STORAGE OF PRODUCE, PRODUCTS AND BYPRODUCTS OF PLANTATION CROPS-MICROBIAL AND PATHOLOGICAL ASPECTS

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INTRODUCTION

Fungi and bacteria are known to colonize the produce of several crops including plantation crops and cause post harvest spoilage/losses during processing/ storage. Such losses are reported especially in coconut, arecanut, cocoa, cashew, black pepper, cardamom and coffee.The produce of the plantation crops like coconut kernel, arecanut seeds, cocoa beans, cashew nuts, are very rich in nutrients and hence are more prone for microbial infection during processing/storage. Improper drying leads to high moisture content in these produce and as a result of this, the produce become highly susceptible to fungi and bacteria. When microbial infection occurs during processing or storage, not only there is a quantitative loss but also it affects the quality of the produce. In certain cases it may lead to health hazards of the consumers due to the production of mycotoxins by the fungi. Fungi and bacteria which cause the spoilage of these produce are distributed abundantly in the air and soil and invade various produce under suitable environmental conditions. The fungi which commonly attack the produce of plantation crops are *Aspergillus, Penicillium, Mucor* and *Rhizopus*. *Aspergillus flavus* is reported to produce aflatoxin in copra which may pose serious threat to the human and animal health. The commercial value of plantation products are very high and hence the post harvest losses may lead to severe economic loss. Hence there is a great necessity to take proper steps to prevent the post harvest losses of these crops.

POST HARVEST DETERIORATION OF COCONUT

Spoilage of copra:

Copra is the dried kernel of coconut and copra making involves drying of the fresh kernel to bring down the moisture content of the wet meat from 50-55% to 5-6%. Deterioration sets in during the different stages of copra preparation and also in storage. The defective methods of processing and high moisture content of copra are major factors responsible for subsequent damages. Sun drying is the most commonly practised method for making copra. Since drying is done under open conditions in this method, spoilage of copra due to fungal infection is very common. Coconut kernel is a favourable substrate for the growth of microorganisms. Humid condition prevail in the coconut growing regions and as a result of this, post harvest losses in copra are very high. Under conditions of bright sunshine, it takes about 7 days to make copra having 6% moisture. However, this is possible only during the dry months. Sun drying becomes very difficult during monsoon because of high RH and intermittent rains. Kiln drying and drying using hot air dryers are the other alternative methods that can be used for making copra during rainy seasons. However, these methods are practised only to a limited extent because of the extra cost involved. Since coconut is grown mostly as a small farmer's crop, the cheapest method of copra making through sun drying is practised by the majority of the farmers.

In the deterioration of copra, usually bacterial action starts first during the initial stages of drying and later mould infection occurs. A gap of more than 4 hours between splitting and drying facilitates the activities of bacteria on the wet surface of the kernel. With RH of 80% and above and temperatures above 30° C, bacteria multiply rapidly and within 4 hours, a surface slime begins to develop on the wet kernel. The slime continues to develop and it becomes more pronounced during the first and second days of drying. The bacteria are active at moisture levels above 20%. As a result of the bacterial growth, the copra turns red and becomes slimy. *Serratia marscessens, Staphylococus aureus* and *Bacillus* sp., are the common bacteria which cause discolouration, sliminess and softening of the copra. By reducing the interval between splitting and drying to less than 4 hours, bacterial action can be slackened/prevented and thus subsequent damages minimized. By avoiding overloading in kiln drying, bacterial development can be prevented.

