Postharvest Handling Practices and Treatment Methods for Okra in Nigeria: A Mini Review

Abstract

Over the years, the growth of Okra has increased in Nigeria due to its economic and nutritional value. Unfortunately, the produced Okra pods perishes due to poor handling and storage methods. To ensure that the wastage of this produced Okra reduces, proper postharvest handling practices and treatment methods of Okra should be properly adopted and deployed by Okra farmers especially in Nigeria. Postharvest handling practices such as harvesting/handling, cleaning/sorting, grading, packaging, transportation and storage have played an important role in maintaining the quality of Okra and extending the shelf life of the okra pods after harvest. Moreover, the use of appropriate postharvest treatment methods such as postharvest heat treatment, 1-methylcyclopropene (1-MCP)/ modified atmosphere packaging (MAP), calcium chloride (CaCl2) application, Edible coating and sanitizing chemicals have shown to be very effective in extending the shelf life of Okra. From this review, it was concluded that the quality of the harvested fruits can be maintained and shelf life extended by simply using appropriate postharvest handling practices and treatment methods.

Keywords: Post harvest; shelf life; quality; okra; storage

1.0 Introduction

Okra (*Abelmoschus esculentus* L.), also known as ladies' fingers, belongs to the malvaceae family, and is a tropical annual herb. Okra is a healthy vegetable that is rich in protein and polysaccharides, and has a high nutritional value. Its fruit is tender, mucilaginous, flavorful, and easy to cook. It can also be canned and used to make kimchi [1]. It is the second most important vegetable in the West African market after tomatoes. It is a non-climacteric vegetable when harvested and handled as an immature fruit [2]. It is one of the most commonly grown vegetable crops in the Tropics [3]. Owing to the high adhesiveness of the okra extract, it can be used as a fat substitute to make low-fat chocolate and cookies. Postharvest loss of okra in Nigeria ranges from 20 to 38% [4]. The fresh okra pods deteriorate rapidly after harvest due to high water loss, fruit softening, and color degradation (blackening of ridges and calyx discs) by oxidation and enzymatic activities, resulting in commercial value deletion [5]. Fruit softening is caused by cellular disintegration and breakdown of proto-pectin into pectin [6]. The main causes of injuries in the pods are improper handling, and packaging and storage at ambient temperatures or even at low temperatures [7, 8]. The tissue of the okra fruit softens gradually during storage, and hence it is very important to maintain the quality of fruits during storage [9]. Physical damage may also significantly affect chemical and physical composition of the pericarp and locular tissue in okra. The incidence and severity of physical and internal damages to vegetables depend on the impact energy; number of impacts; cultivars and the ripening stages, and it's cumulative during post harvest handling practices [8, 10].

Nigeria is the second largest producer of okra in the world and the largest producer in Africa, and the country has experienced a tremendous wastage of okra, this has led to huge economic losses to the farmers, traders, and the entire economy of the Country. Katende [11] had reported that fresh okra fruits are perishable and even when stored at the temperature of 7^0C to 10^0C, its shelf life is only 7 to 10 days. At present, okra is mainly stored under refrigeration, and modified atmosphere combined with preservatives. Similarly, Ogbaji and Iorliam [3] reported that okra fruits stored at 45% relative humidity and 29.9^0C treated with plant extracts have an extended shelf life of up to day 15 in Nigeria. Okra suffer from severe post harvest losses particularly under hot tropical conditions, hence the need for careful handling during harvesting and after, to minimize mechanical injuries such as scratches, punch and bruises to the crop. The use of measurement to determine internal bruising from impact has proven suitable to evaluate injuries in vegetables like Okra [8,10,12,13]. However in developed countries losses are generally small during processing, storage and handling because of the efficiency of the equipment, good quality storage facilities, and close control of critical variables by a highly knowledgeable cadre of managers. Conversely, in developing countries losses in processing, storage and handling tends to be rather higher because of poor facilities and frequently inadequate knowledge of methods to care for the food property [8]. Therefore the various handling steps, from the field to the consumers, must be carefully coordinated and integrated to maximize produce quality [8,10]. For the prediction of okra shelf life, Iorliam *et al*., [14] reported that machine learning techniques can predict okra shelf life based on the okra parameters such as weight loss, firmness, Titrable Acid, Total Soluble Solids, Vitamin C/Ascorbic acid content, and PH. The purpose of this paper therefore is to look at some postharvest handling practices and treatment methods that can be used by handlers of developing countries like Nigeria and how they can affect the postharvest qualities and shelf life of harvested okra.

