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Review Article

Eliminating Postharvest Losses in Fruits and Vegetables Grown in Nigeria: A Review

O. A. Oyelade
National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State
Email: yemibamigbedjdoyelade@gmail.com

Abstract

There are a lot of health benefits attached to the global consumption of fruits and vegetables on daily basis. During the coronavirus disease (COVID-19) era which lasted for more than a year, the World Health Organization (WHO) advised people all over the world to embark on the heavy consumption of fruits and vegetables to boost their immune system as the only alternative in preventing ourselves from contracting the deadly virus pending the time scientists all over the world are busy researching into how they can produce a strong and effective vaccine that can combat the deadly virus that have killed several millions in the world from the time there was an outbreak of the virus in China. This review in seeing to how postharvest losses could be eliminated in fruits and vegetables became necessary having noticed the importance of fruits and vegetables to the human body during the time of the pandemic disease. Quite a number of ways forward were provided in this review as solutions to eliminating postharvest losses observed in fruits and vegetables grown in Nigeria. Factors such as harvesting, material handling, transportation, controlled environment among others formed part of the discussion as these factors were noticed to be a common factor found responsible for the high postharvest losses observed in fruits and vegetables grown in Nigeria.

Keywords: postharvest loss, fruit, vegetable, transportation, farmer, processor

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Introduction

Kikulwe *et al*. (2018) defined postharvest loss at any given point along the postharvest chain as the measurable qualitative and quantitative loss of products from harvest to consumption. Examining it from the view of Gross *et al*. (2000), postharvest loss account for substantial economic losses and food losses. Kader *et al*. (2012) noted that in developing countries, plant foods such as vegetables, fruits, cereals, legumes, tubers, and that of dairy in general accounts for 92% of total losses in food, with the 8% value left are meant for fish (4%) and meat (4%). Kumar *et al*. (2006) viewed postharvest loss from the angle of output by stating that outputs of all agricultural commodities produced in the field have to undergo a series of operations such as threshing, transportation, processing, storage and exchange before they reach the consumer, and there are appreciable losses of outputs during these stages of their handling. The sum quantity of outputs lost in these operations at all of these stages is referred to as "post-harvest losses".

Parfitt *et al*. (2010) observed in low-income countries that food loss generally occurs at the early-middle stages of food supply chain with lesser amount of waste observed at the consumer's level. In countries that are still in their developing state, lack of appropriate packaging, lack of a cold chain system, poor harvesting technique, inadequate harvesting stage, transport, inadequate storage facilities, trading facilities and limited processing knowledge are main factors making postharvest losses to be high. A study into developing countries which was carried out by Hodges *et al*. (2011) revealed that in the middle of the food supply chain losses are likely to be low and quite high at the level of the consumer. Findings made from the studies of Hodges *et al*. (2011) and Parfitt *et al*. (2010) showed that when slight mid-stage losses occur, it can be attributed to extensive and efficient cold chain systems, storage, better management, better transport, more efficient farming systems, and processing plants that ensure that the major part of the harvested product are delivered to the markets.

Fruits and vegetables in their freshly harvested form are very perishable and get spoilt easily resulting from a lot of factors that occurs at the time of postharvest. Storage ability and the quality maintained in fruits and vegetables are affected after harvest by lots of pre-harvest factors like planting distances, fertilization, irrigation, soil type, etc. On a worldwide measure from farm to fork about 25% to 50% of fruits and vegetables are lost, which in term is referred to as losses observed during postharvest or FLW which signifies (food loss and waste). These losses account for one-third in the amount of food produced globally (Bancal and Ray, 2022). Feeding over 9.1 billion persons with harmless food is the primary challenge for agricultural research and policy in year 2050.

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Emana *et al*. (2017) noted that high amount of postharvest losses are observed in some vegetables and fruits like avocado, banana, mango, sweet orange, and papaya. In perishable crops like fruits and vegetables, transport, packaging, handling technologies, and proper and scientific storage are inadequate, therefore a significant volume of produce waste are incurred during the process. The moisture content in vegetables under tropical conditions makes them more liable to deterioration in quantity and quality. Due to their biologically active nature as they do carry out respiration, transpiration, ripening and other biochemical activities, contributes to the deterioration level of the produce. Postharvest losses which takes place in vegetables at the time of postharvest operations are enormous as a result of storage and inappropriate handling. Gauraha (1997) stated that postharvest loss in vegetables ranges from 5.42% to 32.64% in the cases of bottle gourd and tomato, respectively. Losses encountered in postharvest operations in the field can occur in packing areas, during transportation, in storage and in the retail and wholesale markets. Severe losses occur due to lack of know-how, poor facilities, inappropriate market facilities and poor management or because of the careless handling of the produce by farmers, consumers and market intermediaries. Therefore, it is, important that postharvest practices are given the desired attention such as the production practices. Postharvest losses in vegetables at various handling stages would help to assess the extent of losses and to also identify the factors responsible for these losses. This would help in developing proper measures in reducing postharvest losses encountered at different stages from production to consumption point. Reduction in postharvest losses under the situation can help increase the availability of vegetables to a great extent without increasing its production.

In Nigeria, up to 50% of nutrient-rich fresh fruits and vegetables (FFVs) produced are lost or wasted, with nearly half of these losses attributed to post harvesting operation. These losses occur during harvesting, transportation, storage and processing. These losses are both quantitative and qualitative. Quantitative losses are losses in quantity due to physical damage, insect attack, rodents, and micro-organisms. Qualitative losses include loss in edibility, nutritional value, and consumer acceptability of the products. The Postharvest Loss Alliance for Nutrition (PLAN) project identified three main factors responsible for these large proportions of postharvest losses of FFVs. This review is really needed in seeing to how postharvest losses can be reduced to its minimum when it comes to the aspect of fruits and vegetables grown in Nigeria.

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Importance of Fruits and Vegetables to Human Health

World demand for high quality fruits and vegetables in their fresh form is rapidly increasing, and many thanks to the issue of urbanization, a rising level in the middle class, changing consumer habits and an increase in disposable income. The world market for fresh fruits and vegetables is estimated at 144 billion USD, which is anticipated to increase to more than 200 billion USD by 2027 (Stanaway *et al.*, 2022). Fruits and vegetables are important to a well-balanced and healthy diet. They are abundant in essential antioxidants, dietary fibres, vitamins, and minerals, which can help with a range of deficiencies and ailments (Chen *et al.*, 2022).

Fruits and vegetables have many important nutrients that are good for keeping good health. Vitamin supplementation (A, B, C, D, E vitamins) and immune system support played a prominent role during the time of COVID-19 (Chowdhury *et al.*, 2020). Contributing to the balanced functioning of the body was the water- and fat-soluble vitamins. Among the water-soluble vitamins, vitamins B and C have a prominent role (Vállez-Gomis *et al.*, 2021; Hoang *et al.*, 2020). Vitamins A, D, E, and K which falls among the fat-soluble vitamins, were also important in helping the body's defense mechanisms and preventing infections (Chen *et al.*, 2011). The consumption of vitamins needs careful attention. Their consumption is mostly recommended in the form of food intake. This also makes them easily absorbable in the body. Due to their useful properties which also involve the support given to the body immune system, they also stimulate the functioning of organ systems, therefore contributing to the achievement of normal equilibrium. Fruits and vegetables are the most common source of vitamins which contain several other useful ingredients in addition to minerals, vitamins, fibre and water.

