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

Abstract

Over the years, okra's demand has grown in Nigeria as a result of its economic and nutritional benefits. Unfortunately, due to inadequate handling and storage procedures, the okra pods produced deteriorates and loses value. 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. Harvesting/handling, cleaning/sorting, grading, packing, and storage are all key postharvest handling methods for preserving okra quality and increasing the shelf life of the okra pods after harvest. Moreover, efficient postharvest treatment procedures such as postharvest heat treatment, 1-methylcyclopropene (1-MCP)/modified atmosphere packaging (MAP), calcium chloride ($CaCl_2$) application, edible coating, and sanitizing chemicals have been proven to improve the shelf life of Okra. From this review, it was concluded that the quality of the harvested fruits could be maintained and shelf life extended by simply using appropriate postharvest handling practices and treatment methods.

Keywords: *Okra; storage; quality; shelf life; post harvest*

1.0 Introduction

Okra (*Abelmoschus esculentus L.*), popularly known as ladies' fingers, is a tropical annual herb that belongs to the malvaceae family. 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]. After tomatoes, okra is the second most important and significant vegetable on the West African market. 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]. Okra extract can be used as a fat alternative in low-fat chocolate and cookies due to its strong adhesiveness. Okra postharvest losses in Nigeria range from 20% to 38% [4]. Fresh okra pods lose their commercial value quickly after harvest due to excessive water loss, fruit softening, and colour degradation (blackening of ridges and calyx discs) caused by oxidation and enzymatic activities [5]. Cellular disintegration and the degradation of proto-pectin into pectin cause fruit softening [6]. Improper handling, packaging, and storage at ambient or even low temperatures are the leading causes of injury in pods [7,8]. Because the tissue of the okra fruit softens over time during storage, it's critical to keep the fruits in good condition [9]. Chemical and physical composition of the pericarp and locular tissue in okra may be considerably affected by physical damage. Physical and internal damage to vegetables is affected by impact energy, number of impacts, cultivars, and ripening stages, and it is cumulative during post-harvest handling techniques [8,10].

Nigeria is the world's second biggest producer of okra and Africa's largest producer, however the country has faced massive okra waste, 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 suffers from substantial post-harvest losses, especially in hot tropical climates, necessitating careful handling during harvesting and afterward to avoid mechanical injuries to the crop such as scratches, punches, and bruises. The use of measurement to detect internal bruising caused by impact has been shown to be effective in evaluating injuries in vegetables such as Okra [8,10,12,13]. However, because of the effectiveness of the equipment, efficient storage facilities, and strict monitoring of crucial variables by a highly knowledgeable cadre of managers, losses during processing, storage, and handling are often negligible in industrialised countries. Conversely, losses in processing, storage, and handling tend to be higher in developing nations due to a lack of facilities and frequently insufficient knowledge of how to care for the food property [8]. To enhance produce quality, the numerous handling procedures from the farm to the consumer must be carefully coordinated and integrated [8,10]. Iorliam et al., [14] stated that okra shelf life can be predicted using machine learning approaches based on okra metrics such as weight loss, firmness, Titrable Acid, Total Soluble Solids, Vitamin C/Ascorbic acid concentration, 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, even though okra is a non-climateric fruit, it is nonetheless alive and performs all the functions of a living tissue. However, no postharvest technique can improve the postharvest quality of the fruit after harvest; it can only be maintained [15,16]. Some postharvest treatment measures must be followed to maintain this quality. The ways for treating harvested okra are listed below.

