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Chapter

Indigenous and Improved Postharvest Handling Methods and Processing of Fruits

Oluyinka Adewoyin, Adebayo Ibidapo, Lydia Babatola, Folasayo Fayose, Anthony Ekeocha and Temidayo Apata

Abstract

After harvesting, fresh fruit’s quality cannot be improved but it can be maintained. Fruits should be harvested at the appropriate maturity stage and size. Harvesting of fruits at improper maturity stage reduces shelf-life. Time of harvest, method of harvest, tools used in harvesting also contribute to the wholesomeness of harvested fruits. Fruits are living organisms that continue their living processes after harvest; therefore, their handling directly affects freshness as well as optimum flavor. Maintaining cool temperatures, appropriate air combination to maintain the quality of fruits, producers, handlers, and retailers are to ensure that fruits going for processing, marketing, or into storage are at the best quality state. Indigenous handling refers to the native, age-long, cultural system of postharvest handling of horticultural crops. Postharvest handling comprises interconnected activities from harvest to sorting, grading, preservation, transportation, packaging, processing, marketing, and decision by the consumer to accept or reject the food. Improvement is the enhancement made on the traditional postharvest handling methods to reduce losses of agricultural produce by at least 5%. Various means have been developed over time to handle and preserve food and particularly fruits over ages of technology advancement from the Stone Age.

Keywords: fruits, postharvest handling methods, processing, indigenous, improved postharvest methods

1. Introduction

Foods are substances consumed by living organisms to satisfy the appetite, meet physiological and chemical processes of growth, supply energy and facilitate adaptation to climate change [1]. Agriculture evolved from the gathering of fruits and vegetables from the wild, before the domestication of animals and cultivation of crops. Man has devised various methods by which these fruits are kept and handled. The principles adopted over time are to control agents of deterioration to maintain fruit quality [2–4]. Agents of deterioration are microbial activities; effects of temperature resulting in early senescence and death of tissue due to interruption
of metabolic rate as a result of high or extremely low temperature; Loss of moisture through evaporation and transpiration which causes shriveling; low shelf life due to ethylene biosynthesis; low relative humidity; inappropriate proportion composition of air; Inappropriate use of herbicides; hormones; pesticides and insecticides [5–10].

The nutritional quality of harvested fruits is also affected by other factors such as light, water activity and oxygen. Davey further affirmed that temperature and relative humidity were important factors in maintaining the quality of fruits after harvest [11]. Wilson also asserted that deterioration of fresh commodities can result from physiological breakdown due to ripening, water loss, physical damage, and invasion by micro-organisms and their interactions with temperature and relative humidity of the storage conditions [12]. Fruits for export require more attention and appropriate postharvest handling methods because the producers aim at getting the best return from the produce. John stated that maturity at harvest is one of the most important factors that determine the shelf-life and final fruit quality in mature fruits [5]. Fruits harvested at immature stage became insipid with bad flavor soon after harvest. Fruits require very scientific postharvest handling methods with cold storage at an exact temperature, suitable air movement and appropriate humidity [13]. The objective of studying post-harvest handling is to create an understanding of all operations from harvesting to distribution to facilitate proper technology in each step and in such a way as to minimize losses and maintain quality as high as possible during the distribution chain. This chapter takes an overview of the indigenous and improved post-harvest handling methods and processing of fruits considering the total postharvest chain from harvesting methods, harvesting tools and implements, transportation, storage and processing. It identifies aspects of critical postharvest losses and finds solutions that would lead to a remarkable reduction in postharvest losses in quality and quantity of harvested fruits, thereby increasing the quality and quantity of marketable products.