2.0 Post harvest treatment techniques for Okra

After harvesting, okra being a non-climateric fruit still remains living and performs all functions of a living tissue. However, the postharvest quality of the fruit at harvest cannot be enhanced by any postharvest technology but can only be maintained [15,16]. In order to maintain this quality, there are some postharvest treatment methods that have to be adhered to in order to achieve this goal. Below are some of the treatments methods that can be used for harvested okra.

2.1 Some post harvest handling practices for Okra

2.1.1 Harvesting and Handling

Post-harvest losses in horticultural fruit crops are related mainly to handling beginning first from harvest and on to retail shops. Losses can be caused by mechanical injuries, inadequate storage, unsuitable handling in transporting and delay in the display time while at the retail market [17]. Changes in quality of Okra can be of mechanical, physiological, or pathological in nature. Mechanical injuries may cause metabolic and physiological changes in okra leading to the appearance of both typical external or internal signs [10,13]; and alterations in respiratory metabolism [18], flavors and smell [19,20] and firmness [21].

For export purpose, the quality criterion is that the okra pods should be green, tender, 4 –5 ridged and about 6–8 cm in length [6,22]. In developing countries like Nigeria, okra is generally harvested without any safety to prevent bruising and after harvesting it is dumped at one place.

In the whole operation from harvesting to consumption, it has been handled by growers, packagers, transporters and distributors which results to mechanical injuries to the ridges of pods and finally these pods become blacken on ridges and calyx disc, resulting in value deletion and unsaleability in quality conscious markets [6]. Harvesting methods is one of the major factor affecting the quality of okra pods, Tsado [8] reported that 77.3% of farmers in Minna, Nigeria uses breaking/plucking method to harvest okra fruits and this translates to 58% damages associated with harvested pods as compared to other methods of harvesting (Table 1). Similarly Dhall *et al.* [6] showed that the physiological loss in weight (PLW) of okra pods increased during storage, irrespective of the handling methods (Table 2). Pods harvested with maximum handling recorded minimum PLW (15.8%) after 13 days of storage whereas in normal handling method, PLW after 7 days of storage was 12.0%. The probable reason for higher weight loss in the later may be due to higher incidence of injuries on the hairs and surface bruise of pods during harvesting, collection and packing in bags, resulting in excessive moisture loss. The effect of harvesting method in reducing the PLW has also been earlier reported by Uppal *et al.* [23] and Dhall *et al.* [24]. The data on rotting of pods revealed that pods harvested with normal method turned complete black and rotten after 9 days of storage as compared to no rotting till 13 days of storage and only 3% rotting after 15 days of storage in case of minimal handling method (Table 2). The normal method of harvesting resulted in development of dark brown streaks on ridges and other bruised parts on 5th days of storage, making them non-salable. However, no fungal pathogen could be detected from the discoloured parts, even up to 7th day of storage. Consequently, the overall sensory quality of pods decreased at a slower rate in minimum handled treatment as compared to normal handling method during cold storage (Table 2). The overall sensory quality score was highest (6.5) up to 13 days for minimum handled pods whereas pods harvested with normal method recorded the overall sensory score of 6.2 after 5 days of storage. It clearly indicated that overall quality of minimum handled and normal handled pods were acceptable for 13 and 5 days respectively. Thereafter there is loss in the sensory quality due to development of fungus on the injured portion of pods. To reduce the post harvest losses in okra, it should be least handled. In the recent past, some of our country's okra export consignments have been rejected at the destination because of blacking of ridges, shriveling of pods and development of moulds [6].

Table 1: Classification of harvesting method and level of post harvest damages [8]

	Level of damage during harvesting (%)				
Harvesting methods	0	0-10%	11-20%	21-30%	**Total**
Breaking/plucking	9 (12.4)	34 (32.5)	15 (12.4)	0 (0.8)	**58 (77.3%)**
Using Knife	7 (3.2)	7 (8.4)	1 (3.2)	0 (0.2)	**15 (20%)**
Other means	0 (0.4)	1 (1.1)	0 (0.4)	1 (0.0)	**2 (2.7%)**
Total	**16 (21.3%)**	**42 (56%)**	**16 (21.3%)**	**1 (1.3%)**	**75(100%)**

Table 2: The effect of handling methods on the Physiological loss in weight (PLW), rotting and general appearance of okra cv. 'Punjab-8' during cold storage (8±1 °C, 90–95% RH) [6]

Storage Period (Days)	PLW (%)		Rotting (%)		Sensory Quality	
	I	II	I	II	I	II
1	3.4	5.0	NIL	NIL	9.0	9.0
3	4.9	7.1	NIL	NIL	8.4	7.1
5	7.5	9.0	NIL	NIL	7.6	6.2
7	9.7	12.0	NIL	NIL	7.2	5.0
9	11.9	15.2[a]	NIL	8.5[a]	7.0	3.1[a]
11	14.1	-	NIL	-	6.8	
13	15.8	-	NIL	-	6.5	
15	17.6	-	3.0	-	5.2	
18	20.1[a]	-	16.0[a]	-	3.2[a]	
CD (0.05)	0.64	0.52	-	-	0.72	