2.1 Some post harvest handling practices for Okra

2.1.1 Harvesting and Handling

Post-harvest losses in horticulture fruit crops are primarily attributable to handling, which begins with harvest and continues through retail stores. Mechanical injuries, insufficient storage, improper transit handling, and a delay in the display period while at the retail market can all result in losses [17]. Mechanical, physiological, or pathological changes in the quality of Okra can occur. Mechanical injuries can cause metabolic and physiological changes in okra, resulting in visible and internal indications [10,13], as well as changes in respiratory metabolism [18], flavours and smell [19,20], and firmness [21]. The okra pods must be green, soft, 4–5 ridged, and 6–8 cm in length to be suitable for export [6,22]. Okra is commonly picked in developing countries like Nigeria without any safeguards to avoid bruising, and it is then dumped in a single location after harvesting. Growers, packagers, transporters, and distributors have been involved in the entire process, from harvest to consumption, resulting in mechanical injuries to pod ridges and, eventually, blackening of the ridges and calyx disc, resulting in value loss 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] discovered that okra pods' physiological loss in weight (PLW) increased during storage, regardless of the handling techniques used (Table 2). After 13 days of storage, pods harvested with maximal handling had the lowest PLW (15.8%), whereas PLW after 7 days was 12.0%. The increased weight loss in the latter might be owing to a higher frequency of damage to pod hairs and surface bruises during harvesting, collecting, and packaging in bags, causing excessive moisture loss. Uppal et al.[23] and Dhallet al.[24] have previously reported on the influence of harvesting method on minimizing the PLW. The reports on pod rotting revealed that pods collected using the standard approach went completely black and rotten after 9 days of storage, but pods harvested using the minimal handling method showed no rotting until 13 days of storage and just 3% rotting after 15 days of storage (Table 2). On the fifth day of storage, the typical manner of harvesting caused dark brown streaks to appear on ridges and other damaged portions, rendering them unsellable. Even after 7 days of storage, no fungal infection was found on the discolored areas. Consequently, when compared to the conventional handling approach during cold storage, the overall sensory quality of pods diminished at a slower rate in the minimally handled treatment (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. After that 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 impact of handling techniques on PLW, rotting, and overall look of okra cv. 'Punjab-8' during cold storage (8±1 °C, 90–95% RH) [6]

Period of Storage (Days)	%PLW		% Rotting		Sensory Quality	
	Minimum Handling	**Normal Handling**	**Minimum Handling**	**Normal Handling**	**Minimum Handling**	**Normal Handling**
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	

PLW = post harvest loss weight

[a] Experiment discontinued

2.1.2 Cleaning/Sorting

Leaves, stem parts, and other sorts of detritus are typically removed from okra pods during cleaning. Broken pods should be discarded as well. Okra should not be washed because it will increase the risk of postharvest deterioration. In Nigeria, most fruits and vegetables are sorted on the basis of visual inspection to remove damaged, diseased, and insect-infested goods. Different types of sorters are employed in advanced countries. Belt conveyors, push-bar conveyors, and roller conveyors are the most often utilised sorting machinery [25].

2.1.3 Grading

The initial grading of harvested okra should be done in the field when it is harvested. Unmarketable or damaged pods should be separated from marketable pods by pickers. Pods that are too large or partially rotted should be removed off the plant and out-graded in the field. Even with some preliminary grading at the time of plucking, the size, shape, and colour of the okra pods that arrive from the field are usually highly diverse. To satisfy the buyer, uniformity of appearance must be graded [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

One of the most essential elements to consider when addressing postharvest losses in fruits and vegetables is packaging. It is the process of enclosing food produce or products in order to protect them against mechanical accidents, manipulation, and contamination from physical, chemical, and biological causes [16,27]. Packaging is an important postharvest handling procedure in the production of fruits and vegetables because it allows the food to be divided into manageable parts. Unsuitable packing, on the other hand, might result in fruit damage and losses [28]. Wooden crates, cardboard boxes, woven palmbaskets, plastic crates, nylon sacks, jute sacks, and polythene bags are some of the most popular packing materials used in most developing countries [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. The interior of the palm woven baskets used by okra handlers in Nigeria has rough edges that pierce or damage the fruit when utilized. As a result, Idah et al. [28] advised that woven palm baskets be weaved with the smooth side of the cloth facing inward to prevent the undesired compressive pressures that cause interior injuries and may result in lower postharvest fruit quality.

2.1.5 Transportation

In the majority of developing countries, production takes place in rural settlements that are remote from marketing centers and also difficult to reach by road. Transporting harvested okra to market on such a poor road network and without suitable conveyance, such as refrigerated trucks, becomes a major difficulty for both growers and wholesalers. The rail and road systems, according to Idah et al. [28], are the two main modes of transportation available to domestic carriers and handlers of fresh produce in Nigeria. Transporters, on the other hand, grumbled about the rail system's lack of availability and unusual delays, therefore all handlers chose the road system for their regular and long-distance haulage. As a result of this problem, there are unnecessarily long delays in bringing the goods to market. In the meanwhile, any time between harvest and consumption of okra might cause losses [30]. The wobbly nature of most vehicles, along with the poor state of most roads, also causes a great deal of mechanical damage to the produce before it arrives at its destination. On the other hand, handlers in industrialized nations employ refrigerated containers and trailers that drive on relatively excellent highways.