The penetrating moulds make their appearance after the bacterial growth. Four different moulds cause deterioration of copra. Though the optimum conditions for favourable growth of these fungi are different, they are sometimes found together at the same time on badly moulded copra. *Rhizopus* sp., or the white mould thrives on wet meat and destroys high percentage of oil and the oil from the infected meat has a high percentage of free fatty acid (FFA). *Aspergillus niger* group or the black mould has a lower moisture requirement (18 - 20% being the optimum and 12% minimum). This mould causes considerable loss of oil almost upto 40%. The *Aspergillus flavus* group or brown mould is the most serious of all the moulds. It flourishes at 8 - 12% of moisture and the oil loss may be more than 40%. This fungus is reported to produce aflatoxin B1 in copra which can be injurious to humans and animals (Susamma Philip et al. 1991). It causes maximum colour change in the oil and rancidity. The *Penicillum glaucum* group or the green mould is commonly found on copra at a moisture content of 6 - 7%. This fungus did not penetrate deeper and cause minimum reduction in oil content. In addition to these four fungi, *Mucor hiemalis* and *Aspergillus tamarii* (yellow mould) are often found on copra and cause considerable loss.

For making good quality copra and its proper storage without microbial spoilage, the following things are to be considered. Fully matured nuts (11 or 12 month old) are to be used for making copra. Varieties which give rubbery copra should be avoided for making copra. It is important that the split nuts are taken for drying within four hours after breaking to avoid initiation of the bacterial spoilage. The nut water should be drained completely and this could be done by inverting the split nuts face downward for 1-2 hours in the sun. Split nuts should be covered with the polythene sheets during night or when it rains. In the large copra making units, cement or concrete yards may be used for drying along with big screens of bamboo and coconut fronds for covering the yard during night or rains. Alternate methods of drying like kiln drying or through hot air dryers should be adopted during rainy season. The moisture content of the copra should be brought down to 6% before storage. Electronic moisture meters which are available these days may be used for accurate determination of the moisture of the copra before storage . After making good quality copra, it should be stored under proper storage conditions. The copra should be stored in gunny bags lined with polythene sheets in well ventilated godowns. Sulphuring should be carried out peridically when copra is to be stored for longer periods.

Rancidity of coconut oil:

Pure coconut oil is not a suitable medium for the growth of micro organisms. The production of free fatty acid and accompanying bad odour and taste originates in the copra itself due to microbial contamination which sets in long before the oil is extracted. Oil derived from the spoiled copra contains varying amounts of nutrients and moisture which supports the growth of various microbes. Later, the moulds attack the oil itself. Moulds produce free fatty acid in the copra and bacteria cause decomposition of albumin in the moist copra. Oil prepared from such spoiled copra becomes rancid quickly and results in bad taste and odour. For obtaining better quality oil, it is necessary to crush copra having moisture content of less than 6%. The crushing process should be done in clean surroundings and the oil should be collected in clean containers. The crude oil should be filter pressed without much time lag and the storage tanks cleared of sediments and other settled impurities frequently. The oil should be free from moisture (less than 0.25%). In case of refined oil it must be heated to 110 - 120°C to remove even the last traces of moisture. The oil must be stored as far as possible away from the direct light and air. The containers should be filled to the maximum possible extent in order to reduce surface area exposed to the light and air. Small quantities can be successfully stored in soldered aluminum tins and large quantities in storage tanks. Studies conducted on preventing rancidity and prolonging shelf life in coconut oil have shown that vacuum heating at 130 - 150°C for 30 minutes was beneficial. Storing in brown bottles was found to improve the stability and prolong its shelf life. Addition of antioxidants like Butrarylated hydroxyanisole and propyl gallate within permissible limits showed beneficial effects on storage of coconut oil.

Coconut cake:

The coconut cake easily absorbs moisture and as a result of this it is prone to mould attack while in storage. In India, a study on the shelf life of coconut cake revealed that 15.2% was the critical moisture content at which it could be stored to be free from moulds at an RH of below 79%. The study also showed that the cake could be stored without any spoilage for a period of 6 months , if alkathene bags are used. The rancidity of the cake could be effectively checked if its moisture content is kept below the critical level of 15.2%.

POST HARVEST DETERIORATION OF ARECANUT

Lack of proper drying yards, improper spreading and turning of nuts and exposure to rains during the drying period of arecanuts lead to microbial infection of the husk as well as kernel. These infections affect the quality of the nuts rendering them unsuitable for consumption and thus lowering their market value. The invading fungi first attack the embryo and then spread to the central white core. In the advance stage of infection the kernel would present a hollow cavity due to the complete disintegration of the tissue by the fungi. The affected nuts when cut open show the discolouration of the tissues of white core, the colour being dependant on the fungi involved.