2. Indigenous postharvest handling practices of fruits

Indigenous postharvest handling practices of fruits go along with a lot of inappropriate handling methods resulting in huge postharvest losses as a result of knowledge gap for all stakeholders in the postharvest food chain of fruits. Wounding, bruising, and physical injury imparted on the produce from rough and abusive harvest practices and postharvest handling methods will result in significant produce quality loss and an increase in postharvest decay. In Figures 1–4 careless handling of fruits were observed which will result in internal bruising, abnormal physiological damage, splitting and skin breaks. Skin breaks provide sites for infection by disease organisms causing decay. Enzymes contained in the cells of fruit tissues may be released as a result of mechanical damage during postharvest handling. These enzymes break down cellular material. Chemical reactions catalyzed by the enzymes result in the degradation of quality leading to off-flavors, deterioration of texture, and the loss of nutrients [14]. Chemical reaction occurs when fruits are damaged by falling, breaking, crushing, cutting, insect punctures and peeling. These damages release enzymes that trigger chemical reactions such as rancidity in fruits, deterioration of chlorophyll pigments and flavor changes [15]. Other major chemical changes which occur are lipid oxidation and non-enzymatic browning. This leads to deterioration in sensory quality, changes in the color and flavor of foods. The lipid oxidation rate is influenced by light, water activity, local oxygen concentration, high temperature, and the presence of
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catalysts such as iron and copper [16]. In Figure 1, it was observed that the indigenous bamboo basket is already weak and fruits can easily be bruised by the sharp edges of the basket due to weakness in the basket the fruit can fall off during transportation, loading and unloading from one destination to the other. Figures 2 and 3 showed the

Figure 1. Harvested lemon packed in worn-out sharp locally made basket.

Figure 2. Fruits carelessly handled at retail point.
exposure of fruits to direct sun which will increase the internal temperature and speed up chemical processes in the fruit. Food spoilage may be defined as any change that renders food unfit for human consumption. Every change in food that causes the food
to lose its desired quality and eventually become inedible is called food spoilage or rotting [17]. Damage restricts the use of produce, whereas loss makes its use impossible. Quality attributes describe the traits that make fruits acceptable to consumers such as nutritional composition, freedom from defects such as cuts, over-ripeness, spots, and disease infections. Quantitative and qualitative losses occur at all stages in the post-harvest handling system and distribution chain of fruits from harvesting, through handling, packing, processing, storage and transportation to final delivery of the fresh produce to the consumer [18]. Factors affecting post-harvest losses vary from place to place depending on the season, the genetic constitution of the crop, postharvest management practice, temperature and relative humidity (Table 1). Various authorities have estimated that 25–70% of fresh fruit and vegetables produced are lost after harvest [19]. Further studies revealed 20–40 percentage loss in developing countries [20]. Kereth et al. [12, 21, 22] estimated that from 5 to 25% of fruit from the farm gate never reaches the consumer. Post-harvest losses of banana, citrus, grapes, apples,

<table>
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<tr>
<th>Postharvest value chain</th>
<th>Activities</th>
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<tr>
<td>Farm gate</td>
<td>Harvesting, sorting, grading and sizing.</td>
<td>Mechanical, Physiological, pathological</td>
<td>5%</td>
<td>Harvest timely properly, and with pedicel, removal of infected fruit</td>
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<td>Packing house operations</td>
<td>Packaging, sorting, grading, sizing, trimming, washing, degreening</td>
<td>Mechanical damage, pathological losses due to contamination</td>
<td>5–10</td>
<td>Avoid exposure to direct sun-ray, careful handling</td>
</tr>
<tr>
<td>Transport</td>
<td>Handling, sorting, grading</td>
<td>Mechanical losses due to mishandling, physiological changes, pathological damages due to action of micro-organism</td>
<td>5–10</td>
<td>Appropriate packaging method to prevent moisture loss, appropriate container, avoid hard packages</td>
</tr>
<tr>
<td>Wholesale</td>
<td>Packing, sorting, grading, at wholesales point</td>
<td>Mechanical damages due to leveling, pathological damages due to the micro-organism, physiological damage due to moisture losses</td>
<td>10–25</td>
<td>Avoid exposure, store under shade, appropriate packaging materials, use of refrigerator or evaporative coolant structure, avoid delay, separated infected produce, avoid heaping especially fruit and vegetable</td>
</tr>
<tr>
<td>Retail</td>
<td>Buying and selling, packing sorting, and grading.</td>
<td>Pathological losses, slight mechanical damage, moisture loss.</td>
<td>5–10</td>
<td>Appropriate packaging, adequate storage facilities, avoid exposure, store under shade.</td>
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<tr>
<td>Consumers</td>
<td>Buying and selling, palatability test, choices.</td>
<td>Physiological losses, pathological losses.</td>
<td>5–10</td>
<td>Well ventilation, appropriate package, use of refrigerator, use of evaporative coolant, washing</td>
</tr>
</tbody>
</table>

Table 1. Identification of critical causes of postharvest losses and the solutions.
avocado, and papaya were reported to be 20–80, 20–95, 53, 14, 43 and 40–100% respectively in developing countries [23, 24]. Food loss assessment provides the basis for programs aimed at reducing postharvest losses [7, 25–28].