Arah *et al.*[16] reported that transporting fruits in refrigerated trucks is not only convenient, but also beneficial in protecting fruit quality. However, the initial investments as well as the ongoing operating costs of these vehicles are prohibitively expensive for most developing-country producers. As a result, producers in developing nations, convey their goods using the most cost-effective mode of transportation, regardless of the impact on post-harvest quality. Even though developing-country okra handlers may not be able to employ refrigerated vehicles, they should be fully informed about the effects that any other mode of transportation may have on their product.

2.1.6 Storage

In most cases, storage is necessary along the value chain to provide an ongoing flow of raw materials to processors. Storage helps to extend the processing season and ensure product supply consistency throughout the year. Okra pods can be kept at ambient temperatures for short periods of time (up to a week) if there is enough ventilation to prevent heat buildup from respiration [31]. Okra pods can be preserved for a long time at temperatures ranging from 15 to 280 degrees Celsius and 85 to 95 percent relative humidity [2]. Both ripening and chilling damage are minimized to a bare minimum at these temperatures. As a result, it is critical for handlers to understand proper temperature control when storing okra pods, which is critical for increasing the shelf life of the fruit while maintaining fruit quality. Tropical okra handlers can preserve okra pods for a short to medium period of time by employing an evaporative cooling system composed of woven jute bags.

2.2 Post harvest Treatments of Okra

2.2.1 1-Methylcyclopropene protects harvested okra pods against chilling damage

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 depending on the cultivar, specie or concentration.

Okra is a low-temperature-sensitive vegetable native to the tropical and subtropical regions. According to Lyons and Breidenbach [48], okra should be refrigerated at temperatures above 9°C to avoid chilling damage disorder, which includes browning and pitting. Control okra pods displayed chilling injury symptoms such as browning and pitting after 10 days in storage at 7°C, according to Huang et al. [49]. In a concentration-dependent pattern, 1-MCP greatly reduced the development of chilling damage disorder in okra pods. After 18 days in storage, the chilling injury indices were 3.1, 1.6 and 0.8 in control, 1µlL−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, was 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]found that 1-MCP-treated okra fruit had reduced lipid peroxidation, as measured by malondialdehyde (MDA) level, than control fruit (Fig. 2B). As a result, it's thought that 1-MCP treatment decreased browning by inhibiting lipid peroxidation and maintaining membrane integrity. This might be owing to increased antioxidant or free radical radical-scavenging action. The brilliant green color of okra pods is an essential signal of their freshness [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 market place as discoloration is regarded as a sign of senescence[49].

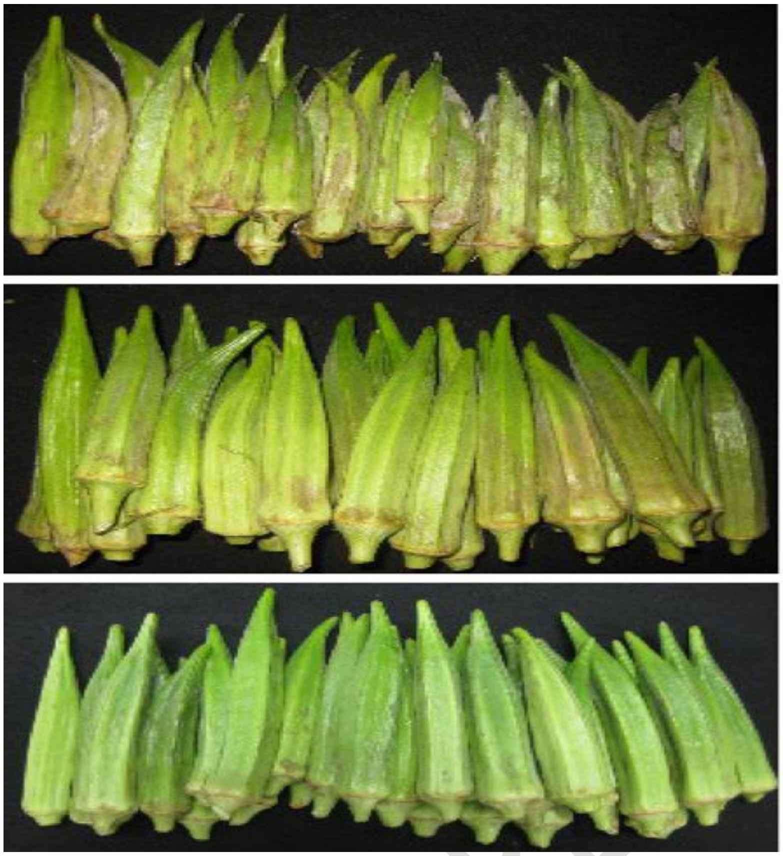

Fig. 1: Visual appearance of okra pods treated with 1-MCP for 16 h after 18 days in storage at 7^0C [49].