The extent of damage due to fungi and other biological agents aiding deterioration depends upon the nature and season of drying. When nuts are stored for one year, the infection increased to 60.7%. It is observed that the fungal infection is highest in the nut dried during October (62%) and lowest in February (21%). The high incidence of fungal infection during October is attributed to the prevailing low temperatures and high RH. The low infection in February is due to high temperature and low RH . Majority of the nuts were infected during the first 5-10 days, presumably from husk.

Usually the microflora associated with husk and kernel of arecanut are *Aspergillus* sp., *Diplodia* sp., *Fusarium* sp., *Mucor* sp., *Thielaviopsis* sp., and certain aerobic bacteria. Fungi associated with spoilage of dried arecanuts are *Aspergilus* group (6.4%) *Botryodiplodia theobromae* (19.3%), *Penicillium* sp., (1.3%), *Rhizopus* (1.8%), *Mucor* sp., (0.7%), *T.paradoxa* (0.2%) (Bavappa *et. al.* 1982).

Elimination of soil contact by the harvested nuts is beneficial in reducing nut infection since it is the prime source of infection. Harvested nuts treated with Copper oxychloride showed less infection. Steeping the nuts in bordeaux mixture followed by drying on cement floor reduced the percentage of infection significantly. Polythene lined gunny bags can be used with advantage over plain gunny bags for storing nuts. Storage of arecanut in air tight bins also minimizes the fungal infection.

POST HARVEST DETERIORATION IN COCOA

Moulds have been described as the worst enemies of cocoa beans as their infection affects the flavour. It is possible to detect the mould off - flavour in the samples with as little as 4% mouldy beans. The other effects of moulds on cocoa beans are increase in free fatty acid content of the cocoa butter and production of mycotoxins harmful to the health of the consumers. Moulds can develop in the beans during the process of fermentation or drying or during the storage. Studies (Bopaiah *et. al.* 1980) on the microflora associated with the processed cocoa beans in India indicate *Aspergillus* group (*A.niger, A flavus* and *A.fumigatus*) and *Mucor pusillus* were the predominant fungi causing spoilage of cocoa beans. *Aspergillus* group of fungi increase the fat content of cocoa butter while *Mucor* sp., decrease the fat content . Contamination with Mucor sp., is common in the beans from black pod affected pods, as this saprophyte develops easily after the invasion of the pathogen. Beans derived from charcoal pod rot affected pods show blackish discolouration due to the infection of *Botryodiplodia theobromae.* Riped pods should be used for proper fermentation . It is advisable not to store the pods for more than four days after harvest, as other wise it will result in the germination of the seeds. Diseased or damaged pods should be discarded. Damage to the beans should be avoided while removing from the pods. Good quality beans with acceptable acidity level can be obtained by providing lateral aeration holes in the boxes or properly turning the beans on second and fourth day of the fermentation in the heap method. The adoption of suitable fermentation and drying process reduces the microbial load in the processed beans.

For the safe storage of cocoa beans the moisture content should be brought down to

6-7%. When the moisture content is above 8%, it could lead to development of moulds within the beans. When the moisture content is below 5%, beans become very brittle and hence the beans should be dried to the correct moisture content. The dried beans when rubbed with fingers, it produce a crackling sound. These beans can be stored safely for 2 or 3 months, however, if the cocoa is to be stored for much longer period, special precautions must be taken to prevent deterioration. Cocoa beans are hygroscopic and hence absorb moisture under humid conditions. Cocoa beans with moisture content of 8% or more are in equilibrium at a RH of 80-85% and such beans turn mouldy. Therefore the RH of cocoa stores should not exceed 80%. Proper ventilation of the godown is essential. The mould development during storage can be minimised by the usage of polythene liners in the storage bags. However, it is essential that the beans packed in liners should be dried to 6 - 7% moisture.