2.1 Harvest indices, tools, containers, storage temperature and relative humidity

In most developing world, orchards were established for a long period up to 50–100 years old. Fruits are plucked from the tree with hand by hired skilled laborer’s with the use of an indigenous bamboo ladder and the fruits are placed in a bamboo basket. Fruits are conveyed by the farmer with the use of a basket or jute bag to the collection sites. The fruits are thrown to the ground from a height of about one meter. In Nigeria, a harvesting knife (usually referred to as ‘go-to-hell’), consisting of a sickle-like metal head attached to a long wooden handle is employed in harvesting these fruits like orange, pear, African star apple, cashew from the trees (Table 2). The impact on the ground due to fall from the tree is reduced by gathering straw on the floor around the tree or heavy mulch is place on the ground with a thick depth of leaves. Sometimes a long cloth is attached to the tree branches from one end to the other and the fruits fall on the cloth without touching the ground. Sometimes the branches of the tree are shaken with hand and fruits will fall from the tree to the ground. The fruits would then be conveyed using the basket to the primary assembly point which is usually unprotected from environmental hazards such as heavy rain or sunshine until they produce are transported to wholesale markets. The delicate nature of the fruits and internal flesh should always be kept in mind while harvesting and handling produce. Physical damage is pronounced in the indigenous harvesting system due to the lack of knowledge and training.

2.2 Distant market

Primary Collection Centre (Farm gate).

