POSTHARVEST HANDLING AND VALUE ADDITION IN VEGETABLE PRODUCTION

Ofor, M.O., Obiefuna, J.C., Ibeawuchi, I.I., Ihejirika, G.O., Okoli, N.A., Alagba, R.A. and Dialoke, S.A.
Department of Crop Science and Technology Federal University of Technology, Owerri
P.M.B. 1526 Owerri, Imo State
Corresponding Author: mariofor2002@yahoo.com

ABSTRACT
The actualization of food security globally can only be initiated when deliberate actions are taken to protect, process and/or preserve harvested food produce; to increase food availability to the growing world population, while maintaining the quality and safety of fresh produce. The inclusion of vegetables and 'fruit vegetables', which are very important for human nutrition and health in daily diets, along with exercise and weight control, have been found to have a remarkable ability in the prevention of most diseases. The highly perishable nature of fresh horticultural produce (especially with its high water content), makes them susceptible to postharvest losses ranging from 30 – 50% in fruits and vegetables. Causes of postharvest losses in vegetable production arise from metabolic, developmental and mechanical factors; environmental factors like temperature, relative humidity and atmospheric composition; biotic factors like diseases, insects and social-economic factors like transportation and marketing. The essence of storage is to retain the fresh state of the product. Strategies aimed at achieving value addition in fruits and vegetables include fermentation, drying, blanching, storage in containers (buckets and clay pots) and storage in a fruit shed. This review highlights various causes of postharvest losses in vegetable production and strategies to successfully combat this trend.
Key words: Postharvest, handling, vegetables, production, value-addition.

Introduction

Food security is a major concern in growing nations like Nigeria, as well as the entire developing world. But, food production must clearly increase significantly to meet the future demands of an increasing and more affluent world population (FAO, 2011). Actualizing the above means that harvested produce must be protected, processed and/or preserved to ensure food for all. According to FAO (2003a), the reduction of post-harvest losses can increase food availability to the growing world population, decrease the area needed for production, and conserve natural resources. Strategies aimed at preventing these losses include the use of proper post-harvest handling practices in order to maintain the quality and safety of fresh produce. The FAO (2008), states that post harvest handling would include a range of processes such as grading, sorting, washing and packaging. This would also include the transport of fruits and vegetables and storage before processing. Different types of fruit and vegetables require different forms of handling and care during harvest, storage and transport.

Vegetables are living, breathing parts of plants and contain 65 to 95% water. Once harvested their internal food and water reserves decline over time and vegetables deteriorate and rot. Anything that increases the rate at which food and water reserves are used up increases the rate of deterioration. Fruits and vegetables provide an abundant, cheap source of fibre and several vitamins and minerals. In general, they have the highest nutritional value when eaten fresh, although an exception may be fermented foods, in which the process of fermentation can increase the content of B-vitamin (Jobling, No Date).

The common leafy vegetables grown in West Africa, according to James *et al.* (2010), are the African garden eggplant, amaranth, cabbage and lettuce. There are two common types of African garden eggplant, which are both indigenous to Africa - *Solanum macrocarpon* and *S. aethiopicum*. *S. macrocarpon* is grown mainly for its succulent leaves, but in some communities the bitter fruits are also eaten. The *S. aethiopicum* is mainly cultivated for its fruits. The edible parts of both *S. macrocarpon* and *S. aethiopicum* are nutritious and contain carbohydrate, cellulose and calcium, fat, protein and water.

Amaranth (*Amaranthus cruentus*) is grown for its leaves which are rich in beta-carotene, calcium, iron, protein, vitamin C and water. Cabbage (*Brassica oleracea*) is native to temperate regions of the world. It is called the head cabbage because the immature leaves cluster up into a spherical ball or 'head', which is the part normally marketed and consumed. James *et al.* (2010) stated that the leaves contain some carbohydrates, proteins and various essential elements e.g. calcium, iron and vitamin C as well as water. Lettuce (*Lactuca sativa*), is however, indigenous to the Mediterranean region and has four varieties. The plant is cultivated for its succulent leaves which are used in salads. Lettuce leaves contain a high proportion of water with some calcium, proteins and vitamins.