Fruits and vegetables which can be considered as functional food because of their useful biological active components forms part of our everyday nutrition. They have a beneficial effect in increasing the body energy balance, body's hydration, cardiovascular, preventing and treating gastrointestinal, nervous and metabolic diseases (Cömert *et al.*, 2020). In the aspect of fruits and vegetables, we can limit our study to the commons ones such as apples, avocados, bananas, beets, carrots, grapes, lemons, onions, and tomatoes among the fruits and vegetables consumed amongst us and as well their useful vitamin contents. It is important to describe the content features and the most important physiological effects. The evaluation of the vitamins and minerals and other useful components of some fruits and vegetables are discussed under this subsection.

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Grapes

Grapes which are rich in vitamins A, B, C and K are available in many countries of the world. In addition, its iron, potassium, selenium and folic acid contents are outstanding. Grapes plays a great role in maintaining physical and mental balance. As a result of its flavonoid content, it has an antioxidant effects. Grapes fibre and fluid contents are also remarkable. The ingredients contained in grape seed are used for preventing cardiovascular disease (Unusan, 2020). Fig. 1 shows the pictorial view of a grape fruit.

Fig. 1. Pictorial view of grape fruits

Apples

Apples which contain several vitamins such as A, B and C are available in many regions of the world. It has other useful sources of minerals like calcium, iodine, potassium, selenium and zinc. The fibre content found in apple helps to treat intestinal complaints. Flavonoid content, like grapes, prevents cancer, protects the immune system and reduces the inflammation (Zhang *et al.*, 2021). Fig. 2 shows the pictorial view of an apple fruit.

Fig. 2. Pictorial view of apple fruits

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Bananas

One of the most widely consumed nutritious snack foods is banana. It is rich in vitamins A, B and C. Aside this, is a good source of many minerals such as calcium, copper, iron, manganese, magnesium, phosphorus and potassium (Pal, 2021). Its flavonoid content is disease preventing and health-protective. Banana's carbohydrate content which is mostly in the form of starch, helps the body to replenish energy (Kraithong and Issara, 2021). The antioxidants contained in banana helps to boost immunity (Pal, 2021). There are several health benefits that are associated with the intake of banana in our daily diet (Pal, 2012; Pal, 2021). Fig. 3 shows the pictorial view of a banana fruit.

Fig. 3. Pictorial view of banana fruits

Carrots

Carrots which contain the most vitamins (vitamin B group, vitamins A, C, E, K) form a popular vegetable that are eaten worldwide. It has an outstanding β-carotene content. The consumption of carrots, has good effect on our immune system and likewise on the health of the human eyes and skin (Boadi *et al*., 2021). Fig. 4 shows the pictorial view of a carrot.

Fig. 4. Pictorial view of carrot

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Beetroots

Beetroots which contains vitamins A, B and C are well-known vegetable in international gastronomy which has many useful physiological roles. It is rich in potassium, useful in anaemia, improves blood circulation and it also stimulates the nervous system. The flavonoids in beetroots has an excellent effect on the functioning of the immune system (Sentkowska and Pyrzynska, 2020). Fig. 5 shows the pictorial view of a beetroot.

Fig. 5. Pictorial view of beetroot

Onions

Onions which are outstanding in vitamins B, C and E are known worldwide as they contain many vitamins and minerals. The minerals contained include calcium, iron, magnesium, phosphorus, potassium and sodium. Onions are rich in flavonoids and can be eaten as a herb, spice and vegetable (Bibi *et al*., 2021). Fig. 6 shows the pictorial view of an onion.

Fig. 6. Pictorial view of onion

Lemons

Lemon is a versatile fruits with many health benefits. Is widely consumed by people in the world. It contains many vitamins such as ascorbic acid, choline, niacin, riboflavin, panthothenic acid, and thiamine. Is rich in several minerals like calcium, copper, iron,

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manganese, magnesium, phosphorus, potassium and zinc. The vitamin C contained in lemon fruits plays an important role in immunity and helping to neutralize free radicals and thus minimizing the risk of cardiovascular disease (Pal, 2017). Fig. 7 shows the pictorial view of a lemon fruit.

Fig. 7. Pictorial view of lemon fruits

Tomatoes

Tomato which are rich in vitamins A and C are everywhere in and on our food. They are among the most versatile of all fruits and vegetables as they are loaded with antioxidants and other nutrients. The intake of tomatoes helps to (1) lower the heart disease risk and cholesterol, (2) lower cancer risk, (3) increase immunity, (4) improve sperm motility, and (5) protect against sunburns. Fig. 8 shows the Pictorial view of a tomato fruit.

Fig. 8. Pictorial view of a tomato fruit

Avocados

Avocados are good source of vitamins B-6, C, E, and K, as well as potassium and folate. The fruit contain a wide range of nutrients. Avocados which are considered as a type of berry are also known as alligator pear or butter fruit. Avocados which are also rich in many vitamins and minerals, provide a substantial amount of monounsaturated fatty

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acids. The health benefit of avocado fruits when consumed include (1) healthy for the heart, (2) great for vision, (3) helps to prevent osteoporosis, (4) prevents cancer, (5) supports fetal health, (6) reduce depression risk, (7) improves digestion, (8) provides natural detoxification, (9) relief osteoarthritis, (10) protect chronic disease, (11) it contain antimicrobial properties that defend the body against both streptococcus agalactiae and staphylococcus aurous infections, and (12) prevent bone loss. Fig. 9 shows the pictorial view of an avocado fruit.

Fig. 9. Pictorial view of avocado fruits

It is good to conclude under this subsection that during the period of the COVID-19 pandemic that it became very important to provide protection for the immune system which helps in preventing diseases. Healthy diet consumed then where fruits and vegetables which offered an excellent opportunity in supplementing vitamins as it kept stimulating the immune system. As a result of their consumption, many diseases were prevented, it also provided a good effect on digestion, well-being and the body's energy levels were also increased. Fats and water-soluble vitamins found in fruits and vegetables, play an important role in fighting disease and maintaining body's balance.

Causes of Postharvest Losses in Fruits and Vegetables Grown in Nigeria

Alao (2000) observed that all vegetables grown in Nigeria are consumed in the country. Production is seasonal resulting in scarcity at off seasons and a glut during its season. Because of the soft texture they have, they easily get wounded or bruised during harvesting, and other postharvest handling operation like storage, packaging and transportation. In Northern Nigeria, despite accounting for the production of fruits and vegetables in adequate quantities, yet on account of losses in the field as well as in storage, they become inadequate. Almost 30% of fruits and vegetables grown are rendered unhealthy for consumption resulting from spoilage after harvesting. This is considered a

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

massive valuable food loss even when not meeting the minimum food requirement of the population.