In the indigenous settings, open ground is used where fruits are heaped on bare ground for transportation to distant markets (Figure 5). At this point, there is no sorting, grading, sizing, precooling or washing. The fruits are packaged in baskets or used rice bags or jute bags and then loaded in Lorries or commuter vehicles and then transported to wholesale point or distant market which is usually on market days. The traditional method utilizes a local basket for packing and transportation of fruits. A sizable quantity of the fruits gets damaged in transit. The loading of the vehicles also exceeds the vehicle’s carrying capacity on very rough roads that promotes vibration and jostling of the produce on vehicles that are poorly maintained where the shock absorber may not be well fixed with poor ventilation. The loading and unloading of the vehicle are not done with careful handling; the produce is thrown over high elevations and over wide distances which promotes cuts and bruises. The environmental conditions in these center’s may promote excess heat, low humidity, mechanical damage, improper postharvest handling methods, poor sanitation, and poor environmental control. The field containers should be put under shade to minimize produce heating in the interval between harvest and transport to the packinghouse. In the improved postharvest handling system efforts to control these factors are often very successful. In the improved system, air-conditioned structure is usually erected where packing house operations takes place such as sorting, grading, washing, disinfection, degreening, waxing packaging. The plastic fruit crates ‘area’ are a more suitable option in this system [29–31]. The modern fruit plastic crates take care of problems such as
<table>
<thead>
<tr>
<th>S/N</th>
<th>Fruit</th>
<th>Botanical name</th>
<th>Origin</th>
<th>Harvest indices</th>
<th>Storage °C RH%</th>
<th>Ethylene Sensitivity</th>
<th>Harvest Containers</th>
<th>Harvest tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>African star apple</td>
<td><em>Chrysophyllum albidum</em></td>
<td>West Africa</td>
<td>Colour change green to orange, ease of abscission</td>
<td>28 ± 2 °C 90–95%</td>
<td>Insensitive</td>
<td>Harvesting basket.</td>
<td>Long harvesting knife</td>
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<td>2.</td>
<td>Apple</td>
<td><em>Malus domestica</em></td>
<td>North America</td>
<td>Colour changes from leaf green to yellowish-green, firmness</td>
<td>0 °C 90–95%</td>
<td>Sensitive</td>
<td>Apple basket</td>
<td>Apple picker Ladder</td>
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<td>3.</td>
<td>Apricot</td>
<td><em>Prunus armeniaca</em></td>
<td>China Central Asia</td>
<td>Harvest when fruits are fully colored</td>
<td>0 °C 90–95%</td>
<td>Sensitive</td>
<td>Gently place in a basket</td>
<td>Hand picking</td>
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<td>4.</td>
<td>Avocado</td>
<td><em>Persea americana</em></td>
<td>Africa</td>
<td>Colour change, Ease of abscission</td>
<td>6–7 °C 85–95%</td>
<td>Sensitive</td>
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<td>5.</td>
<td>Banana</td>
<td><em>Musa domestica</em></td>
<td>South East Asia</td>
<td>Colour change dark green to light green, peel/pulp ratio</td>
<td>18 °C 80–85%</td>
<td>Sensitive</td>
<td>Gentle handling of bunches</td>
<td>Cutlass, Sharp knife</td>
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<td>6.</td>
<td>Chestnut</td>
<td><em>Castanea sativa</em></td>
<td>Asia Minor</td>
<td>Fullness of size, Browning of pods</td>
<td>0 °C 90–95%</td>
<td>Insensitive</td>
<td>Basket or wooden boxes</td>
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</tr>
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<td>7.</td>
<td>Cherimoya</td>
<td><em>Annona cherimola</em></td>
<td>Tropical America</td>
<td>changing in color from a darker to a light green or greenish tan</td>
<td>15-30 °C 40–90%</td>
<td>Sensitive</td>
<td>Plastic box or Paper boxes</td>
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<td>8.</td>
<td>Cashew</td>
<td><em>Anacardium occidentale L.</em></td>
<td>South eastern Brazil</td>
<td>ease of abscission, Acidity level, firmness</td>
<td>30 °C 67%</td>
<td>Insensitive</td>
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<td>9.</td>
<td>Custard Apple</td>
<td><em>Annona squamosal linn</em></td>
<td>South America</td>
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<td>25–30 °C 60–70%</td>
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<td>Clementine</td>
<td><em>Citrus clementine</em></td>
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<td>Dates</td>
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<td>Harvest indices</td>
<td>Storage T°C RH%</td>
<td>Ethylene Sensitivity</td>
<td>Harvest Containers</td>
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<td>12</td>
<td>Elephant Apple</td>
<td>Dillenia indica</td>
<td>Indonesia</td>
<td>Colour change from dark green to olive green</td>
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<td>Sensitive</td>
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<td>Fig</td>
<td>Ficus carica</td>
<td>Northern Asia Minor</td>
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<td>Grape</td>
<td>Citrus paradisi</td>
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<td>Guava</td>
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<td>Jackfruit</td>
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<td>Western Gluts of southern India</td>
<td>Firmness, ease of abscission</td>
<td>13°C</td>
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<td>Kiwi</td>
<td>Actinidia de liciosa</td>
<td>Southern China</td>