Vegetables can be classified in different ways. However, the most important classifications used in postharvest physiology are the classifications according to the use of different plant organs; sensitivity to cold

during the postharvest period and intensity of metabolism i.e. ethylene production (Kader, 1982; 1983). Some examples of vegetables, classified according to the plant organs used are shown in Table 1. Typically, root vegetables and leafy vegetables are more commonly known. However, the term *immature fruit vegetable* suggests that the plant parts are harvested before they reach the full maturity stage and if harvested otherwise, i.e. at the full maturity stage, they might not be useful for the purpose for which they are meant. Figure 1, also shows different types of vegetables.

The classification according to the intensity of metabolism can be defined as ethylene production and it is significant mainly for fruit vegetables. Here, fruits may be grouped as climacteric or non-climacteric fruits (FAO, 2003b). In very general terms, climacteric fruits can be picked from the tree at full size or maturity but before it is 'ripe' and allowed to ripen off the tree while non-climacteric products do not ripen after harvest and therefore they should be picked when they are fully ripened. There is usually an increase in flavor quality, juice, sugars as well as other factors. Climacteric crops generally produce more ethylene than the non-climacteric crops. More technically, in climacteric fruits, 'ripening' is controlled by the fruits production of ethylene and a significant increase in CO_2 production, while non-climacteric fruits produce little or no ethylene and no large increase in CO_2 production, i.e. these fruits tend to maintain whatever quality they had at harvest without many beneficial changes.

Knowledge about the ripening of non-climacteric fruit remains poorly understood. Some varieties of different fruit may exhibit a change in ripening when picked but still be mostly non-climacteric. Some literatures suggest that some grape varieties are climacteric while some citrus are considered better flavoured after chilling or storage. Table 2, shows the classification of fruit vegetables according to the intensity of metabolism or behaviour during ripening (climacteric and non-climacteric).

Importance of Vegetables

Vegetables and 'fruits vegetables' are very important for human nutrition and health. Diseases of the heart and some types of cancer can be prevented with diets low in fat and rich in fruits and vegetables; along with exercise and weight control. Many phytochemicals found in fruits and vegetables have a remarkable ability to disrupt the formation of tumors and in the prevention of other diseases (FAO, 2008a).

Phytochemicals have several modes of actions, but many of them act as antioxidants. The antioxidant action of most fruits and vegetables, which has a positive health effect on man stems from its phytochemical content. Vitamins C and E are potent antioxidants. They can inhibit the synthesis and action of free radicals. About 90% of the sources of vitamin C in the human diet are from fruits and vegetables. Several polyphenols, found in many plants are very important for health and several of them are antioxidants.

Fruits and vegetables are important sources of vitamins. Table 3, shows some of the vitamins present in different types of vegetables and examples of plants where they are found. Vitamins C and B are not stored in the human body and must be replenished daily. However, Vitamins A, E and D can be stored in the human body. Some of the postharvest factors that can cause losses in vitamins include high temperature, high oxygen content and mechanical injury.

Fruits and vegetables contain several pigments that have positive health effects. They may be classified into four groups namely - chlorophylls, carotenoids, flavonoids and betalaines. According to FAO (2008a), several carotenoids have been shown to act as antioxidants, and some of them are pro-vitamin A. For instance, lycopene (a carotenoid found in tomato) is linked with several positive effects including the reduction of the risk of prostate cancer. Betacarotenes, found in many plants such as carrots, are pro-vitamin A. Several flavonoids have been associated with the reduction and/or prevention of several diseases, including some types of cancer.

Many fruits and vegetables are also good sources of dietary fibers, which are linked to several positive health effects like a reduction in the risk of colon cancer, hernia, diabetes, obesity and constipation. They may also contain about 0.1 to 4% of the total minerals needed in man. These include Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sodium (Na), Chlorine (Cl), Sulphur (S), Iron (Fe), Copper (Cu), Cobalt (Co), Manganese (Mn), Zinc (Zn), Iodine (I) and Molybdenum (Mo), (FAO, 2008a).

Postharvest Losses in Fresh Horticultural Produce

Fresh horticultural produce are highly perishable with some estimates suggesting a postharvest loss of 30 – 50% in fruits and vegetables. The losses occur due to poor pre-production and postharvest management as well as lack of appropriate processing and marketing facilities. According to Atanda *et al*., (2011), these losses have several adverse impacts on farmers' income, consumer prices and nutritional quality of the produce.