POST HARVEST DETERIORATION IN CASHEW NUTS

The moisture content of cashew nuts at harvest depends on the climatic conditions and the moisture of the soil on which the nuts have fallen. The moisture percent of the harvested cashew nuts can be as high as 25% and this may cause deterioration of the kernel due to mould or bacterial attack or enzyme action. It is therefore important that the nuts are frequently harvested during the conditions of high rainfall and RH. The whole nut moisture content should be brought down to 9% or below for safe storage. Drying the nuts immediately after harvesting is essential to preserve their quality. The quality of the nuts, especially on those stored in heaps are often affected by fungi. Deterioration is irreversible and cannot be made good by subsequent drying. As the main damage in the kernel quality occurs at farmers level, it is very important that the farmers are adequately instructed about the drying and storage of nuts. Sun drying can be done on drying floors or mats made of palm leaves or bamboo during summer periods. The nut should be dried until they make a rattling sound when fallen on the floor. This may take several days depending upon the climatic condition. As soon as the nuts are dried they should be stored in godowns. Nuts exposed to RH of above 75% turn mouldy within few weeks and hence the godowns should be properly ventilated to avoid development of humidity above 70%.

The moisture content of the processed kernel should be dried to a moisture content of 5% before packing. As cashew kernels are subject to rancidity and go stale very quickly, packing should be air tight and impermeable to moisture. It was observed that the cashew kernels remain in good condition for a period of more than one year when stored in air tight containers.

POST HARVEST DETERIORATION IN OIL PALM FRUITS

Palm oil is derived from the freshly harvested oil palm fruits. In the palm oil extraction process, harvested bunches are processed immediately (within 24 hours) and as a result of this, chances of microbial contamination of the fruits are limited. However, fruits which have been kept for several days without processing are prone for mould attack. Several lypolytic fungi like *Oospora, Rhizopus, Aspergillus, Penicillium, Marasmius, Sclerotium, Diplodia* and *Phoma* have been reported to increase the free fatty acid in the oil palm fruits (Hartley, 1977).

Under normal plantation practice, this cause is insignificant as compared to the lipase enzyme activity originating in the oil palm fruit itself. Harvesting of the fruits at right maturity, avoiding damage to the fruits during harvest and transport and immediate processing of the fruits are important with respect to yield and quality of palm oil. Since immature fruits yield less oil and over mature fruits have higher amounts of free fatty acids (FFA), proper and timely harvesting of fruit bunches is an important operation which determines the quality of the oil. The degree of ripeness of the bunches is based on the fruit detachment and the bunches are usually harvested when the number of fallen nuts or easily removable fruits from each bunch varies between 5-10 depending upon the age of the palm. Harvesting rounds should be made as frequent as possible during peak period of production and less frequent during lean period of production. Excessive bruising of the fruits should be avoided during harvest and transport, since damage to the fruits result in increased activity of lipase enzyme and release of FFA. High FFA not only makes the oil inedible but also increases the rate of rancidity, fixes colour and increases refining losses. Suitable methods should be followed to avoid damage to the fruits during harvest and transport. Processing of fresh fruit bunches within 24 hours after harvest is essential to avoid release of FFA Therefore palm oil mills should be located nearer to the plantations in order to process the fruits immediately after harvest. The quality of palm oil obtained should have less than 1% FFA and 0.2% moisture and other impurities and carotin content of 700 ppm, good colour, flavour and consistency. In India, there is no report of lypolytic fungi causing spoilage of palm oil during extraction stages.

