awaits the attention of the investigator. Problems such as those of the effect of volatiles, gas storage, transport of mixed consignments, quick freezing, etc., are practically or, in some instances entirely untouched.

Refrigeration applied to agricultural industries in the tropics does not stand alone but should be treated as an integral part of the general business organization of the community. Some words spoken by the President of the British Association of Refrigeration (1938) are apposite to the occasion: "If we are adequately to conserve our supplies, if we are to protect our agricultural heritage and if we desire to secure what has frequently been termed the quantitative regulation of market supplies of perishable foodstuffs, then it would seem to me that the science of refrigeration must be embraced to a much greater degree than it is to day." *Journal of the Royal Society of Arts.*