The problems of postharvest food losses in developing countries was given a focus by the United States National Academy of Science in 1978, who stated the need to give consideration to losses in food products other than cereals; particularly roots and tubers, fruits and vegetables (Atanda *et al.*, 2011). Typical postharvest losses in vegetable and fruits, roots and tubers range from 10 – 25%, but it is estimated that

at least 5% and as much as 100% of a given crop can be lost between the field and the consumers (NAS, 1987). According to Babarinde and Fabunmi (2009), fruits and vegetables are highly perishable due to high water content and are thereby susceptible to rapid deterioration soon after harvest, which necessitates their being properly packaged and stored, if not consumed immediately. Traditionally, storage materials such as calabash, earthen-ware pots, baskets etc. have been used for the purposes of extending shelf-life few days after harvest (Kordylas, 1991).

Causes of Postharvest Losses in Vegetable Production

According to FAO, (2008), there are many causes for postharvest losses during vegetable production. These are highlighted as follows:

i. Metabolic factors: All fresh horticultural crops are made up of living tissues. They are highly active and undergo high metabolic activities such as tissue respiration. The natural process of respiration involves the breakdown of food reserves, and the aging of these organs, and thus to food losses.

ii. Developmental factors: These may include undesirable activities like sprouting, rooting, seed germination, which may lead to deterioration in quality and in nutritional value.

iii. Mechanical factors: Major losses in fresh horticultural crops are due to mechanical damage and rough handling. Inappropriate packages and packaging materials; overfilling and lack of good lining materials may increase mechanical damage.

iv. Diseases: As a result of physical injuries, mechanical bruises and compression, many decay organisms gain entrance into horticultural crops leading to deterioration and losses.

v. Insects: Many insects can infest horticultural crops, especially before harvest resulting in significant losses.

vi. Temperature: Temperature management is very important when handling fragile produce like vegetables. High temperatures in the tropics and the lack of refrigeration can lead to significant quantitative and qualitative losses. Low temperatures (0-10^{o}C) can cause chilling injury and losses to several chilling sensitive commodities. Exposure of produce to sun may however enhance wilting and decay.

vii. Relative humidity: Low relative humidity promotes water loss and shriveling, and increases qualitative and quantitative losses. The creation of artificial, high humidity micro-environment through the use cellophane packaging can help save some of these fragile horticultural crops.

viii. Atmospheric composition: The high content of O_2 in the atmosphere increases ethylene production and respiration. The reduction of O_2 and the increase in CO_2 concentrations in the atmosphere reduce metabolic activity and deterioration. There is therefore the need to have knowledge of controlled atmospheres, especially as it relates to the specific needs of individual crops.

ix. Transport: Losses in horticultural vegetables during transport, especially when not refrigerated, can be very significant, due to mechanical damage, lack of use of refrigeration, use of inappropriate packages, inadequate air flow and circulation, etc.

x. Marketing: Losses are common during marketing, especially when fresh commodities are exposed to heat. This is most pronounced in the developing countries in the tropics. Vegetables may be exposed to high ambient temperatures; produce are displayed on the ground in the markets and undesirable elements may contaminate the produce.

Reduction of Postharvest Losses

Postharvest losses can be reduced through the following processes:

- Harvest products at optimum maturity, and adequate (cool) time.
- Protect the product from exposure to the sun after harvest.
- Avoid mechanical injury during harvesting.
- Use of pre-cooling and refrigeration.
- Use of appropriate high relative humidity during storage and transport.
- Avoid infestation with diseases and insects, and use adequate control measures.
- Use appropriate packing and packaging systems.
- Transport products adequately.
- Store the product properly at the appropriate conditions.
- Adequate handling (avoid rough handling) of the produce during all the postharvest chain.

Factors Affecting Storage of Vegetables

Loss of water: The commercial and physiological deterioration of vegetables after harvest is mostly affected by loss of water through transpiration. This loss of moisture adversely affects the appearance, texture, flavour and weight of the products. The softening of the tissues caused by loss of turgidity is the most noticeable effect of moisture loss.

Respiration and metabolism: Long after harvest, vegetables continue to respire because they are

living commodities. The act of respiration requires the use of the stored food, leading to its depletion and consequently the loss of quality. Hence, storage life of vegetables is influenced by rate of respiration and is associated with biochemical activity.