Perishable agricultural products such as fruits and vegetables in food supply chains have continued to observe high postharvest losses (Idah *et al*., 2007a). Usually, wastages encountered from deterioration during the process of food supplied from developing nations such as Nigeria is around 90% (Onifade *et al*., 2013). At the postharvest stages, an estimated amount of 40% to 50% loss takes place in tomato fruits (Olayemi *et al*., 2013). Idah *et al*. (2007b) stated that commonly in the tropics, the estimated loss observed in fruits and vegetables which usually occur between production areas and consumption points was found to be within the range of 50% to 70% (Olanrewaju *et al*., 2018). Reports gathered from FAO (1989) stated that vegetables produced in Nigeria have not met world standard due to poor harvest handling. There is calls for growing more and saving what has been grown at high cost (Alao, 2000; Elias *et al*., 2010). Fresh fruits and vegetables are perishable and highly prone to these losses because they are composed of living tissues. These tissues must be kept alive and healthy throughout the process of marketing. These are composed of thousands of living cells which require care and maintenance (Alao, 2000; Mustapha and Yahaya, 2006).

Generally, many factors influences postharvest losses observed in fruits and vegetables. These factors include losses due to mechanical, physiological, physical and hygienic conditions. Fruits and vegetables are mostly characterized by their high level metabolic activities which are known to have short shelf life. Resulting from these factors, a substantial percentage of loss take place between harvesting to consumption of the produce (Hayatu, 2000; Sani and Alao, 2006). In addition, other factors such as mite injury and insect, diseases which occur due to non-infectious pathological rots and pathogens also cause postharvest loss of fruits and vegetables. However, among these identified causes, pathological rots are the most serious which is followed by mechanical injury. Pathological rots when combined with mechanical damage cause serious damage to the perishables (Mustapha and Yahaya, 2006; FAO, 2011a). Environmental factors such as oxygen, relative humidity and temperature balance most especially during storage are greatly responsible for damage. Likewise environmental conditions such as relative humidity and temperature are responsible for the pathological attacks noticed in fruits and vegetables. However, the loss of fruits and vegetables due to physiological and biochemical damage are closely interrelated (Sani and Alao, 2006; Williams *et al*., 1991). Hence, postharvest loss of fruits and vegetables can be discussed under primary causes and secondary causes. Factors causing losses during postharvest operation in fruits and vegetables are discussed under this subsection.

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Improper Maturity Stage and Harvesting

The most important factor responsible for quality determination in fruits and vegetables is the maturity stage. Early picked fruits have lower quality making them to be susceptible to physiological disorders. They possess shorter storage life when compared with fruits picked at the proper maturity stage (Arah *et al*., 2015). The ripening of fruits and vegetables during harvest time is the main factor that determines their shelf life and quality of product. Yet, due to economic reasons can make some farmers to harvest immature crops. Fruits that are unripen, are more susceptible to mechanical damage and likewise deterioration as they may become poor in the quality of fruits produced resulting from low sugar and high acidity observed through the fruit's ripening process. However, fruits that are overripe possess a low shelf life. The ripening process that involves both cases (under ripening and over ripening), fruits in this case are more susceptible to physiological disorders. Crops economical and nutritional value reduces during early harvesting. Whole products, in some cases, can be lost because they are unsuitable for consumption (Azabağaoğlu, 2018; Kader, 1995). In Ethiopia, inappropriate time for harvesting is the major problem associated with losses encountered during postharvest of fruits and vegetables. Fruits harvested at the proper maturity stage helps in attaining their high quality and the possibility of postharvest losses is reduced (Mebratie *et al.,* 2015).

Losses can also be caused due to the harvest techniques adopted (Kasso and Bekele, 2016). Losses in perishable foods like fruits and vegetables rises when they are exposed to more treatments other than one. At times, farmers may not have containers for storage either at harvesting or after harvesting stage. This cause mechanical damage in root and tuber, vegetable and fruit plants during harvesting, resulting in losses. Inappropriate application of cultural practices like hail, drought, excessive rainfall, physiological disorders, frost, diseases, irrigation, plant nutrition, fertilization, pruning, and plant protection in the pre-harvest period cause losses in fruit and vegetable. The inappropriate estimation of the time of harvesting leading to harvesting at the wrong time, failure to apply pre-cooling to fruits like cherries and inappropriate application of harvesting practices accounts for 4% to 12% loss during the harvesting period (Özdemir *et al*., 2003).

Improper Packaging Method

Packaging method in its well-designed form helps to decrease damage of horticultural products, mainly perishable ones such as fruits and vegetables (Fellows, 2011). Looking into the case of Ethiopia, quite a lot of traditional packaging materials are used for holding agricultural products, but there exist a shortage of standardized packaging materials used for fruits and vegetables (Bereda, 2016). The common ones used are

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

baskets, wooden boxes, sacks and plastic bags (Kuyu and Tola, 2018). The wooden boxes with 30 kg – 50 kg holding capacity are too big and rough to protect the fruits packed at the bottom, which causes bruising and crushing during transportation (Mebratie *et al*., 2015). Bananas are transported mostly in baskets, plastic bags, or wooden boxes while avocado, mango, sweet orange and papaya – in sacks (Debela *et al*., 2011). In some parts of Ethiopia, jute sacks are used as packaging materials for fruits like avocado and mango, which have poor ventilation and cannot protect the fruits from compression and mechanical damage (Humble and Reneby, 2014). Leafy vegetables such as lettuce, cabbage, Swiss chard and spinach are packed using sacks made of local materials (Rahiel *et al*., 2018). All packaging materials in either its traditional or rudimentary form are expected to prolong the shelf life by maintaining the required quality of the products. As a result, farmer's products are faced with severe postharvest losses before they arrive at the consumer level (Bantayehu *et al*., 2018; Debela *et al*., 2011; Rahiel *et al*., 2018; Mebratie *et al*., 2015).

With the practice of timely and accurate harvesting, losses can be prevented to a large extent. The use of refrigerated car for cold storage, intercity transport and use of material for packaging can make moisture loss to be prevented. Farmers fresh produce are either sold in fresh or wholesale markets. At retail level, this fresh produce are either sold in unpackaged form or are tied in bundles. In this kind of market, the handling approach applied on fresh produce significantly reduces their shelf life if they are not sold quickly (Kiaya, 2014). The packing of tomato from olden days started with the use of broad green leaves, graduated to earthen pots and gourd, then weaved baskets, wooden crates, cardboard crates and boxes (Shankara *et al*., 2005). Among these packaging containers mentioned, only the weaved baskets are still commonly used today because they are cheap, easy to produce and readily available. Yet, the damages mete out on tomato fruits resulting from the use of weaved baskets are numerous, causing tomato damage which at the long run force farmers to sell their products at throw away prices.