<td>Firmness, ease of abscission, Increase in sugar content</td>
<td>~0.5°C</td>
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<td>Harvesting box</td>
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<td>Citrus aurantifolia</td>
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<td>Lemon</td>
<td>Citrus limon</td>
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<td>10–13°C</td>
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<td>Mammee Americana</td>
<td>South America</td>
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<td>Sensitive</td>
<td>Harvesting boxes</td>
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<td>Harvest Containers</td>
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<tr>
<td>22.</td>
<td>Mango</td>
<td>Mangifera indica</td>
<td>South East Asia</td>
<td>Olive green colour, smooth and shiny, TSS 10–14% Starch content, flesh colour.</td>
<td>April–June 12°C 90–95%</td>
<td>Sensitive</td>
<td>Harvesting boxes</td>
<td>Hand plucking</td>
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<td>24.</td>
<td>Sweet Orange</td>
<td>Citrus sinensis</td>
<td>Southern China, Northern and East India and South East Asia.</td>
<td>Ease of abscission, colour change from dark green to light green</td>
<td>November, December 0–9°C 85–90%</td>
<td>Insensitive</td>
<td>Basket. Harvesting box</td>
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<td>26.</td>
<td>Peach</td>
<td>Prunus persica</td>
<td>China</td>
<td>Ease of abscission, golden colour, firmness</td>
<td>May—September −0.5–0°C 90–95%</td>
<td>Sensitivity</td>
<td>Basket. Harvesting box</td>
<td>Hand plucking</td>
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<tr>
<td>27.</td>
<td>Passion fruit</td>
<td>Passiflora edulis</td>
<td>Southern Brazil</td>
<td>Ease of abscission, dark green to light green depending on the variety</td>
<td>December – January in the tropics 5–10°C 85–90%</td>
<td>Sensitive</td>
<td>Basket. Harvesting box</td>
<td>Hand plucking</td>
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<td>28.</td>
<td>Pomegranate</td>
<td>Punica granatum</td>
<td>Iraq and Himalayas in northern India</td>
<td>Sugar percentage should be 12–16% and acid percentage 1.5–2.5%,</td>
<td>September–November 5°C 90–95%</td>
<td>Insensitive</td>
<td>Basket or cloth bag</td>
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<td>29.</td>
<td>Pawpaw</td>
<td>Carica papaya</td>
<td>Panama and Columbia</td>
<td>Patches of yellow, Jolliness of seed</td>
<td>August – September 7–13°C 85–90%</td>
<td>Sensitivity</td>
<td>Harvesting boxes</td>
<td>Long stick or hand plucking</td>
</tr>
<tr>
<td>S/N</td>
<td>Fruit</td>
<td>Botanical name</td>
<td>Origin</td>
<td>Harvest indices</td>
<td>Storage T°C RH%</td>
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<td>Harvest Containers</td>
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<td>30.</td>
<td>Pear</td>
<td>Pyrus communis</td>
<td>China</td>
<td>May – August</td>
<td>-1.5 – 0.5°C 90–95%</td>
<td>Sensitivity</td>
<td>Harvesting box</td>
<td>Long harvesting knife</td>
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<td>31.</td>
<td>Plum</td>
<td>Prunus domestica</td>
<td>Eastern Europe and China</td>
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<td>-0.5°C 90–95%</td>
<td>Sensitivity</td>
<td>Harvesting box</td>
<td>Pluck with hand</td>
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<td>32.</td>
<td>Pineapple</td>
<td>Ananas comosus</td>
<td>South America</td>
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<td>7–13°C 85–90%</td>
<td>Insensitive</td>
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<td>Persimmon</td>
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<td>November–January</td>
<td>-1°C 90%</td>
<td>Sensitivity</td>
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<td>34.</td>
<td>Raspberry</td>
<td>Rubus spp.</td>
<td>North America</td>
<td>April–August</td>
<td>-0.5–0°C 90–95%</td>
<td>Insensitive</td>
<td>Paper Boxes</td>
<td>Pluck with hand</td>
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<td>Strawberry</td>
<td>Fragaria spp.</td>
<td>North America</td>
<td>April–August</td>
<td>0–0.5°C 90–95%</td>
<td>Sensitive</td>
<td>Paper Boxes</td>
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<td>36.</td>
<td>Tangerine</td>
<td>Citrus reticulate</td>
<td>South Asia</td>
<td>April–November</td>
<td>9–10°C Humidity: 85–90%</td>
<td>Insensitive</td>
<td>Basket, Cloth bag, Boxes</td>
<td>Pluck with hand</td>
</tr>
<tr>
<td>S/N</td>
<td>Fruit</td>
<td>Botanical name</td>
<td>Origin</td>
<td>Harvest indices</td>
<td>Storage T°C RH%</td>
<td>Ethylene Sensitivity</td>
<td>Harvest Containers</td>
<td>Harvest tool</td>
</tr>
<tr>
<td>-----</td>
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<td>--------------------</td>
</tr>
<tr>
<td>37.</td>
<td>African Walnut</td>
<td>Plukenetia conophora</td>
<td>Tropical West African nations</td>
<td>Ease of abscission September–December</td>
<td>10–20°C 85–95%</td>
<td>Insensitive</td>
<td>Jute bag or boxes</td>
<td>Pluck with hand</td>
</tr>
<tr>
<td>38.</td>
<td>Watermelon</td>
<td>Citrullus lanatus</td>
<td>Egypt</td>
<td>Colour change from dark green to light green, sound, browning tendrils April – September</td>
<td>10–15°C 90%</td>
<td>Insensitive</td>
<td>Jute bag or boxes</td>
<td>Pluck with hand</td>
</tr>
<tr>
<td>39.</td>
<td>Plantain</td>
<td>Musa paradisi</td>
<td>South Asia</td>
<td>Colour change from dark green to light green, blackness of tip, peel/pulp ratio, blackness of tip, peel/pulp ratio, January – March</td>
<td>18°C 80–85%</td>
<td>Sensitive</td>
<td>Gentle handling of bunches</td>
<td>Cutlass, Sharp knife</td>
</tr>
</tbody>
</table>