I = Minimum handling; PLW = post harvest loss weight

II = Normal handling

[a] Experiment discontinued

2.1.2 Cleaning/Sorting

Cleaning of okra generally involves the elimination of leaves, stem sections, and other types of debris from the pods. Broken pods should also be discarded. Okra should not be washed, since this would lead to a greater incidence of postharvest decay. In Nigeria sorting is practiced for most of the fruits and vegetables to remove damaged, diseased and insect infested produce on the basis of visual observation. However, in the advanced countries different types of sorters are used. The commonly used sorting equipment are belt conveyor, push-bar conveyor and roller conveyor [25].

2.1.3 Grading

The initial grading of the harvested okra should take place in the field at the time of harvest. Pickers should separate unmarketable or damaged pods from the marketable ones. Oversized and partially decayed pods should also be removed from the plant and out-graded in the field. Even with some preliminary grading at the time of picking, the okra pods arriving from the field are usually quite variable in size, shape, and colour. Grading for uniformity of appearance is important to satisfy the buyer [26].

At the packinghouse, the pods are usually graded according to size, shape appearance and amount of surface defects. The pods intended for market must be fresh, tender, not badly misshapen, and free from decay and damage. The stems should be cut cleanly and not have the appearance of being torn off the plant

2.1.4 Packing

Packaging is also one of the important aspects to consider in addressing postharvest losses in fruits and vegetables. It is enclosing food produce or product to protect it from mechanical injuries, tampering, and contamination from physical, chemical, and biological sources [16,27].

Packaging as a postharvest handling practice in fruits and vegetables production is essential in putting the produce into sizeable portions for easy handling. However, using unsuitable packaging can cause fruit damage resulting in losses [28]. Some common packaging materials used in most developing countries include wooden crates, cardboard boxes, woven palm baskets, plastic crates, nylon sacks, jute sacks, and polythene bags [16,28]. Good packages must cope with long distance transportation, multiple handling, and changed conditions of storage, transport and marketing. The usual means of packaging okra are plastic sacks and gunny bags. Improved packaging is not usually practiced in okra trading [29]. However, some farmers use more improved and recently introduced plastic crates for okra packaging for long distance transportation. This is due to the fact that plastic crates are durable and reusable. It also helps reduce transport damage and thereby extend shelf life of produce. In Nigeria the palm woven baskets used by okra handlers have sharp edges lining the inside which puncture or bruise the fruit when they are used. Idah *et al.* [28] therefore had recommended that woven palm baskets should be woven with the smooth side of the material turned inward to reduce the undesirable compressive forces which cause internal injuries which may result in reduced postharvest quality of fruits.

2.1.5 Transportation

In most developing countries, the production locations are in the rural communities which are far from the marketing centres and also inaccessible by road. Transporting harvested okra to the market on such bad road network and the lack of proper transportation like refrigerated vans become a big challenge for both producers and distributors. Idah *et al.* [28] identified the two main modes of transportation available to domestic transporters and handlers of fresh produce in Nigeria, the rail and the road systems. However, transporters complained of the non-availability and unusual delays in the rail system, so all the handlers used the road system for their regular and long distance haulage. This challenge therefore causes unnecessary delays in getting the produce to the market. Meanwhile, any delay between harvest and consumption of okra can result in losses [30]. The wobbling nature of most of the vehicles coupled with the bad nature of roads causes a lot of mechanical damage to the produce before it reaches its destination. Handlers from developed countries on the other hand use refrigerated containers and trailers which travel on reasonably good roads. Arah *et al.* [16] reported that transporting fruits like tomatoes in refrigerated trucks is not only convenient, but also effective in preserving the quality of fruits. However, both the initial investment and the operation costs of these vehicles are very high and beyond the affordable reach of most producers in developing countries. Handlers of developing countries therefore transport their produce using the most affordable mode of transport without considering the effect it will have on the postharvest quality of the produce. Even though okra handlers from developing countries may not have the capacity to use refrigerated trucks, they should be well educated on the consequences that any other transportation option they use may have on their produce.