Packaging is an essential factor for extending the shelf life and in reducing the losses observed in fresh fruit and vegetable. Hence, one main reason that account for losses in fruit and vegetable at the postharvest stages is the use of unsuitable packaging material and inappropriate packaging. The use poor quality packaging materials can accelerate spoilage of fresh produce as they are incapable of adequately protecting the fresh produce from damages. Regrettably in many parts of the world, packaging materials of low quality are widely used as a result of their low cost. Mainly in developing and under-developed countries, packaging container of poor quality are more commonly used. Some delicate fruit and vegetables packed in poly-sacks do cause severe damage to these

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delicate products. In some South Asian and Sub-Saharan African countries, it observed that 46% of their horticultural plants (crops) were packed inside cloth bundles or in big sacks as 31% of these horticultural crops were packed in open baskets while those that had no package were 8%. (Kitinoja and AlHassan, 2010).

Improper Transportation and Marketing

The transportation mechanisms used in Ethiopia for horticultural products are rarely trucks, animals (donkey, horse, or mule), shoulders and human backs (Emana *et al*., 2017; Dessalegn *et al*., 2016; Mebratie *et al*., 2015; Humble and Reneby, 2014). Most cases, farmers and traders use human labour or carts for short distance transport. This kind of transportation methods subjects the transported products to mechanical damage and overheat (Mebratie *et al*., 2015; Kuyu and Tola, 2018; Dessalegn *et al*., 2016). Agents in charge of collecting these products from farm use vehicles (Emana *et al*., 2015), however, do not have ventilation facilities provided in their cars for transporting highly perishable products like fruits (Dessalegn *et al*., 2016). Such transportation method, according to Hussen *et al*. (2013), contributes 5% to 20% of the total postharvest losses. Prolonging the transport time of fruit and vegetable without the use of cushioning materials, in uncovered vehicles (Dessalegn *et al*., 2016; Debela *et al*., 201), together with loading them with other harmful chemicals (Emana *et al*., 2017), overfilling and mixing the products from different sources (Kuyu and Tola, 2018) are the other important factors increasing postharvest losses in fruit and vegetable.

Generally in most parts of Ethiopia, poor access to market is a common problem (Teshome and Dürr, 2016). Lack of coordination among the producers to increase their bargaining power, lack of sufficient markets to absorb products, unsatisfactory pricing system, low price of the products at the market and lack of transparency in the market information are the other factors accountable for postharvest losses observed in fruit and vegetable (Emana *et al*., 2017). The absence of well-organized markets is highly noticed for retailers, producers and agents dealing with tomato produce (Emana *et al*., 2017: Debela *et al*., 2011). The supply of marketable vegetable is also significantly affected by distance from the market, inaccessibility to market information and farming experience (Woldesenbet, 2013).

Facts gathered from FAO (2011b; 2015) reports on major food losses observed in developing countries occur as a result of transportation, storage, managerial and technical limits in harvesting techniques, infrastructure, processing activities, packaging, lack of proper cooling facilities, and marketing system. On the other hand in developed

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

countries, postharvest loss relates mainly to quality standard requirements, consumer behavior and strict safety policies for fruits and vegetables.

Storage

A cold chain involve the continuous supply of a product at a certain temperature from production to consumption. The provision of a continuous cold chain in perishable food ensures that the product are not spoilt or in deteriorating state at the time of reaching the consumer. Effective cold chain management begins with pre-cooling and goes on with cold storage, cold transport and the display of a refrigerated state. The International Refrigeration Institute (IIR) confirmed that 23% of the perishable foods in developing countries were spoiled as a result of not using the cooler to cool their perishable foods (IIR, 2009). Some treatments after their application such in the case of sorting, cleaning and packaging on postharvest products, may warrant storing the products in periods which may range from few hours to few months. Giving room for storing these products, there will be improvement in time management, whereby consumption and marketing can be done leisurely. This method of storage is effective when the storage operation is carried out under suitable conditions; otherwise, serious losses may occur in the products. However, recall when these products are stored in their best condition, the consume-ability and quality of the products depend on the stage of the complete food supply chain. Storage is evenly provided throughout the complete supply chain from the production stage in developed countries. Combining cold storage with postharvest technology as in the case of a controlled atmosphere, shelf life of perishable foods considerably becomes longer. In developing countries, the absence of proper storage facilities was observed as the main cause of postharvest losses (FAO, 2013).

Transportation

In Nigeria, the packing of freshly harvested tomato fruit in locally made woven raffia baskets whereby they are been transported in open trucks makes them highly susceptible to mechanical damage as a result of inappropriate transport system and poor packaging container (Ebimieowei and Ebideseghabofa, 2013; Babarinsa and Ige, 2012). Ineffective and inefficient packaging system has become a disadvantage to the marketing of tomato as it has direct influence on cost, quality and overall postharvest losses.

The delivery of perishable foods with refrigerated vehicles is a standard practice in developed countries. Losses only occurs when the cooling system of the vehicle is broken down, when there is a delay in the loading/unloading areas or when an accident occurs. In developing countries, poor roads, absence of appropriate means of transport and inefficient logistics management prevent perishable foods from being properly

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

preserved. More so in these countries, unloading and loading operations are carried out by uneducated and unskilled workers who generally do not carry products carefully. This leads to mechanical damage of the agricultural products (Azabağaoğlu, 2018). Presented in Figures 10 (a) and (b) shows the pictures of the loading pattern of harvested farm produce on a vehicle from the farm to the market in a developing country like Nigeria.

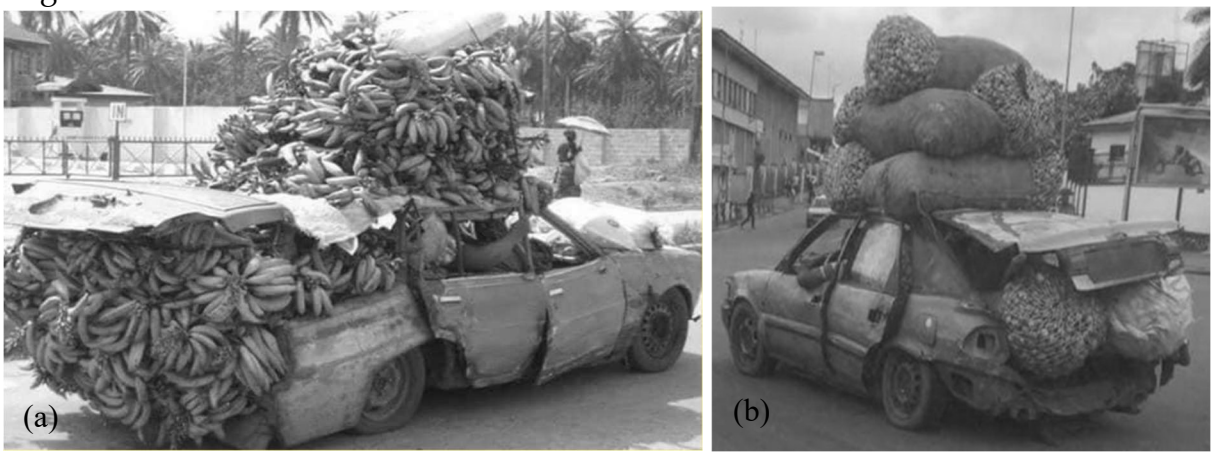

Fig. 10. Vehicle overloaded with harvested farm produce on a farm route in Oyo State, Nigeria. Source: Mijinyawa (2023)

Figures 11 (a) and (b) shows the nature of our poor roads leading to our farm site in Nigeria.

