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A SURVEY OF POST-HARVEST LOSSES IN SOME FRUITS AND VEGETABLES AND THE FUNGI ASSOCIATED WITH THEM

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ABSTRACT

A survey was conducted of the post-harvest losses in some fruits and vegetables in the Central Province of Sri Lanka where 35 fruit and vegetable stalls were visited and information on storage practices and losses in various commodities gathered. The figures showed that losses in the range of 5-25% are commonplace in most commodities. Shelf life in many of these did not exceed 6-7 days. Thirty seven species of fungi belonging to 13 genera were isolated from the diseased fruit and vegetable samples collected in this survey. According to the nature of the infection and subsequent rotting these fungi could be divided into two major categories: (i) those fungi that invade overripe fruits through mechanical wounds and cause extensive rotting, and (ii) those that cause latent infections in the immature fruits and develop rotting only when the fruit is ripened.

INTRODUCTION

Post-harvest losses of perishable crops in developing countries have been authoritatively estimated to be in the range of 5-50% or more of the harvest (Salunkhe and Desai, 1984). Because of their high moisture content, fresh fruits and vegetables are very susceptible to attack by pathogenic fungi and bacteria during the period between harvest and consumption (Eckert and Ogawa, 1985). The economic losses due to post-harvest diseases is proportionally greater than losses in the field because the costs of harvesting, transport and storage must be added to those of production.

Although it is generally known that the post-harvest wastage of locally produced perishable crops is substantially high there is very little data available on the proportion of such losses and their causes. Adikaram and Theivendirarajah (1981) reported that more than 15-25% of the avocado fruits harvested are wasted due to lack of proper technique to store and extend their shelf-life. Data collected from the Kandy market showed that the shelf-life of most fruits does not exceed 4-7 days (Adikaram and Theivendirarajah, 1978).

This paper describes the results of a survey of the post-harvest losses in some fruits and vegetables in the Central Province of Sri Lanka and the fungi associated with post-harvest diseases.

MATERIALS AND METHODS

Survey of post-harvest losses in fruits and vegetables

A survey of post-harvest losses in some fruits and vegetables was carried out in the Central province of Sri Lanka. Areas visited were Kandy, Katugastota, Peradeniya, Gampola, Pussellawa, Nuwara Eliya, Kegalle and Matale. Frequent visits were made during 1983, 1984 and 1985 to major retail fruit stalls in these areas, the total number of such stalls visited was 35. A questionnaire based on fruit harvest, transportation, marketing, storage practices, market losses and their cause and prevention etc., was distributed among the fruit sellers as one way of collecting information. In addition the fruit and vegetable sellers were interviewed and the required data were obtained.

After the survey the results were pooled and analysed, the average loss per item was calculated. Samples of fruits and vegetables, both diseased and free of visible damage, were collected and taken to the laboratory for investigation.

Laboratory investigation of fruit and vegetable samples

Fruit and vegetable samples collected during the survey were visually examined and separated into three categories: those that show (a) symptoms of microbial rotting, (b) mechanical damage, and (c) no visible disease symptoms or damage. Materials with visible microbial rotting or such symptoms were subjected to careful examination; first the symptoms were recorded and then microscopic studies were done on the rotted/infected area taking sections and scrapings from those sites. Those fruits and vegetable samples that did not show any visible infections or damage were stored in metal trays and incubated on the laboratory shelves. These were examined throughout the incubation period for any infection development.

Isolation of fungi from the diseased fruits and vegetables

Fungi present in the diseased fruits and vegetables were isolated on Potato Dextrose Agar (PDA) or Cook's No.2 Agar medium. Pieces (about 2-4 mm^2) of diseased tissue cut from the leading edge of the lesions were surface sterilized in $HgCl_2$ (1:10,000) for 2-3 mins. and washed thoroughly in sterile distilled water until all the $HgCl_2$ was washed away. The surface sterilized tissues were further cut into smaller pieces using a sterile blade and placed on agar medium using sterile forceps. The plates were incubated at 26 ± 2^oC until fungal growth had taken place. The fungi were sub-cultured on fresh agar plates and identified by their morphological and cultural characteristics. Identity of some of these fungi was confirmed by the Commonwealth Micological Institute, England.