POST HARVEST DETERIORATION IN SPICES

Black pepper:

The traditional methods used in the preparation of black and white pepper results in heavy contamination by microbes and the levels found are the highest for commonly used spices. A number of species of *Aspergillus* and *Penicillium* have been found in pepper. An American study found very low concentrations of aflatoxins in pepper. Mould contamination has been found to be essentially on the surface of the seeds of black pepper, whereas internal contamination is also found in white pepper. The level of contamination of micro organisms is dependant on the care taken during drying and preparation of black and white pepper. It is imperative to dry the berries as quickly as possible to a safe moisture content of 11% or less. During sun drying, it is important to rake the berries regularly and to cover during wet weather or when overnight dew occurs to avoid mould attack. Sun drying takes seven to ten days during which, the moisture content is reduced to 10 to 15 %. In recent years artificial drying using flow hot dryers have been reported in India and Brazil. However, the temperature used in this dryers should not exceed 55° C. Maintaining the moisture content at low levels during storage, not only prevents further mould development but also inhibits propagation of other micro organisms. Mould contamination of pepper detracts from its appearance and odour and may cause health hazard. Bacterial contamination is an inherent risk in the traditional methods of black and white pepper preparations. However, mould development can be controlled to a greater extent by exercising proper care in drying and subsequent storage. Artificial drying methods being more rapid and efficient, it provides a product with much lower microbial contamination level. A number of sterilizing treatments for pepper, including exposure to the ethylene oxide and ionizing radiation have been reported . However, the possibilities of toxic residues and deterioration in flavour is likely in these methods. Since much of the contamination is on the surface of the spices, washing is quite effective in reducing the contamination level and re-drying to below 11% moisture and storing under good storage conditions. Pepper if adequately cleaned and dried can be stored without quality deterioration under dry conditions.

Cardamom:

One of the characters used for assessing the quality of cardamom is the appearance. Drying of the fruit must be done efficiently to avoid mould formation which results in skin blemishes that detract from its appearance. At harvest, fruits have a moisture content of above 75%. It must be reduced to less than 10% for safe storage. In the trade circles, 8 - 9 % of moisture is considered ideal for storage. Moisture levels above 10% is detrimental to chlorophyll and will result in fading of the green colour. Well dried samples should produce typical tinkling noise on shaking and such well dried cardamom can be stored under dry conditions without any deterioration.

Ginger:

There are three main primary products of ginger rhizome viz., fresh (green) ginger, preserved ginger in brine or syrup and the dried ginger. Normally fresh green ginger is sold in the market immediately after harvest and is being used directly as vegetable. Fresh ginger can be stored in sand lined pits for three months without deterioration. Dried ginger is generally prepared by sun drying method and during drying care must be taken to avoid mould growth and the moisture content is brought down to 7-12%. Artificial drying minimizes microbial contamination. Dried ginger is susceptible to mould attack and hence should be stored in dry atmosphere. Even after bagging, it should be exposed periodically to the sun to avoid mould attack during storage.

POST HARVEST DETERIORATION IN COFFEE

The practice in India for preparation of cherry coffee is to dry the fruits immediately after harvest in the drying yards directly exposed to sun light. In the evenings the fruits are heaped together and this condition enhances microbial contamination which results in reduction in the quality of coffee beans. Since coffee berries have high moisture content it provides a fertile medium for microbes such as moulds and bacteria. *Aspergillus niger* was found to develop on cherry heaps and form stinker beans. Fungi like *Penicillium* sp., *Aspergillus* sp. and *Cladosporium* sp. were found associated with ripe cherries of Robusta. It is important to keep the temperatures around 30°C to minimise the incidence of fungal contamination by proper turning of the heaps during drying. Coffee beans should be dried to a moisture content of less than 13 % before storage.

POST HARVEST DETERIORATION IN TEA

The micro organisms occur as

contaminants on the layers of fermented juice covering on the processing machines and other equipment employed during tea processing. Proper sanitation and cleanliness throughout the process of fermentation during black tea manufacture are essential, as the presence of bacteria imparts taint, maltiness, flatness and other undesirable properties, resulting in the reduction of the quality. The commonly adopted practice to prevent microbial contamination is to meticulously clean the processing machines with detergents, followed by repeated washing with plain water. Although several antimicrobial chemical agents are being used to avoid microbial contamination in tea manufacture, these cannot be employed in the manufacture of export quality tea in view of the stringent food laws enforced against the toxic residues in tea by various countries. UV irradiation during fermentation was found to be effective in the microbial eradication without affecting the quality. However, complete inhibition of microbes could not be achieved with UV irradiation because of its poor penetration.

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