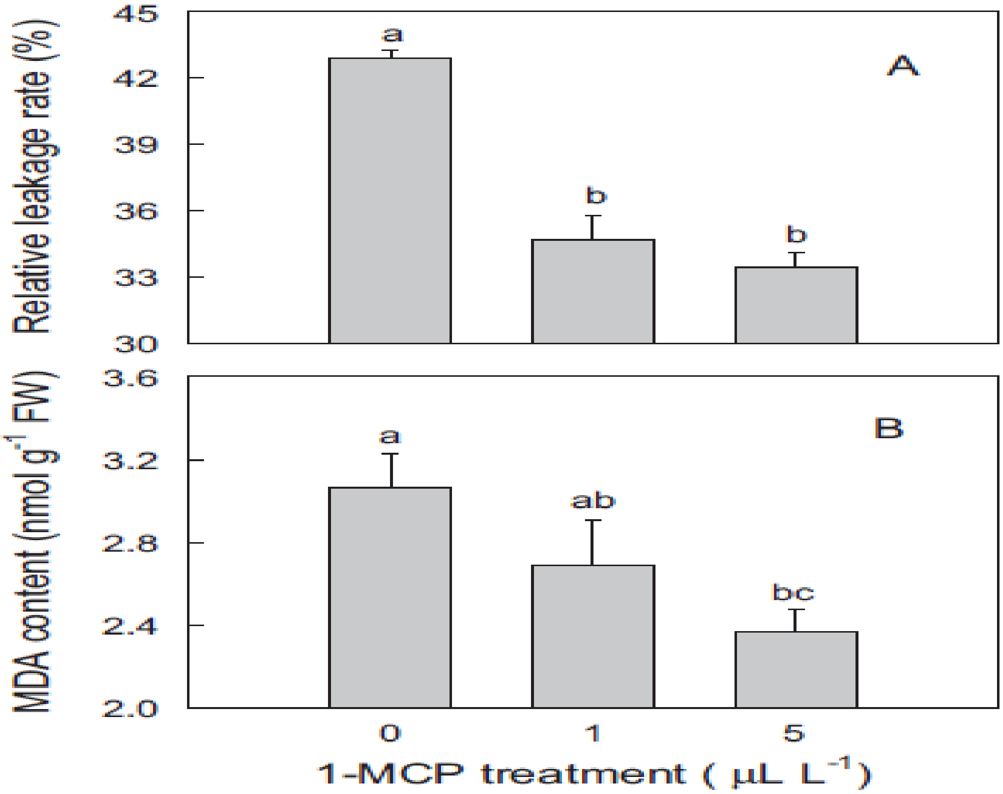

Fig. 2: After 18 days of storage at 70°C, the effect of 1-MCP treatment on (A) relative leakage rate and (B) lipid peroxidation of okra pods. The values with different letters are statistically different (p 0.05) and each data point indicates a mean standard error (n = 3) [49].

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]. The most significant parameters determining the shelf life of okra are temperature and relative humidity [54]. Okra pods may be kept successfully for 7–10 days at temperatures ranging from 7 to 10^{0}C [4, 88]. Due to significant water loss or transpiration rates, fresh okra pods have a very limited shelf life. Due to wilting, yellowing, and deterioration, okra stored at 25^{0}C lost 14 percent of its mass after 5 days when compared to okra stored at 4^{0}C [55]. Similarly, the rate of respiration, transpiration, and ethylene production were all reduced when the okra fruits were stored at low temperatures [56].

Okra is very susceptible to water loss, color fading, and deterioration at high temperatures, becoming squashy, losing economic value, and difficult to swallow when fresh [49]. As a by-product of the respiration process, heat production, also known as 'Vital heat' in fresh food, is created. Okra has a high respiration rate of 40–60 mg CO_2 kg-1 h-1 and a vital heat of 427–640 J kg-1 h-1 at 50°C [56]. As a result, a cooling process should be considered while designing the storage chamber as well as during transit [57]. Cooling fresh fruit as soon as possible after harvesting is vital for removing heat from the product and is a must for maintaining optimal product quality, especially for products with naturally high respiration rates [58]. The export of fresh-from-the-field okra has been done using forced-air chilling [59]. In India, room cooling at 15^0C before storage at 8^0C is used for the export of okra [6]. Similarly, the procedure of no cooling resulted in decreased fruit quality and increased fruit decay. Yang *et al.*[60] showed that when no cooling was used throughout the whole storage and shipping chain, post-harvest loss of commercial fruits and vegetables rose by 25–30%, but only 5–10% when an 8^0C chilling step was used. Wang et al.[61] found that room chilling at 20°C decreased alterations in button mushroom physiological quality (*Agaricus bisporus*). However, there has been little study on chilling settings and the efficacy of cooling procedures for reducing heat output in okra to lengthen storage or shelf life.