Re-inoculation into their original hosts to confirm the pathogenecity

Fruits and vegetables used were either bought from the Kandy central market or obtaind from plants in the Peradeniya area and were free of any visible damage. Sets of forty fruits/vegetable pods were arranged in metal trays lined with moist filter paper. Twenty of them were wounded by using a sterile needle (about 2mm long). Suspensions of conidia/spores were prepared by first scraping mycelia from sporulating cultures and then suspending in sterile distilled water. The suspensions were filtered through glass wool and the filtrate containing conidia/spores was used for inoculation. The concentration of conidia/spores was adjusted to about 5×10^5 per ml. With those fungi that do not produce spores, discs of mycelia cut from the margins of actively growing colonies were used as the inoculum. Drops (20 l) of conidia/spore suspension or discs of mycelia were placed on the wounded or unwounded sites of the fruit/vegetable pod. Ten wounded and another 10 unwounded fruits/pods were used for inoculation and the rest of the control fruits were treated with drops of sterile distilled water or discs of agar without mycelia. The inoculated and control fruits/pods were covered with loose-fitting glass plates and incubated at 26 ± 2^oC. The fruits/pods were observed daily for symptom development. Symptoms and the time taken to develop such symptoms were recorded. Fungi were re-isolated from the diseased regions and compared with the original isolates.

Examination for those fungi that cause latent infections

From the observations made during the survey and in the laboratory certain fungi were suspected to establish latent infections in the unripe fruits which develop into progressive lesions only when fruit ripening had begun. These fungi and their respective hosts were selected and subjected to detailed studies. Unripe fruits were obtained and inoculated with drops of conidia as described above and incubated. These were visually examined daily for symptom development and the number of days taken for symptom development and the stage of maturity at the time of lesion expansion were noted down. Some fruits were removed daily and peel sections were taken from the area beneath th inoculum drop and examined under the microscope. The fungal structures present on the surface were examined. Fungi were re-isolated from the lesions and compared with the original isolate.

RESULTS

Post-harvest losses in fruits and vegetables in the Central Province

Table 1 shows the results of a survey conducted on post-harvest losses of some fruits and vegetables in the Central

Province of Sri Lanka. The figures show that the total losses range from 5 to 25% for most of the crops. A part of these losses occurs during transport of the product to the market but a large proportion of this takes place during storage on the market shelves. The average losses vary with the type of fruit or vegetable, the method of harvest and post-harvest handling, the mode of transport and storage practices. Fruits such as grape, banana, guava, mango and papaw etc., are usually subject to higher post-harvest losses in the market shelves than the more hardy vegetables such as chilli and lemon. Also the more perishable fruits such as grape and tomato are generally prone to substantial damage during transport.

Shelf-life in most of these commodities does not exceed one week. Physical factors such as heat and sunlight reduce the market quality of most vegetabls like chillies by desiccation and colour changes which consequently shorten shelf-life. Fruits such as papaw, mango, banana etc., which ripen faster and are subject to microbial attack following ripening have somewhat shorter storage life than those that undergo slow ripening such as mangostine, orange and guava (Table 1).

Fungi associated with post-harvest rotting in fruits and vegetables

Thirty seven species of fungi belonging to 13 genera were isolated from fruits collected during the survey and Table 2 lists these fungi and their respective hosts.

According to the nature of infection and subsequent rotting these fungi could be divided into two distinct categories. One category of fungi invades overripe fruits through mechanical wounds and causes extensive rotting. Fungi belonging to genera such as *Aspergillus*, *Fusarium*, *Mucor*, *Penicillium* and *Rhizopus* were commonly isolated from many varieties of ripe fruits causing this kind of rotting and these were not restricted to specific hosts. These were frequent in ripe papaw and wood apple fruits. However, *Penicillium digitatum* and *P. italicum* were found only in *Citrus* species (Table 2) causing rotting particularly in the Nuwara Eliya area.

The second category of fungi gains entry into immature fruits and produces latent or quiescent infections in the superficial tissues but shows no further activity until the fruits have become ripe or senescent. *Glomerella cingulata* (*Colletotrichum gloeosporioides*), the cause of anthracnose disease in many fruits, was the most common fungus isolated showing this type of behaviour. This was isolated from avocado, chilli, cucumber, pomegranate, green pepper, mango, orange and papaw. *Colletotrichum capsici*, *C. coccoides*, *C. lindemuthianum* and *Gloeosporium musarum*, the causal agents of anthracnose in chilli, tomato, bean and bananas respectively were frequently found in the samples collected from all these areas.