Storage of Vegetables for Value Addition

According to Ofor (2011), the main objective of storage is to retain the fresh state of the product. Deterioration following harvest is caused by a number of factors but the principal physiological factors are transpiration and respiration. Most fresh vegetables retain their top quality for only a few days. All green vegetables of high water content are best consumed when fresh. When allowed to stand long after gathering, the vegetables become wilted and tough through loss of moisture. The flavour is also impaired due to enzymatic action and the conversion of sugar to starch (TNAU, 2008). Fresh immature vegetable deteriorate faster in storage than mature vegetables particularly roots and tubers and bulbs. The rapid rate of respiration of most vegetables may be one of the reasons for their short storage life.

According to James (1985), storage may serve one or all of the following roles:

i. Slow down the biological activity of product by maintaining the lowest temperature that will not cause freezing or chilling injury and by controlling atmosphere composition.
ii. Slow growth of micro organism by maintaining low temperatures and minimizing surface moisture.
iii. Reduce product drying by reducing the difference between product and air temperature and maintaining high humidity in the storage organ.
iv. The storage facility may also be used to apply special treatments, for example, potatoes and sweet potatoes are held at high temperature and high relative humidity to cure wounds sustained during harvest.

Extending the shelf life of most fresh green vegetables may be achieved by covering them in containers or plastic bags in the refrigerator; that way, they are kept fresh and crisp. Not all vegetables require washing before storage e.g. onion and irish potatoes. According to TNAU (2008), vegetables that require washing before storage should be drained thoroughly because too much moisture can increase the possibility of a spoilage and decay. Seeds such as cowpeas can remain fresh longer if left in the pods. Tubers and bulbs must be cured following harvest before they can be stored in a cool place, in the absence of refrigeration.

Strategies for Achieving Value Addition in Fruits and Vegetables

Fermentation: Fermentation is a cheap and energy efficient means of preserving perishable raw materials. When harvested, fruit and vegetables undergo rapid deterioration, especially in the humid tropics where the prevailing environmental conditions accelerate the process of decomposition. According to FAO (2003b), lactic acid bacteria develop during the fermentation of raw vegetables, transforming the natural sugars present and the added sugar into acid. The characteristic flavour and texture of fermented vegetables is produced by the action of lactic acid bacteria. It is a technique that has been employed for generations to preserve food for consumption at a later date and to improve food security.

Drying: Fresh fruits and vegetables are mostly preferred by humans. However, in areas where irrigation is not possible; production and availability of fresh products are limited to the rainy season (Fabre and Mihailov, 1985). During the dry season, people are compelled to eat products preserved in various ways. Drying is a prominent means of preserving surplus food products for the off-season. According to Ofor *et al.* (2012), drying reduces moisture thereby reducing weight, prolongs the shelf-life, preserves nutritional quality of foods and reduces the risk of contamination by toxic moulds etc. However, the traditional open-air drying on the ground is known to suffer from various inadequacies such as infestation by insects, contamination by dirt and by rodent and bird droppings; and rewetting. Although this method is cheap, it often results in a poor quality dried product. Drying has also been improved through the use of solar dryers built specifically to trap solar energy in custom-built units, for the sole purpose of drying food materials in a safe and hygienic environment.

Storage in Buckets: Okon *et al*. (2004) highlighted how pumpkin and amaranth leaves can be preserved, by bunching up and dipping them in a bucket of water; with the tips of the stems steeped in the water. Waterleaf and bush okra are not dipped but rather sprinkled with water. The leaves are then covered with a thin polythene sheet, tied to the bucket and kept in a cool place. Daily, the polythene sheet is removed temporarily and water sprinkled on the leaves. This method keeps the leafy vegetables fresh for about 6 days.

Storage in Clay Pots: Vegetables can be stored using the clay pot method. Clay pots of convenient sizes are washed clean and placed on a firm support. At the bottom of the pot is placed a layer of sterilized (boiled) wet jute bag and wire gauze on top of it. On top of the wire gauze, the washed vegetable leaves are placed and covered with another layer of wire gauze and a second jute bag. This bag is kept moist at all times. In the event of transporting the vegetables to long distance markets, bunches of the leaves are wrapped in a clean

or sterilized wet jute bag that is kept wet. Alternatively, the vegetable leaves can be placed in vegetable baskets made from raffia or other flexible plant material with smooth surface, with the inside completely lined with wet jute bags.