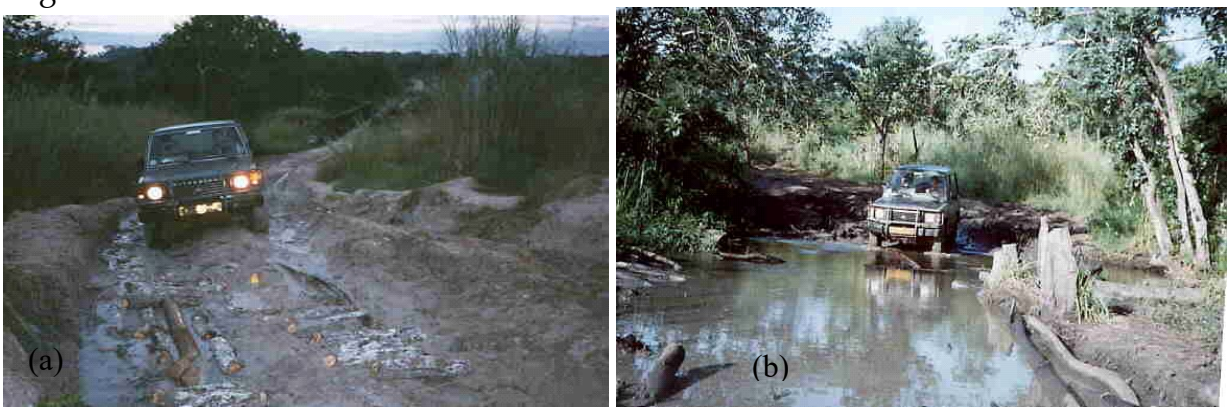

Fig. 11. Poor condition of our roads leading to the farm site in Oyo State, Nigeria Source: Mijinyawa (2023)

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Consumers' Waste

Consumption stage starts from the moment of purchase by the consumers and ends at the moment of consumption. At the consumption stage in the food supply chain for fruits and vegetables, considerable losses occur. Fresh fruits and vegetables contribute closely 50% of food wasted at the household level. According to FAO (2011b), fruits and vegetables accounts for 39% of the total household waste. In the study done by WRAP (2008), this figure reach up to 40% of the total household waste. The causes of consumers' waste were credited to lack of planning, poor home-storage management, over-purchasing, etc. Magnitude of consumers' waste depend on both material and socio-cultural factors like lifestyle, gender, home storage facilities and income (Porat *et al*., 2018).

Mechanical Injury

Mechanical damage seen in fruits and vegetables are caused by careless handling during harvesting, transportation, packing, storage etc. Some birds and insects are also responsible for the mechanical injury seen in fruits and vegetables (Alao, 2000; Hayatu, 2000; Yahaya, 2005). Damage caused by mechanical injuries like in the case of cracking and bruising of fruit and vegetable, in many cases, render them more prone to attack by organisms thereby increasing the rate of water loss and gaseous exchange (Alao, 2000; Yahaya, 2005).

The likelihood that fruits and vegetables coming across maximum mechanical damage during harvesting is very possible if proper means of harvesting and picking are not adopted. Hence, large quantity of tuber and root crops such as sweet potato, potato, etc. becomes damage and unmarketable due to faulty methods of digging them out. In fruits like apples, due to its soft outer skin are highly prone to mechanical damage. As a result, damage in fruits are also prone to pathological attacks like rotting (Alao, 2000; Yahaya, 2005). Gradually, fruits quality deteriorates giving room for the produce to be fetched at lesser price in the market. Processing operations such as abrasion, peeling, trimming, spillage and excessive polishing add to the product loss. The use of punctured containers and defective seals causes mechanical injury (Alao, 2000; Yahaya, 2005).

Microbial Action

Fruits and vegetables are prone to damage caused by microbial attack. Microbial spoilage are mainly caused by bacteria, fungi, moulds and yeast. However, during postharvest period the significant portion of losses observed in fruits and vegetables are attributed to diseases caused by bacteria and fungi. The succulent nature of fruits and vegetables makes them easily attacked by these organisms (Elias *et al*., 2010). Apart from the attacks

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mete out by these organisms on fresh fruits and vegetables, they also cause damage to canned and processed products. Several times, serious postharvest diseases occur rapidly and may cause extensive break down of the product, at times spoiling the whole package (Alao, 2000; Yahaya, 2005).

It is estimated that 36% of decay in vegetable are caused by soft rot bacteria. Also, rot in soft fruits caused by fungi are very destructive. Showing more concern for vegetables, naturally these infections come from contact with equipment, the field, storage environment and water used for cleaning the surface. Common pathogens causing rots in fruits and vegetables are fungi like Penicillium, Botrytis, Fusarium, Alternaria, Monilinia, Diplodia, Rhizopus, Phomopsis, etc. Pseudomonas, Ervinia just to mention a few are among the bacteria causing extensive damage. Fungi generally attacks more acidic tissue, but fruit and vegetable with pH level above 4.5 are attacked mainly by bacteria (Opadokun, 1987).

Environmental Factors

Environmental factors such as humidity, temperature, composition and proportion of gases in controlled atmospheric storage play an essential role in the postharvest loss of fruits and vegetables. High temperature and relative humidity favour the growth of postharvest decay organisms which result in serious damage to the produce. High temperature increases the rate of respiration in fruits and vegetables which subsequently result in the breakdown of the inner tissues. Similarly, high temperature and relative humidity increase the decay in fruits and vegetables. The decrease in temperature slows down the rate of microbial attack on different crops especially when it is below 5°C.

Chilling injury which is caused by low but not freezing temperature is mainly observed in tropical and subtropical fruits and vegetables. However, the symptoms caused by chilling injury may not be noticeable when the fruits and vegetables are held at chilling temperature but may become noticeable only when the fruits and vegetables are transferred to room temperature (37°C). In the postharvest environment, the role played by relative humidity is very important as temperature. The effects of relative humidity and temperature are mainly comparable and interrelated because the capacity of air holding moisture varies with the temperature. The aeration provided in storage containers or in stores has its bearing on relative humidity and hence indirectly on disease development. The effects of high relative humidity on decay is closely related with the effects of temperature and, for many fruits and vegetables, relative humidity near saturation results in lower decay losses only if the temperature is near O°C. The relative humidity below 90% does not however, permit micro-organisms to grow on the surface

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

of fruits and vegetables (Danladi, 2000). Hence, all fruits and vegetables have their own specific heat requirement during processing. Excessive or insufficient heat supply during processing, and un-desirable gaseous composition of controlled atmosphere of storage and improper cold storage temperature lead to physical damage due to tissue break down (Cho, 2008).