Table 2. Harvest indices, tools, containers, storage temperature and relative humidity.
bruises, cuts and other likely mechanical damage. For example, reducing mechanical damage during grading and packing greatly decreases the likelihood of postharvest disease because many disease-causing organisms would enter through wounds [32–36].

2.3 Indigenous temperature management practices of fruits

Farmers usually employ hired labour or collaborate among themselves by mobilising each other for harvest as early as 6 am when the temperature is low before 12 pm. The harvested produce is moved to the market for early sales to consumers or retailers. Sometimes, the produce harvested in the evening will be spread on flat surfaces overnight not allowing the produce to overlap one another; this will be sold in the market in the next morning. Oranges, Grapes, pear, mango, guava, African star apple, Avocado pear, African star apple are harvested when the color changes from deep green to slight yellow. At this stage, the produce can be transported to distant markets (Figure 6).

2.4 Improved temperature management practices

The improvement in temperature management requires rapid removal of the field heat through: hydro-cooling, packaging in iced containers, top icing, evaporative cooling, room cooling, forced air cooling, serpentine forced air cooling, vacuum cooling, and hydro-vacuum cooling. The cold chain system is required in the value chain of fruits from the farm gate to the consumer.
2.5 Indigenous pre-harvest quality management

Farmers have the age-long practice of keeping the best of their harvest as seed for the next season with the concept of maintaining the appropriate genetic resources from generation to generation to maintain produce qualities. The land preparation is done thoroughly to minimize weed infestation which reduces the quality of harvested produce. Farmers depend on accumulated hand-on experience or indigenous knowledge on when to harvest and how to harvest. Leguminous food crops are planted like cocoyam, melon, wrapping leaves, and vegetables are intercropped with the fruit trees to supply staple food for the household and regular income. It also reduces maintenance cost.

2.6 Improvement on pre-harvest quality management

Pre-harvest factors affect the rate of deterioration in the following ways:

- **Genetic factors**: The rind thickness, skin layer affects rate deterioration. Some fruits outer layer has been improved to prolong shelf-life.
- **Maturity**: Fruits should be harvested at the proper maturity stage to give the best quality.
- **Seed Selection**: The right seed that is disease free and give the best quality output should be used.
- **Site Selection**: The soil fertility status must support growth and development and insect pest status should be low.
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*Tools and Implements:* These must be free from disease and the most appropriate implement for harvesting of that particular fruit.

*Climatic conditions:* Erratic changes in temperature will reduce the quality of fruits in terms of water stress, which will reduce the liquid content of fruits while excess water will result in rot, absence of cold period will affect the formation of the orange color in citrus.

*Cultural practice:* All cultural practices must be done appropriately and timely. Planting must not be delayed in other to avoid pest peak period.

*Use of chemicals:* Use of various chemicals in excess should be avoided.

*Water stress:* Irrigation should be planned along with field establishment.

*Disease, insect, rodents:* Activities of field pest reduce quality of produce through boring, feeding and laying of egg. Often disease and pest are transferred from field to storage and along the postharvest chain.

*Injury:* This can be caused by insect pest or farm implements, sometimes lack of moisture in the atmosphere may result in cracking of fruits.

*Irregular weeding:* Weeds serve as alternative host for diseases and pests; therefore, it must be controlled.

*Management practices:* This can also affect postharvest quality. Produce that has been stressed by too much or too little water, high rates of nitrogen, or mechanical injury (scrapes, bruises, abrasions) are susceptible to postharvest diseases. They are also susceptible to mold and decay caused by fungus *Rhizoctonia*, as a result fruits lying on the ground, and it can be alleviated by using mulch (*Figures* 7 and 8) [37, 38].