Botrydiplodia theobromae was associated with rotting in ripe avocado, mango, orange and passion fruit. Infections by this fungus were seen in immature avocado fruits as minute, black spots and in the fully ripe fruits the fungus grow luxuriantly giving the entire fruit a black crusty appearance. This fungus usually develops a few days after the development of anthracnose lesions. In mango fruits the fungus invades through the cut end of the stalk and advances downwards making the whole fruit or most of it black. In ripe passion fruits the fungus causes black spots and this was rather common in the Nuwara Eliya area. Among the other fungi which caused quiescent infections were Myrothecium roridum in aubergine (dark brown, large, oval shaped depressed lesions), Macrophoma musae in bananas (black pin head size spots in the unripe fruit), Ascochyta caricae in papaw (brown, small lesions, Alternaria laternata in tomato, Corynospora cassicola in aubergine and tomato ('target spot', dry circular, light-brown, sunken spots). All these fungi except M. musae produced bigger lesions when the fruit was allowed to ripen.

Table 1 - Post-harvest losses in fruits and vegetables in the Central Province of Sri Lanka

	% loss during transport	% loss on market shelf	Total loss %	Shelf life(d)
Aubergine	4.9±2.9*	9.7±7.4	14.6	6±4
Avocado	5.9±4.5	10.8±7.0	16.7	8±3
Banana	4.6±2.7	14.3±9.5	18.9	6±2
Chili	4.2±2.6	2.5±1.5	6.7	3±2
Chili(large)	2.8±1.6	6.6±4.9	9.4	4±3
Cucumber	4.9±3.3	7.8±6.4	12.7	4±3
Grape	13.9±6.6	10.6±9.7	24.5	5±2
Guava	4.0±2.0	36.0±24.0	40.0	11±4
Lemon	3.2±1.7	7.8±5.0	12.0	6±2
Mango	7.1±4.3	18.5±16.9	25.6	6±2
Mangosteen	6.5±3.0	10.0±4.3	16.5	11±5
Orange	4.1±1.8	10.0±4.7	14.1	12±7
Tomato	6.8±5.7	9.1±6.7	15.9	6±3

* Standard deviation of mean.

Table 2. Fungi isolated from fruits and vegetables during the survey

Fruit/vegetable	Fungi isolated
Aubergine (Solanum melongena)	Corynospora cassicola Myrothecium roridum Tode:Fr. Fusarium solani Glomerella cingulata
Avocado (Persea americana)	Botrydiplodia theobromae Colletotrichum gloeosporioides Fusarium solani Phomopsis spp.
Banana (Musa sapientum)	Gloeosporium musarum Macrophoma musae Glomerella cingulata
Bean (Phaseolus vulgaris)	Colletotrichum lindemuthianum Macrophomina phaseolina Fusarium sp.
Chilli (Capsicum frutescens)	Colletotrichum capsici Colletotrichum gloeosporioides Alternaria sp. Mucor sp. Rhizopus sp.
Cacao (Theobroma cacao)	Botrydiplodia theobromae Diplodia sp. Fusarium decemecellulare Brick. Glomerella cingulata Monilia fructicola
Cucumber (Cucumis sativus)	Glomerella cingulata Fusarium sp. Myrothecium roridum Tode:Fr.
Durian (Durio zibethinus)	Mucor sp. Rhizopus stolonifer
Pomegranate (Punica granatum)	Colletotrichum gloeosporioides
Grapefruit (Citrus grandis var. racemosa)	Colletotrichum gloeosporioides
Green pepper (Capsicum annuum)	Colletotrichum capsici Colletotrichum gloeosporioides
Mango (Mangifera indica)	Botrydiplodia theobromae Gloeosporium mangiferae Phoma sp.
Orange (Citrus sinensis)	Colletotrichum gloeosporioides Fusarium epitheles Botrydiplodia theobromae

	Phytophthora sp.
	Phytophthora digitatum
	Phytophthora italicum
	Aspergillus
Papaw (*Carica papaya*)	*Colletotrichum gloeosporioides*
	Ascochyta caricae
	Phomopsis sp.
	Fusarium spp.
	Rhizopus stolonifer
	Aspergillus sp.
	Penicillium spp.
	Botrydiplodia theobromae
	Colletotrichum capsici
Passion fruit (*Passiflora edulis*)	*Ascochyta passiflorae*
	Botrydiplodia theobromae
	Fusarium sp.
Tomato (*Lycopersicon esculentum*)	*Alternaria alternata*
	Colletotrichum coccoides
	corynospora cassifola
	Fusarium oxysporum f.sp. lycopersici
	Glomerella cingulata
	Phoma sp.
	Septoria sp.
Wood apple (*Feronia limonia*)	*Aspergillus* spp.
	Botrydiplodia theobromae
	Colletotrichum capsici
	Fusarium spp.
	Penicillium spp.