Inadequate methods involved in harvesting, storage, marketing facilities and transportation and legislation result in favourable conditions for the secondary causes of loss. Likewise, rough handling and inadequate harvesting equipment during harvesting results in bruising and increase the possibility of contact of the produce with the soil which may lead to contamination with micro-organisms (Yahaya, 2005). The extended time taken to carry out harvesting and grading in field exposes the fruit and vegetable to field heat for a longer period of time which may lead to faster senescence and reduction in shelf life. In addition, the use of improper machinery and equipment for mechanical harvesting may cause serious losses. For instance, mechanical harvesting of tomato has been reported to result in more cracking which amounts to 33% than hand picking which amounts to 10%. While harvesting of fruits and vegetables during rain or immediately after the rain creates conditions favourable for decay organisms. But harvesting during hotter part of the day results in faster senescence, shrivelling and wilting of fruits and vegetables as compared to produce harvested in the early morning or later in the afternoon (Yahaya, 2005).

Inadequate storage facilities available in the producing or marketing centres, exposes the produce to the natural causes of losses i.e. damage by transpiration respiration, micro-organisms and other biochemical reactions. While proper storage, however, creates conditions unfavourable to these factors. Transportation and distribution of fruits and vegetables are two important stages in postharvest loss. The mechanical and physical damage occur during transportation and distribution. Longer shipment and distribution period gives room for heavy losses (Alao, 2000; Yahaya, 2005). The earlier the harvested produce are consumed, the minimum is the loss incurred, as the period of senescence and organism invasion, multiplication and damage is shortened. This can be achieved if a well plan marketing system is set up. Therefore, the presence or absence of correct legal standards can affect the eventual retention or rejection of a fruit or vegetable for human consumption. But legal standards vary from country to country and are influenced by the economic status of the population and pressure of the population on the fruit or vegetable consumption. So strict legal standards will give better prices to farmers and superior quality to the consumers.

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Approaches Needed in Tackling Posthavest Losses in Fruits and Vegetables Grown in Nigeria

Harvesting Factors

Harvesting is considered one of the most important unit operation deciding the quality and storage life of produce that helps to prevent huge amount of losses witnessed in fruits and vegetables. The main goal of practicing a good harvesting culture is to ensure maximizing crop yield, minimizing losses and quality deterioration of the crop and to also keep the harvested produce in good condition until the time it is consumed or sold off. Maturity standards, harvesting tools, harvesting containers, harvesting practices, transport and field packing conditions to the packing house are key factors that affects product quality and postharvest losses.

In ensuring that proper harvest is carried out, the setting of an optimal maturity date for the fruit and vegetable becomes important. The time when fruits are ready to be picked is referred to harvest maturity. A lot of studies have been carried out in establishing the ideal time of harvest for fresh fruits and vegetables also putting the minimum or maximum concentration of the nutritional and functional constituents, and the correlation that exist between them into consideration (Fawole and Opara, 2013; dos Santos Neto *et al*., 2017). Rahman *et al*. (2016) carried out a study that revealed harvesting strawberries at two-third maturity stage was found suitable for keeping safe at room temperature up to 3 days. Fruits that are one-third matured produces a longer shelf life at room temperature, however, the quality degraded. The collection of fruits that are matured is also important as the produce needs to be harvested and gently handled. Untimely harvesting; rough handling; lack of appropriate and/or poorly-designed harvesting containers, harvesting tools and equipment may be the causes of losses (Kiaya, 2014).

Solidity, shape, size, colour, fruit opening, firmness, tenderness, textural properties, juice content, nutrient composition such as dry matter content, starch, sugar, oil, titratable acidity and soluble solid are examples of maturity induce for some fruits and vegetables. Quite a few parameters such as acidity levels, sugar content and pH are commonly used for monitoring grapes maturity level. The use of soluble solids concentration (SSC) of 14 to 17.5% for determining harvesting time depends on the production area and cultivar. For the black and red coloured varieties, there is a minimum colour requirement (Mencarelli and Bellincontro, 2005). Tomato fruit age, colour and structure, surface morphology, internal colour and structure and seeds slipping when fruit is cut, or green colour turning pink are some maturity indices which correlate significantly with

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

nutritional and physico-chemical characteristics including total titrable acidity (TTA), total soluble solids (TSS) and protein content (Okiror *et al*., 2017).

Temperature management is an important factor after harvesting for the extension of shelf life and postharvest losses reduction. Several methods are used for the cooling of fresh produce after harvest like evaporative cooling, hydro cooling, forced air cooling, serpentine forced air cooling, room cooling, etc (Elansari, 2009). The harvesting method used also determines the quality of fruit and vegetable. Irreparable damage observed on horticultural produce can be as a result of using poor harvesting practices. Standardizing harvesting techniques is therefore needed for each and every fruit and vegetable in minimizing damage at harvesting time. It is good to note how important it is to avoid unnecessary bruising, wounding, crushing or damaging of produce by equipment or containerizing in reducing mechanical damage. Harvesting method which could either be manual or mechanical and perhaps combined are used as harvesting methods. Mechanical harvesting where several number of devices are used for harvesting the produce is usually carried out at the commercial scale level. Pickers used during harvesting should be carefully used by gentle cutting, digging, picking and handling or pulling the fruit or vegetable from the plant to minimize waste and damage. Manual harvesting is applied in a situation where various stages of maturity are noticed within the crop, while mechanical harvesting is only applied when the crop is harvested at one time (FAO, 1989).

Best Storage and Transportation Practices

In the marketing channel, transportation is often the most costly factor noticed. The value of the product, perishability and distance are factors to be considered when selecting the choice of the transportation method to use for fresh fruit and vegetables. The globalization of fresh products trade requires the need for a better long distance transportation system in preserving the quality of the product. Multiple steps are required for the transportation of fresh produce between the points of source to the point of consumption. A number of links are been provided through transportation from the field to the consumer in the movement chain of fresh fruits and vegetables.

During transportation the produce should be kept at optimum conditions. Air circulation systems and adequate temperature control systems are the most important means in ensuring the quality preservation of perishables (Vigneault *et al*., 2009). Cold chain, according to Negi and Anand (2014), is the logistics system providing ideal condition to perishable goods from the point of source to the point of consumption through thermal

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

and refrigerated packaging methods and logistical planning in protecting the quality and increasing the shelf life of these shipments.

During transport and storage, the shelf life depends mainly on temperature deviations (Hertog *et al*., 2014). Temperature is the key environmental condition that affects the quality of the produce as it has strong effect on the rate of biological reaction. Other factors affecting the quality of produce, according to Vigneault *et al*. (2009) are physical injury and stress, environmental humidity and water loss, initial quality, mixed loads, atmospheric gas concentration and transport conditions (surface road conditions, time of the day, etc.)