Blanching: Blanching or scalding is a method of preserving fruits, fresh vegetables and root vegetables, whereby the cut pieces can be immersed in a bath containing hot water (or boiling water) for 1 – 10 minutes at 91 – 99^0C, to reduce microbial levels; and partially reduce enzymatic activity that could lead to deterioration. The heating time will depend on the type of vegetable product processed (FAO, 2003b). Before freezing, vegetables can be cooked briefly in boiling water, a process known as blanching, to inactivate enzymes altogether and reduce discoloration and nutrient loss. According to Ofor (2011), some leafy vegetables like *Gnetum* spp. can be briefly blanched to suppress enzymatic activities and loss of colour before drying. Blanching of vegetables, as a pre-processing technique before solar drying, was found to result in better nutrient retention, especially carotene, better palatability and appearance when done under laboratory conditions (Bustrillos, 1985).

Storage of fruit and vegetables in a fruit shed: Rapid deterioration in fresh fruits and vegetable after harvest is usually caused by exposure to heat. This exposure to the sun's heat is common during handling of fresh fruits and vegetables at transit collection centres; on the farm, or at markets in rural or urban centres; and these results in rapid spoilage of these crops. The Nigerian Stored Products Research Institute (NSPRI) has conducted research into ways of reducing the rate of spoilage of crops by keeping them in properly constructed fruits shed which provides cooler environment than the ambient for keeping these crops. The floor may be wetted periodically with portable water to increase the relative humidity of the shed for enhanced performance of the shed. This is best done when the floor is cemented. The wetting of the floor of the fruit sheds provides more humid and therefore more conducive storage environment for fresh fruits and vegetables.

Conclusion: The innumerable benefits of vegetables necessitate making extra efforts to have them in our diet. The vegetables also need to be wholesome for the full benefits to be properly tapped. Some of the constraints which prevents the teeming population of the developing nations from having wholesome vegetables in their diets include lack of awareness; highly perishable nature of the commodity and the high cost of wholesome fruits and vegetables which is a direct result of the high cost of production. Government, Civil Society Organizations (CSOs), corporate bodies and highly placed individuals can engage themselves in the promotion of research into ways of reducing the overall cost of production of these highly prized vegetables; thereby making it available to the teeming population of the developing countries.

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Table 1: Classification of Vegetables According to the Plant Organs Used

Class	Produce (Examples)
Root vegetables	Carrot, garlic, onion, Irish potato, sweet potato
Leafy vegetables	Cabbage, green onion, lettuce, Telfairia (Ugu), spinach (Green)
Flower vegetables	Green bean, cucumber, okra, pea, Pepper, sweet corn
Mature fruit vegetables	Melon, tomato

Source: Weichmann, (1987).

Fig. 1: Courtesy: http://agritech.tnau.ac.in/postharvest/pht_vegetables_index.html

Table 2: Classification of Different types of Fruits (Climacteric or Non-Climacteric)

Fruit Type	Scientific Name	Common Name
Climacteric	*Annona muricata*	Soursop
	Artocarpus altilis	Breadfruit
	Carica papaya	Papaya
	Lycopersicon esculentum	Tomato
	Malus domestica	Apple
	Mangifera indica	Mango
	Musa sp.	Banana
	Psidium guajava	Guava
	Punica granatum	Pomegranate
	Pyrus sp.	Pear
Non-climacteric	*Anacardium occidentale*	Cashew
	Ananas comosus	Pineapple
	Citrullus lanatus	Watermelon
	Citrus aurantiifolia	Lime
	Citrus paradisi	Grapefruit
	Citrus sinensis	Orange
	Vitis sp.	Grape

Source: Adapted from Kitinoja and Kader, (2003)

Table 3: Vitamins present in some Fruits, Vegetables and Root Crops

Vitamin	Source
A (retinol)	Carrots, green leaves (carotene), pawpaw, tomato
B1 (thiamin)	Green vegetables, some fruits
B2 (riboflavin)	Green leafy vegetables, pulses
B6 (Pyridoxine)	Bananas, peanuts
Niacin (nicotenic acid)	Peanuts, pulses
Folic acid	Broccoli, Avocado, beets, cabbage, lettuce, dark green leaves, spinach
C (ascorbic acid)	Cauliflower, citrus, guava, mango, pawpaw

Culled from FAO, (2008a) - Training manual on Postharvest handling and Marketing of horticultural Commodities