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*Figure 7.*
*Fruit display by retailer with partial provision of shade.*
2.7 Indigenous postharvest quality management

Transportation to the market is done by trucks, lorries, wheelbarrows, and motorcycles. During loading, fruits are carried in basket on head and thrown over straw or fruits already present inside the truck from a meter height. These practices result in bruising of the fruits and as a result become unmarketable. Fruits have to face the same fate of rough handling during unloading. Storage is a much-neglected aspect in the whole process and there is no permanent structure for storage in any point of time during the whole process of harvesting to marketing. Rough handling practices are practiced during loading of the field containers in transit. Throwing of the field containers and excessive drop at high heights is practiced by the handlers. The consequences of these undesirable practices included noticeable physical injury and bruise damage to the product. The likelihood of postharvest decay of the injured items is high. The process of loading the field containers onto the transit vehicle and unloading at the packinghouse needs closer supervision [2]. Indigenous method of temperature management includes exposing harvested fruit to frozen air at night, or putting fruits in water immediately after.

2.8 Improved postharvest handling methods of fruits

Harvesting and handling;

1. Harvesting should be done with extreme care due to soft tissue of the fruits
Fruit Industry

2. Produce should be harvested at the best quality for storage to prolong shelf life.

3. Harvesting should be done under cool condition

4. Harvest in batches to give highest quality available to customers.

5. Plant at different times using varying varieties to extend harvest season.

6. Hold produces in a shaded area before transportation

7. Poor quality produce should be removed to avoid contamination and distractions.

8. Avoid increase in temperature and moisture loss during transportation and storage.

9. Commodities for export must be handled carefully.

10. Use appropriate tool, container and implements during handling

2.9 Evaporative cooling system as improvement on the use of clay pot to preserve fruits

Different types of Evaporative Cooling Systems have been developed for the small- and large-scale storage systems.

i. Pot-in-Pot: This comprises of two clay pots in which a smaller pot with the smaller mouth is placed inside a bigger one and the interspace filled with riverbed sand. Fruits for storage are kept inside the smaller pot and covered with an insulating material. The riverbed sand is kept moist by wetting it once daily. Fruits kept in it can remain fresh for up to 1 month.

ii. Metal-in-Pot: This is similar to pot-in-pot except that the smaller inner pot is replaced with a metal pot – an old kerosene tin. The working principles are the same.

iii. Wall-in-Wall: This is the commercial size of (i) above. It involves building a block inside another block with a small door made of wooden materials. The inner part of the small block is provided with shelves. Tap water pipe could be connected to the interspace for the case of water supply to wet the riverbed sand. It could keep fruits for 1–3 months without a problem. This structure of size measuring 2.5 m × 2.5 m × 2.5 m could be used to store 15–20 baskets of fruits at a time.

iv. Metal-in-Wall: This is similar to (iii) above but for the fact that the inner block wall is replaced with a metal tank that has shelves inside. The working principles are the same.

v. Bamboo Coolant Structure: The base of the cooler is made by a large diameter tray that contains water. Bricks are placed within this tray and an open ware cylinder of bamboo or similar materials is placed on top of the bricks. Hessian cloth is wrapped around the bamboo frame, ensuring that the cloth is dipped in water.
to allow it to be drawn up the cylinder’s wall and food kept in the cylinder with a lid placed on the top.

vi. **Charcoal Cooler:** The charcoal cooler is made from an open timber frame of approximately 50 mm × 25 mm in section. The door is made by simply hinging one side of the frame. The wooden frame is covered in mesh, inside and out leaving a 925 mm (1") cavity; this is filled with pieces of charcoal. The charcoal is sprayed with water and when wet provides an evaporative cooling effect. The framework is mounted outside the house on a pole with metal to deter rats and a good coating of grease to prevent ants from getting to the food stored.

vii. **Almirah Cooler:** The Almirah cooler is a more sophisticated cooler that has a wooden frame covered with cloth. There is a water tray at the base and on top of the frame into which the cloth is dipped, thus keeping it wet. A hinged door and internal shelves allow easy access to the stored produce.