During transportation, the produce is prone to physical or chemical damage as well as microbial contamination. As a result, it is critical that an ample food safety and quality programme give adequate attention to transportation environment management (www.LSUAgCenter.com). The transport of each variety of fresh fruit and vegetables has widely differing requirements for safe preservation. Whatever the method used, the principles of transport are the same:

i. Loading and unloading should be as careful as possible;
ii. Transition time should be as short as possible;
iii. The product should be well protected in relation to its suitability to physical injuries;
iv. Overheating should not be permitted - maintaining the correct temperature throughout the period of transport;
v. Provide ventilation and extraction and air supply;
vi. Maintain proper relative humidity - water losses by the produce should be restricted to the minimum;
vii. Whenever possible, the transport vehicle should not stop under the sun, and the produce should be protected with a cover; and
viii. Providing shelter from sun and rain at loading and unloading areas (Paltrinieri, 2016).

Storage is the art of preventing deterioration by keeping the quality of agricultural materials for a specific period of time that is beyond their normal shelf life (Kiaya, 2014). In storage, there is no improvement on the food produce but its basic aim is to slow down the ageing process caused due to disease decay, moisture loss and respiration. Storage of fruits and vegetables are essential in extending food availability period and avoiding malnutrition problem. However, the scientific principles is what this technique is purely based upon. Hence, one should understand the basic principles behind the successful

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

storage of fruits and vegetables (Khan *et al*., 2017). In ensuring the successful storage of horticultural produce, a wide range of storage structures are used throughout the world to achieve this. Generally, this storage structure has to be kept cool (refrigerated, or at least ventilated and shaded). The produce put into this storage structure must have high initial quality (Kiaya, 2014).

Controlled atmosphere storage (CAS) which is meant to control the gaseous atmosphere in a store has proven to improve the maintenance of their postharvest quality over and above the extensions gained by ordinarily controlling humidity and temperature. The huge benefit attached to the use of controlled atmosphere storage is related to food deterioration reduction from pests and diseases, since at higher level of CO_2 have negative impact on the growth and development of microorganisms. Therefore, having fruits and vegetables stored under a controlled atmosphere may significantly reduce the amount of postharvest chemicals used for their protection against microorganisms and insect (Thompson, 1998).

Zero energy cool chambers (ZECC) as the name applies are systems adopted for storage based on direct evaporative cooling principles. The main gain of this on-the-farm low cost cooling technology is that there is no need for electricity or power to operate it while the materials needed for its construction such as sand bamboo, bricks, etc. are cheaply, easily and readily available (Khan *et al*., 2017). Lawrence and Tiwari (1989) reported that an evaporative cooling system operating on 50% efficiency, have significant effect on a non-air-conditioned room temperature as well as shaded rooms. Taha *et al*. (1994) designed and evaluated an evaporative cooler under different conditions and concluded that ambient temperature reduced by 10–13°C.

Packaging in order to Reduce Post-Harvest Losses and Wastes

Fruits and vegetables in their fresh form at ambient temperature have limited shelf life ranging from a few hours to few weeks. They do have living organisms that makes them continue their biochemical and physiological activities even after harvest. Contained in fresh produce are 80 - 90% of moisture or even more and equilibrate humidity as high as 98%. For this very reason, transpiration (rapid drying) occurs under normal atmospheric conditions. This causes shriveling and wilting due to the shrinking of cells. The present postharvest loss observed in fruits and vegetables could be considerably reduced using improved packaging (Verma, 2000).

Fresh produce of different crops need different types of packages depending on their physiology, anatomical and physical (mainly respiration, ethylene production rate and

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

transpiration) nature and susceptibility to microbial decay. Ventilation, relative humidity and temperature do play an important role in the determination of the fresh produce postharvest life. Therefore, the packaging requirements for fresh produce can be summarized as: (1) protection against bruising and physical injury; (2) protection against microbial contamination and deterioration; (3) slowing down respiration rate, delay ripening and increase storage life; (4) protection against moisture/weight loss; (5) controlling ethylene concentrations in the package; and (6) providing ventilation for respiration and exchange of gases (Ahvenainen, 2003; Ahmad and Siddiqui, 2016; Ramaswamy, 2014).

Table 1. Lists of packing options for reducing food waste during the post-harvest period

Possible reasons for fresh fruits and vegetables losses	**Potential packaging solutions**
Compression of overfilled packages causes bruising.	The usage of shallow containers with a smooth surface the mass of the product in the container has decreased.
Transport-related vibration damage (roller bruising).	Transport packaging optimization for exporting Retainers, individual packing, and padding are all used.
Injuries caused by impact.	The use of hard boxes with each item cushioned.
Injuries caused by puncturing.	The usage of sturdy containers with good grips is recommended. Smooth containers and handling facilities are used.
Withering or moisture loss.	Improved and innovative methods like modified atmosphere packaging and packing materials are being used
Growth caused by microbes.	Irradiation and modified atmosphere packaging therapy combined.
Insufficient airflow.	Respiration was enabled through the use of packing materials.

An important part of the whole chain accounting for reduction in food waste is packaging. It plays a serious role in the extension of the shelf life of the fresh produce and it also protects the fresh produce during the stages of postharvest. Food losses can be reduced through the design of better and smarter packaging to keep food fresher for longer time. This is to say that the packaging of fresh fruit and vegetables reduces food losses. Therefore, the design of appropriate packaging systems are needed in reducing food losses. Presented in Table 1 are the packaging solutions needed for minimizing food

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

waste during postharvest. Examples of problems causing food losses along food supply chains and potential packaging solutions are also contained in Table 1.

External factors which attack fruits and vegetables at certain level may be protected by using the packaging materials used for traditional packaging methods. Advanced packaging systems and appropriate packaging materials need to be developed in reducing postharvest losses and increasing the shelf life of fresh fruit and vegetables. Truly, there exist various advanced packaging systems for the packaging of fresh fruits and vegetables. Smart (intelligent) packaging technologies, active packaging and modified atmosphere packaging are considered the most important advanced packaging technologies available. They are innovative concept that refers to the modification of atmosphere within package or the integration of bioactive compounds into packaging systems with the goal of maintaining the quality or extending the shelf-life of fresh produce. For instance, using a well-designed modified atmosphere packaging system, the shelf life of the packaged products can be extended by 50% to 200% (Siddiqui, 2016). The shelf life pattern of some products under modified atmosphere packaging technology and normal weather conditions is shown in Table 2. Despite noticing the tremendous contribution of advanced packaging systems on the shelf life of fresh produce, their uses for industrial application is not very common (Siddiqui *et al*., 2018).