2.1.6 Storage

Storage in the value chain is usually required to ensure uninterrupted supply of raw materials for processors. Storage extends the length of the processing season and helps provide continuity of product supply throughout the seasons. For short-term storage (up to a week), okra pods can be stored at ambient conditions of if there is enough ventilation to reduce the accumulation of heat from respiration [31]. For longer-term storage, okra pods can be stored at temperatures of about 15–28^{0}C and 85–95% relative humidity [2]. At these temperatures, both ripening and chilling injuries are reduced to the minimal levels. It is therefore necessary for handlers to understand the correct temperature management during storage of okra pods which is vital in extending the shelf life of the fruit whilst maintaining fruit qualities. Okra handlers in tropical countries can store okra pods for short to intermediate time by using evaporative cooling system made from woven jute sacks.

2.2 Post harvest Treatments of Okra

2.2.1 1-Methylcyclopropene reduces chilling injury of harvested okra pods

1-MCP, an inhibitor of ethylene perception, is thought to interact with ethylene receptors and thereby prevents ethylene-dependent responses [32]. Studies have shown that 1-MCP inhibited the chilling injury symptoms of some horticultural products, such as apple [33, 34, 35], avocado [36], pineapple [37], persimmon [38, 39], 'Fallglo' tangerine and grapefruit [40], 'Nova' and 'Ortanique' mandarins [41], plum [42], loquat [43] and jujube fruit [44].

Nevertheless, chilling injury symptoms of banana [45], 'Shamouti' orange [46] and peach [47] were induced by 1-MCP. Therefore, differential responses of fruit to 1-MCP at low temperature depend on the cultivar, specie or concentration.

Okra is a vegetable originated from tropical and subtropical area, which is sensitive to low temperature. Lyons and Breidenbach [48] suggested that okra should be stored at temperatures above to 9^{0}C to avoid the development of chilling injury disorder, including browning and pitting. Recently, Huang *et al.,* [49] reported that control okra pods showed chilling injury symptoms such as browning and pitting after 10 days in storage at 7^{0}C. Application of 1-MCP significantly alleviated the development of chilling injury disorder of okra pods in a concentration-dependent pattern. After 18 days in storage, the chilling injury indices were 3.1, 1.6 and 0.8 in control, 1μIL−1 and 5μl −1 1-MCP-treated okra fruit, respectively (Fig. 1).

Boontongto *et al.* [50] and Finger *et al.* [31] reported that methyl jasmonate and modified atmosphere packaging reduced or delayed the development of chilling injury symptoms of harvest okra pods stored at low temperature, respectively, which, possibly, act in a way different from 1-MCP. Browning is the typical chilling injury symptom for okra fruit stored at low temperature [48,49]. It is well established that browning is associated with loss of membrane integrity which occurs during stress and senescence in plant tissues [51]. 1-MCP treatment significantly inhibited the loss of membrane integrity in okra fruit stored at 7^{0}C. After day-18, membrane permeability, as an indicator of membrane integrity, were 42.9%, 34.7% and 33.4% in control, 1μl L−1 and 5μlL−1 1-MCP-treated okra fruit (Fig. 2A). Studies have shown that biophysical changes in membrane lipids and enzymatic and non-enzymatic lipid peroxidation lead to altered membrane properties and result in loss of membrane integrity and cellular decompartmentation (Marangoni *et al.,* 1996 [51, 52]. Chilling injury often leads to similar patterns of deterioration [52]. Huang *et al.*, [49] showed that lower lipid peroxidation, expressed as malondialdehyde (MDA) content, in 1- MCP-treated okra fruit also was observed than that in control fruit (Fig. 2B). It, therefore, is suggested that 1-MCP treatment inhibited lipid peroxidation, and relatively maintained membrane integrity, possibly due to enhanced antioxidant or free radical radical-scavenging activity, which was responsible for reduced browning. The bright green is an important indicator for evaluating the freshness of okra pods [7], which is reflected in the color parameters as well as in the chlorophyll content. Loss of greenness in most products is inhibited by 1-MCP [32]. For okra fruit, maintenance of green color by 1-MCP is desirable in the marketplace as discoloration is regarded as a sign of senescence [49].