DISCUSSION

Data collected in this survey showed that a considerable amount of fruits and pod vegetables go waste during transport and on market shelves. The extent of loss is much greater in perishables than hard-skinned fruits or pod vegetables. A number of factors contribute to these losses and broadly these result from improper harvesting and transport methods and inadequate storage facilities.

One important factor that affects fruit quality is the maturity at harvest and this has been given little consideration in this country. In general the selection of fruits to be harvested is based on the external appearance and the size of the fruit. When fruits are harvested immature they do not undergo the normal ripening process and lose water rapidly, and thereby their market quality is reduced and the fruits become more susceptible to microbial rotting (Salunkhe and Desai, 1984). It is essential that proper maturity indices be developed in order to avoid harvesting immature fruits. Mechanical damage during harvest, transport and storage is another factor that leads to heavy losses. This normally results from rough handling and injuries by insects, rodents and birds. In addition to direct losses this mechanical damage reduces the economic value and renders the fruit and vegetable liable to further losses due to microbial spoilage. Storing damaged fruits together with undamaged may provide an excellent substrate for pathogens to colonize and spread to che healthy fruits (Booth and Coursy, 1972).

The data collected in this survey indicated that a large proportion of the post-harvest losses is due to microbial spoilage while on the market shelves. Fungi are the most important group of microorganisms causing rotting while in store and in this study thirty seven species of fungi were isolated from rotted fruit and vegetable samples. Broadly there are two categories of fungi involved. The first category of fungi invade overripe fruits through mechanical injuries and generally do not have specific hosts; they were found colonizing in many fruit samples collected. Mechanical damage due to improper handling, and poor sanitary conditions prevailing in the retail stores that leads to heavy inoculum accumulation are the major factors that facilitate colonization by this group of fungi.

The second category of fungi are those that cause latent or quiescent infections in the immature fruits and develop progressive rotting in the ripe fruits. Their occurrence does not become noticeable until fruit ripening takes place. *G. cingulata* (*C. gloeosporioides*) is the commonest fungus isolated causing this kind of rotting and this was found associated with a number of fruit and vegetable crops. It has been shown by many workers that the active fungal propagules can remain on the surface or in the superficial layers of fruits for a considerable length of time before the formation of lesions that give an indication of their presence (Baker, Crowdy and McKee, 1940). This subject has been reviewed by Verhoeff (1974) and Swinburne (1982). In this country, however, very little emphasis has been given to this category of host-pathogen relationship. The importance of latent infection may not be directly apparent to the grower, but to the retailer or wholesaler the presence of such troubles may prove a serious problem. Apart from the actual loss sustained the element of uncertainity introduced by their occurrence reacts to the detriment of the consumer and producer alike (Simmonds, 1941).

In spite of heavy losses experienced in fruit and vegetable crops following harvest no attempts have been made in this country to develop proper techniques that prolong the shelf-life and reduce post-harvest losses. Post-harvest diseases of fruits and vegetables can be suppressed by low temperature storage, a low-oxygen atmosphere, and treatment with growth regulators that delay tissue senescence (Eckert and Ogawa, 1985). However, these beneficial practices are not suitable for developing countries due to their high costs. These methods anyway do not adequately protect the crop from microbial attack, especially during prolonged storage or movement of crops through marketing channels. Maximum storage life of many fruits and vegetables can be achieved by treatment with antifungal agents before storage (Eckert and Ogawa, 1985). Use of chemicals in the control of post-harvest diseases also has several disadvantages such as the toxic effects of these chemicals on humans and their high cost.

Reduction of a good proportion of these losses can be achieved in this country by employing proper harvesting and transport methods which minimise mechanical damage and improving sanitary condition of the retain stores. In addition the practice of inexpensive and convenient methods of fruit treatment and storage such as hot water dips and packing in polythene bags would be desirable for the local fruit and vegetable industry.

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