Table 2. Shelf life of certain fresh produce in modified atmosphere packaging

Fresh produce	**Shelf life in modified atmosphere packaging**	**Shelf life in natural atmosphere**	**Source of information**
Cherry	30 – 40 days	7 – 14 days	Padilla-Zakour *et al*. (2007)
Fig	28 days	Less than 14 days	Alturki (2013)
Grape	7 days	4 days	Deshpande and Sharkla (2006)
Tomato	60 days	30 days	Ali and Thompson (1998)

Coating

The importance of good postharvest practices in minimizing postharvest losses cannot be overemphasized. During postharvest, there exist different mechanisms for controlling deterioration of fruits, extending their shelf life and also maintaining the quality of which coating is one of them. Coating can be described generally as a thin layer that covers something. Guilbert (1986) in his own definition defined edible coatings as a thin application of material forming a protective barrier around an edible product which can be consumed along with the coated product. The essence of coating is for protecting a

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

product from foreign organic matters that may lead to deterioration or loss of quality in any way. The purpose of coating in fruits is mainly for safe transport, handling and storage. Fruit coating just done after harvesting process is becoming popular (Cohen *et al*., 1990). Though controlled atmosphere (CA) storage has proven to extend the shelf life of fruits such as mango (Bender *et al*., 2000), it is very expensive. The use modified atmosphere (MA) storage was reported to slow the ripening process in some fruits but was often accompanied by high CO_2 and off-flavour (Gonzalez-Aquilar *et al*., 1997).

Coatings in time past have been used to improve appearance and to conserve food products. Wax coatings which are the common ones used for fruits were reportedly used in China years back. Edible coatings are used for creating a modified atmosphere and for reducing weight loss, water loss and respiration rate and making the fruits to become disease-resistant during handling, transport and storage (Baldwin, 1994). Agbo *et al*. (2018) carried out a study in Nigeria with the aim of investigating the effect of cassava starch and beeswax coatings on the shelf life of avocado and mango fruits. The specific objective entail assessing and comparing the effect of different thicknesses of cassava starch and beeswax coatings on weight loss of avocado and mango fruits. The coating application used for this same study involve dividing the fruit samples into four groups, with respect to their coating levels. The first group known as control had no coating thicknesses applied to the fruits, while the other three groups had the application of coating thicknesses of 0.96 mm, 1.92 mm and 2.88 mm. A vernier caliper was used to measure the thin layers of the coatings applied to the fruits. Application of the coating was done by dipping the fruit samples in cassava starch and beeswax emulsion until the three levels of thicknesses were attained. After carrying out the experiment, results obtained revealed that the two coating materials (Cassava-starch and Beeswax) at the three coating thicknesses applied on avocado and mango fruits were significantly different from that of control but not significantly different from each other. The application of the two coating materials examined shows that the choice of coating material to be used should be based on availability and cost and not on efficiency and performance since both materials have nearly the same effectiveness. Coating thickness, however, has significant effect where that of 2.88 mm coating thickness gave the best protection against weight losses.

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Ways Forward and Conclusion

Ways Forward

Several approaches have been discussed to tackle post-harvest losses observed in fruits and vegetables. As a result of these approaches, the following ways forward are presented as the only way out in reducing or eliminating post-harvest loss observed in fruits and vegetable grown in Nigeria. These ways forward include:

1. Adequate storage facilities that can preserve fruits and vegetables grown in Nigeria needs to be provided.
2. The Nigerian government needs to adopt the standard practice of making use of refrigerated vehicles for the delivery of perishable foods such as fruits and vegetables.
3. The lack of appropriate transport means, inefficient logistics management, poor road networks, use of unskilled and uneducated workers for loading and unloading operations are critical factors responsible for allowing perishable products from being properly preserve. The Nigerian government needs to look deeply into the critical factors itemized.
4. Majority of the fruits and vegetables produced in Nigeria comes from the rural areas where the roads leading to them are poor. This calls for their repair throughout the country as findings have made us to know that these poor roads are responsible for the increase in food losses during the transportation process from the farm house to the market.
5. Farmers should note the appropriate time for harvesting of fruits and vegetables as losses can largely be prevented if timely and accurate harvesting are put into effective use.
6. The use of refrigerated car should be encourage for intercity transport as this will give room for the cold storage of the fruits and vegetables being transported during delivery.
7. The use of appropriated packaging material that can prevent moisture loss in fruits and vegetables should be encourage by the Nigerian government as they see into how these materials can be made available to all farmers and processors of fruits and vegetables at affordable prices.
8. Farmers and processors should be made to realize that the earlier harvested food produce are consumed, the minimum losses incurred, as the period of damage, multiplication, senescence and organism invasion are shortened. A well planned set up marketing system is the only way to achieved it.

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

9. Farmers during harvesting operation should carefully avoid anything that can lead to the causes of mechanical damage observed in fruits and vegetables grown in Nigeria.
10. Harvesting techniques need to be standardized for all fruits and vegetables grown in Nigeria in minimizing damage observed at the time of harvest. Henceforth, it is necessary note the importance of avoiding unnecessary crushing or damaging, bruising and wounding of produce by equipment or containerizing to reduce mechanical damage.
11. Due to tissue break down resulting from un-desirable gaseous composition of controlled atmosphere of storage, excessive or insufficient heat supply during processing and improper cold storage temperature make fruits and vegetables to be subjected to physical damages. Therefore, there is need to know the specific heat requirement for each of the processing stage involved during the processing of fruits and vegetables.
12. Legal Standards of our country needs to be looked into as the adoption of a correct legal standard can affect the eventual rejection or retention of a fruit or vegetable for human consumption. However, legal standards approved for use varies from country to country which are influenced by pressure and economic status of the population consuming the fruit or vegetable. The use of strict legal standards will give better prices to farmers and superior quality to the consumers.
13. The aspect of food grading should properly be looked into. Buckets made of plastic material in their smooth form and without having sharp edges are suitable containers for the harvesting of fruits that are easily crushed, such as tomatoes. Depending on the type of fruit or vegetable grown, the appropriate harvesting container should be selected.
14. Storage structures needs to be taken into consideration as the produce put into storage must be of high initial quality/
15. The storage of fruits and vegetables under a controlled atmosphere should be promoted and practiced within the country as the amount of postharvest chemicals used for their protection against insect and microorganisms will significantly be reduced.
16. The use of zero energy cool chambers (ZECC) which is based on direct evaporative cooling principles which offers on-the-farm low cost cooling technology should be promoted and encouraged for use in the country
17. Local coating materials such as cassava starch and beeswax should be applied to freshly harvested avocado and mango fruits for the purpose of achieving good storage, good handling and safe transport of the produce.

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Conclusion

The intake of fruits and vegetables have great significance to human life especially during the COVID-19 period where many lives were lost throughout the world. The World Health Organization (WHO) which kept record of daily mortality advised the people in the world to allow for the more intake of fruits and vegetables to dominate our meals on daily basis as the only way to boost the human immune system which will help to prevent the body from contracting the deadly virus pending the time research is ongoing to produce a strong and effective vaccine that can combat the virus. Because of the great importance both crops offer the body system, it became very necessary to take a deep look into how postharvest losses observed in fruits and vegetables can be eliminated. Facts gathered from various studies, shows that the issue of harvesting, material handling, transportation, controlled environment among others should be handled properly well so that postharvest losses observed in fruits and vegetables could be eliminated or reduced drastically to the barest minimum.

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