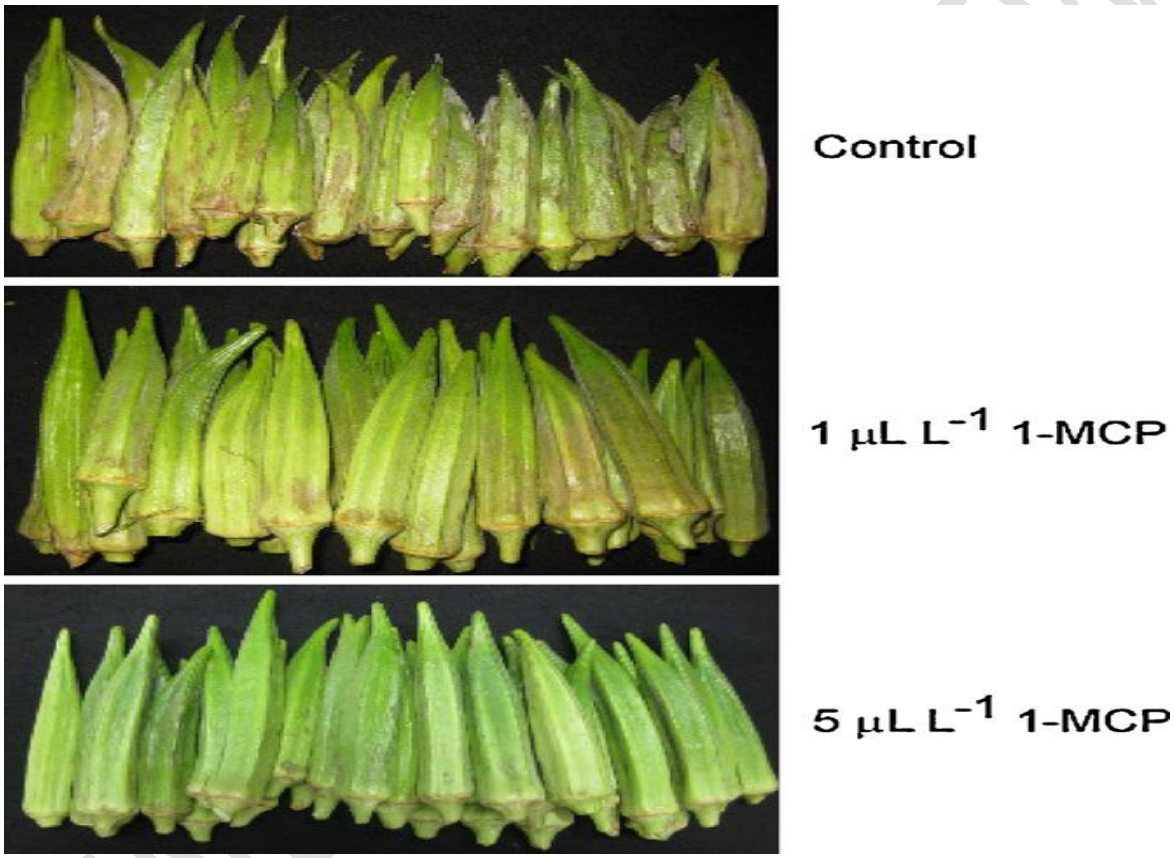

Fig. 1: Visual appearance of okra pods treated with 1-MCP for 16 h after 18 days in storage at 7^{0}C [49].