Various researches were carried out to investigate the effectiveness of the evaporative coolant structure in prolonging the shelf life of fruits [39]. Babatola and Adewoyin [40] observed that Cucumis sativus stored best for 3 weeks under the refrigerator followed by evaporative coolant structure and then open shelf. The evaporative coolant stored Cucumber fruit effectively for 2 weeks. Babatola [41] also investigated the effect of storage conditions on nutrient composition and quality of *Capsicum frutescens* under three storage conditions. Observations were made on colour, firmness, weight loss, disease incidence and pungency level of pepper fruit, it was observed that pepper fruits kept well for 21 days in the evaporative coolant structure at a temperature of 20–22°C. Babatola [42] further investigated the effect of NPK fertilizer levels on the growth, yield and storage of pepper on *Capsicum annum*. The result showed that fruits stored in the refrigerator stored best for 3 weeks, followed by evaporative coolant structure which stored for 2 weeks while fruits under the ambient deteriorate rapidly after 4 days. Another research was conducted on the postharvest quality of okra fruit under three storage conditions. Evaporative coolant structure was found to store okra effectively for 2 weeks [43]. The physicochemical changes and shelf life of guava as influenced by postharvest condition were observed, refrigeration was observed to prolong shelf life for 16–28 days followed by evaporative coolant structure [44]. Further research on the influence of storage conditions, such as deep freezing, refrigeration and evaporative coolant structure on the quality of varieties of carrots showed that carrots stored best in the deep freezer at the temperature of 0–4°C in terms of color, firmness and disease infection [45].

Postharvest technology is crucial in agricultural production and utilization system. It plays a key role in loss reduction, value addition, food security, employment and income generation [38, 39]. A postharvest technology revolution is essential with strong linkages of storage, marketing and distribution. Inappropriate postharvest management system resulted in large quantity of fruits gets damaged during the process of handling, transportation and marketing **Figure 3** [36, 37]. Due to the absence of proper storage and marketing facilities, farmers are forced to sell their produces at throw-away prices. Sometimes farmers do not even get the two-way transportation cost, so they would rather dumb their produce near the market area than bear the transportation cost required for taking the product back. It is of utmost importance to identify all aspects of critical postharvest losses and find solutions that would lead to a remarkable reduction in postharvest losses.
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Processing is a postharvest activity carried out to maintain or raise the quality of produce or change the form or characteristics of fresh produce, spoilage agent must be destroyed withoutruining the nutritive value or palatability of the farm produce. Processing easily destroys Vitamin C in fruits, especially where heat is used. Produce that has been processed can also be stored to prevent spoilage and extend storage life; hence we have the term preservation. Processing and preservation aim at achieving the following goals:

i. Increase the shelf life of the produce.

ii. Increase variety in the diet by providing a range of attractive flavours, colours, aromas and textures.

iii. Increase the economic value of the produce by raising its quality.

iv. To create a new product.

v. To remove inedible parts of produce.

vi. Facilitate efficient and easy transportation

vii. Reduce bulkiness

viii. Produce easy to display

ix. Increase sales

x. It makes fruits available where it is not produced

xi. It makes fruits available throughout the year e.g., dried mango, pineapple.

xii. Stabilizes price

xiii. Reduce postharvest losses

xiv. Value addition is possible

xv. The waste from processing can be used to generate income.

3. Conclusion

Fruits are to be harvested at the appropriate maturity stage and size to prolong shelf life. Major losses in the postharvest chain of fruits are due to mechanical damages, physical bruises, a physiological disorder due to high temperature and unhygienic conditions. Time of harvest, method of harvest, tools used in harvesting, transportation affects wholesomeness or increased rate of deterioration of harvested fruits. The inappropriate postharvest management system in the postharvest chain of fruits results in huge losses during the process of harvesting, grading, packaging, handling, transportation and marketing. These losses are due to inappropriate harvesting
methods and tools, unavailability of cold chain systems, absence of appropriate storage facilities and poor marketing strategies. To maintain and effectively preserve fruit quality. Postharvest handling must be efficient, rapid and coordinated by ensuring immediate removal of field heat, reducing damages by protecting from sun and unhygienic conditions. Knowledge on specific produce handling method, market requirement, appropriate container and simplified packing line is essential to achieve uniformity and ensure produce are properly placed and strapped for delivery to consumers. Workers involved in critical postharvest handling steps are to be well trained, remunerated and equipped with appropriate tools, risk-free and conducive working condition.

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