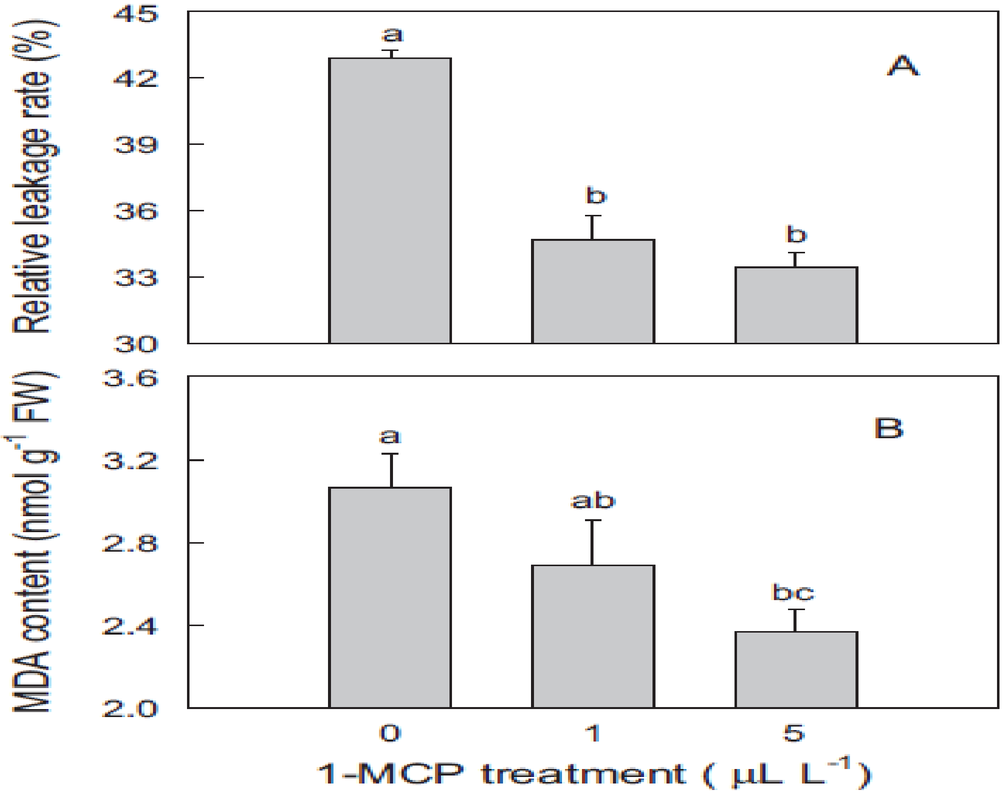

Fig. 2: Effect of 1-MCP treatment on relative leakage rate (A) and lipid peroxidation (B) of okra pods after 18 days in storage at 7^0C. Each data point represents a mean ± standard error (n = 3) and the values with different letters are significantly different ($p < 0.05$) [49].

2.2.2 Heat Treatment

The rate of respiration has direct correlation with temperature, as the temperature is high more will be the rate of respiration and multiplication of decay organisms. But it should be noted that the temperature and relative humidity requirements differ for different fruits and vegetables [53]. Temperature and relative humidity are the most important factors affecting the shelf life of okra [54]. The optimal storage temperature of okra ranged from 7 to 10^0C, and the pods can be stored satisfactorily for 7–10 days [4, 88]. Fresh okra pods exhibited extremely short shelf life due to high water loss or transpiration rates. Storage of okra at 25^0C resulted in a higher mass loss (14%) compared to a lower temperature of 4^0C after 5 days due to wilting, yellowing, and decay [55]. Storage at low temperatures led to a reduction of respiration rate, transpiration, and ethylene production [56]. At high temperatures, okra is highly susceptible to water loss, color fading, and decay, becoming squashy with a loss of commercial value and not easy to consume when fresh [49]. Heat generation, specifically known as 'Vital heat' in fresh produce, is produced as a by-product, primarily through the respiration process. Okra is classified at a very high respiration level, with a respiration rate of 40–60 mg CO_2 kg-1 h-1 and vital heat ranging from 427 to 640 J kg-1 h-1 at 5^0C [56]. Consequently, a cooling process should be taken into consideration when the storage room is designed as well as during transportation [57]. Cooling as quickly as possible after harvesting is critical to remove heat from the fresh produce and is a very important requirement for maintaining optimal product quality, especially for merchandise with naturally high respiration rates [58]. Forced-air cooling has been used for the export of okra received directly from the field [59]. In India, room cooling at 15^0C before storage at 8^0C is used for the export of okra [6]. The procedure of no cooling resulted in decreased fruit quality and increased fruit decay. Yang *et al.* [60] showed that post-harvest loss of commercial fruits and vegetables increased by 25–30% when no cooling was employed through the whole storing and transporting chain, while it was only 5–10% when a cooling step at 8^0C was practiced. Wang *et al.* [61] showed that room cooling at 2^0C reduced changes in the physiological quality of button mushroom (Agaricus bisporus). However, scant research has reported on cooling conditions and the efficiency of cooling processes to reduce heat generation in okra to extend storage or shelf life.

Pallet cover is an alternative method used as packaging technology to reduce waste from food spoilage by minimizing temperature and humidity change during the transportation of fresh produce [62, 63, 64]. Research on packaging for vegetables revealed that covering the pallet side and bottom with insulated pallet cover (Reflectix™) resulted in a reduction of mass loss and wilting in amaranth and preserved a desirable dark green color. Use of pallet cover for amaranth gave a high score in overall quality, with improvement on no cover [62]. Liu [65] reported the use of an insulated cover to keep pre-chilled lettuce at low temperatures. The insulated cover was also suitable for low-temperature phosphine fumigation to control western flower thrips on harvested lettuce. Chaiwong and Bishop [63] reported on lightweight insulation bags. Results showed that insulated bags provided cool temperature management and reduced the cool chain breakdown of strawberries from the supermarket to domestic refrigerators. The insulated pallet covers also gave better temperature preservation compared to no cover, and temperature changes occurred more slowly in chard, cucumber, and carrot [62, 63, 64]. However, very few studies exist about the use of thermal insulation cover to prevent post-harvest losses of okra under different temperature conditions.

Rattanakaran *et al.*, [66] evaluated a combination of room cooling and the use of thermal insulation materials to maintain okra quality under simulated storage and transportation. Okra pods were packed in plastic baskets and either cooled at 18^0C or not cooled in a room for 2 h. After either room cooling or no cooling, the okra pods were covered with three different materials: (1) perforated linear low-density polyethylene (P-LLDPE), (2) two layers of heat-reflective sheet with thin nonwoven (HRS+TNNW), and (3) metalized foam sheet (MFS). Typical handling (TP) without cooling and covering with PLLDPE was used as the control. The six treatments were conducted during simulated storage (18^0C for 48 h) and transportation (30^0C for 15 h). Their findings demonstrated that room cooling combined with HRS+TNNW had the highest efficiency for preserving cool temperature and reducing decay of okra fruits, compared to TP and room cooling plus MFS. Table 3 shows the effect of different packaging materials and control atmosphere (CA) technique on the shelf-life of okra at different storage temperatures and relative humidity ranges. Ngure *et al.*, [67] unveiled that dipping okra pods in hot water at 50°C for 1 min followed by storage at room temperature (15-20°C) reduced pod weight loss, electrolyte leakage, off odour, decay, and enhanced visual appearance and had no chilling injury. The treatment improved shelf life for 21 days and it can be practical under rural farming conditions.

Table 3: Effect of different packaging material and control atmosphere on the shelf-life of okra [68]

	Technique	Storage Conditions		Storage Period	References
		Temperature	Relative Humidity		
Packaging	HDPE (High density Polyethylene)	12.5^{0}C and 3^{0}C	80 ±5%	8 days	[89]
	Polyvinyl chloride (PVC)	5^{0}C, 10^{0}C and 25^{0}C	85–95%	7-10 days	[31]
	LDPE (low density Polyethylene)	15 ± 2^{0}C and 28 ±2^{0}C	85–95%	9 days	[2]
	Polypropylene O_2 (6.3–8.4%) CO_2 (10.7–11.8%)	15^{0}C	75%	9day	[7]
	MAP	20 ± 7^{0}C	80-80%	4 days	[68, 86]
Control Atmosphere	5% O_2 + 10% CO_2	11 ±1^{0}C	90–93%	12 day	
	4–10% CO_2	7–12^{0}C	90–95%		[87]

2.2.3 Calcium application

Calcium Chloride (CaCl2) at low temperatures is used to suppress senescence, reduce chilling injury, control development of physiological disorders and increase disease resistance in stored fruits and vegetables [69, 70]. The chemical prevented chilling injury in stored African eggplant as reported by Chepngeno *et al.*, [71]. Also, tomatoes treated with Calcium Chloride were stored for 21 days without spoilage and indicated little physiochemical properties changes compared to untreated tomatoes in Nigeria, hence extended shelf life [72]. Okra treated CaCl2 was effective in increasing cell membrane integrity leading to improving texture, minimizing weight loss, decreasing microbial load, and preventing polyphenoloxidase (PPO) from contacting its phenolic substrates and thus reducing blackness thus extending okra pods shelf life during storage [73]. The extended shelf life can ensure income gain from harvested crops and making fruits vegetables available and accessible to supplying micronutrient in the diet.

2.2.4 Edible coating

Edible coating is the thin layer of edible materials applied on the surface of fresh fruits and vegetables. It enhances the natural waxy cuticle on the surface of a produce, protecting it against spoilage microorganisms and physical damage [74, 75]. Also, edible coating minimize moisture losses; slow down respiration, senescence and enzyme activity; preserve color, flavor and texture; protects against mechanical damage and microbial growth; thereby, retaining freshness, active volatile compounds and plant antioxidants [76]. They are applied direct on fruits and vegetables surface by spraying, dipping, smearing or brushing followed by drying to create a modified barrier [74]. Their functions and effects depend on the type of coating materials, temperatures, alkalinity, thickness, as well as, variety of fruits and vegetables [77, 78].

Approved fruit and vegetables edible coatings including chitosan, cellulose, starch, gum (polysaccharides), bees and paraffin wax (lipids), mineral oils, polyvinyl acetate and several proteins based (like gelatin and soy proteins) that proves good barrier properties without residue taste or odor impairment [74,79]. They are mainly used in combination and incorporated with antioxidants, antimicrobials, or nutraceuticals and functional compounds for improved shelf life, quality, stability, safety and nutrition of fruits and vegetables [79]. On the other hand, edible coating provides a carrier for postharvest chemicals treatment on fruits and vegetables and reduces the use of synthetic packaging materials, hence reduce the risks of greenhouse gases emission Alam *et al.* [80]. This can provide a chance for SSA countries to use less energy and chemicals to reduce fruits and vegetable postharvest losses. Example, okra surface coating with 1% N, O-carboxymethyl chitosan had improved shelf life, delayed weight loss and maintain texture profile of the okra fruit [9]. Also Ogbaji and Iorliam [3] coated okra fruits with Neem and moringa retained firmness and their quality for 15 days compared to 7 days of the uncoated fruits in Makurdi, Nigeria. Therefore, the produce can be transported and stored for long period to marginal areas with limited access to fruit and vegetables and make them available to needy population. Extension of shelf-life due to delay of chlorophyll degradation in okra was assessed using guar gum coating alone or mixed with sodium chloride. Sarpong *et al.*, [81] revealed that all coatings preserved chlorophyll content over 21 days of storage in a range of 1.30- to 2.35-fold higher compared with the distilled water treated control. A Gum coating has potential to preserve nutrients in pods while reducing the microbial load in okra.

2.2.5 Sanitizing chemicals

Several chemicals are used to sanitize surfaces and processing areas for fruits and vegetables to reduce, remove or kill spoilage and pathogenic microorganisms [82]. The best practice is to focus on preventing contamination of fruits and vegetables at the first place along the value chain. However, this is not always possible and use of techniques that reduce or eliminate microbes is important to prevent food borne outbreaks and product spoilage. Most of cleaning and sanitizing chemicals used for postharvest treatment of fruits and vegetables includes: chlorine (hypochlorites, chlorine dioxide), ozonation, hydrogen peroxide, trisodium phosphate, organic acids (acetic, lactic, citric and tartaric acid), electrolyzed water and calcium based solutions [83]. Depending on a crop and situation, sanitizing chemicals are applied at different recommended concentrations by dipping, rinsing or spraying on fruits and vegetables surfaces for a predetermined contact time [84].

Sanitizing chemicals must be safe to the environment and human health, have trivial effect on produce quality, and cost effective [84]. According to Faid *et al.*, [85], okra treated with boiling and chemical solution treatments (250 ppm zinc chloride, 0.5 % potassium meta bi-sulfite, 0.1 % magnesium oxide and 0.1 % sodium bicarbonate) of okra pods to reduce the pesticide residues and improves pod quality.

Table 4: Summary of postharvest handling and treatments for okra

	Effects	References
A: Harvesting Method and practices		
1. Harvesting and Handling	Harvesting methods is one of the major factor affecting the quality of okra pods	[6,8,23,24]
2. Cleaning and sorting	Cleaning of okra involves elimination of leaves, stem sections and other types of debris from the pods	[25]
3. Grading and packing	Separation of unmarketable or damaged pods from the marketable ones for easy handling and packaging	[16,26,28]
4. Transportation	Movement of harvested okra from the production locations to marketing centres	[16,28]
5. Storage	Storage extends the length of the season and helps provide continuity of product supply throughout the seasons (either short term or long term storages)	[2, 49]
B: Postharvest Treatments of Okra		
1. 1-Methylcyclopropane (I-MCP)	The application of 1-MCP significantly alleviate the development of chilling injury disorder of okra pods thus extends pod shelf life	[31,32,49,50]
2. Calcium application (CaCl2)	Okra treated with CaCl2 effectively increased cell membrane integrity leading to improved texture, minimizing weight loss, decreasing microbial load thus extending pod shelf life during storage.	[73]
3. Edible coatings	Okra coated with edible coating provides protection against spoilage, microorganism and physical damage, thus extending shelf life during storage	[3,9,81]
4. Sanitizing Chemicals	Okra pods treated with sanitizing chemicals reduces	[82, 83, 85]

		pesticide residues and improves pod quality

3.0 Conclusion

The postharvest quality and shelf life status of the fruits in part will depend on some postharvest handling practices and treatments carried out after harvest. Even though the quality of any fruit after harvest cannot be improved by the use of any postharvest handling practices or treatment methods, it can however be maintained. Shelf life of the fruit can also be extended when appropriate postharvest handling practices and treatment methods are employed. Failure to adhere to these best practices has resulted in high amount of loss especially in developing countries. Although most okra handlers from developing countries may not have high-tech postharvest technologies in addressing postharvest losses in okra, understanding simple and the best postharvest practices has been found to be beneficial. Postharvest handling practices like harvesting/handling, cleaning/sorting, grading, packaging, transportation and storage played an important role in maintaining quality and extending shelf life of the okra pods after harvest. Also, the use of appropriate postharvest treatment methods like postharvest heat treatment, 1-methylcyclopropene (1-MCP)/ modified atmosphere packaging (MAP), calcium chloride (CaCl2) application, edible coating and sanitizing chemicals were also found to be vital (Table 4). It is concluded by this study that the quality of the harvested fruits can be maintained and shelf life extended by simply using appropriate postharvest handling practices and treatment methods. Consequently, in developing countries like Nigeria, until these simple postharvest practices are followed, postharvest losses in okra will continue to be a major challenge for its handlers. It is recommended that government, NGOs, private organizations should key into awareness creation and sanitization of rural farmers (okra handlers) on the simple postharvest practices to reduce losses, making okra available even during off seasons thereby ensuring food security. In the future, the authors would like to explore the application of internet of things for the shelf life extension of vegetables as reviewed in [90].

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