Pallet cover is a packaging system that minimizes temperature and humidity changes during the transportation of fresh produce, reducing loss from food spoiling [62, 63, 64]. According to research on vegetable packing, covering the pallet side and bottom with an insulated pallet cover (Reflectix^{TM}) reduced mass loss and wilting in amaranth while maintaining a desired dark green color. The use of a pallet cover for amaranth resulted in a good overall quality score, with an improvement as compared to no cover [62]. The use of an insulated cover to maintain pre-chilled lettuce at low temperatures was described by Liu [65]. The insulated cover was also useful for low-temperature phosphine fumigation of harvested lettuce to combat western flower thrips. Lightweight insulating bags were discussed by Chaiwong and Bishop [63]. Insulated bags offered cool temperature management and minimized strawberry cool chain breakdown from store to home refrigerators, according to the findings. Temperature variations in chard, cucumber, and carrot were slower with the insulated pallet coverings than without them [62, 63, 64]. However, there are few researches on the usage of a thermal insulating cover to prevent okra post-harvest losses under various temperature settings.

To keep okra quality intact during simulated storage and transit, Rattanakaran *et al.*,[66] used a mix of room cooling and thermal insulation technologies. Okra pods were placed in plastic baskets and left to cool in a room for two hours, either at 18^0C or at room temperature.

The okra pods were coated with three different materials after either room cooling or no cooling: (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). The control was typical handling (TP) without cooling and covering with PLLDPE. The six treatments were carried out during simulated storage and transit (at 18^0C for 48 hours) (30^0C for 15 h). In comparison to TP and room cooling with MFS, their findings demonstrated that room cooling combined with HRS+TNNW had the maximum efficiency for maintaining cool temperatures and decreasing okra fruit degradation.

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 for 1 minute at 50°C, then storing at room temperature (15-20°C) There was no chilling harm and the pod weight loss, electrolyte leakage, off odor, decay, and visual appearance were all minimized. The treatment extended the shelf life by 21 days and can be used in remote agricultural situations.

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 ($CaCl_2$) 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 edible coatings for fruits and vegetables include chitosan, cellulose, starch, gum (polysaccharides), bees and paraffin wax (lipids), mineral oils, polyvinyl acetate, and several protein-based coatings (such as gelatin and soy proteins) that demonstrate good barrier properties without leaving a residue taste or odour [74,79]. They're mostly employed in conjunction with antioxidants, antimicrobials, nutraceuticals, and functional chemicals to increase fruit and vegetable shelf life, quality, stability, safety, and nutrition [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. Surface coating of okra with 1% N, O-carboxymethyl chitosan, for example, enhanced shelf life, slowed weight loss, and preserved the textural 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

To decrease, eliminate, or destroy spoilage and harmful bacteria, many chemicals are used to sanitize surfaces and processing areas for fruits and vegetables [82]. Focusing on reducing contamination of fruits and vegetables at the start of the value chain is the best strategy.

However, because this is not always achievable, it is critical to employ measures that minimize or remove germs in order to avoid foodborne outbreaks and product degradation. Chlorine (hypochlorites, chlorine dioxide), ozonation, hydrogen peroxide, trisodium phosphate, organic acids (acetic, lactic, citric, and tartaric acid), electrolyzed water, and calcium based solutions are the most common cleaning and sanitizing chemicals used for postharvest treatment of fruits and vegetables [83]. Sanitizing chemicals are applied at varying recommended doses by dipping, washing, or spraying on fruits and vegetables surfaces for a set contact duration, depending on the crop and environment [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) to reduce the pesticide residues improves the 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 season's length and ensure product supply continuity across 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)	$CaCl_2$ treatment of okra enhanced cell membrane integrity, resulting in better texture, reduced weight loss, and reduced microbial load, increasing 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 pesticide residues and improves pod quality	[82, 83, 85]

3.0 Conclusion

Postharvest handling procedures and treatments will affect the quality and shelf life of the fruits. Although no postharvest handling activities or treatment methods may increase the quality of any fruit after harvest, it can be preserved. When proper postharvest handling procedures and treatment methods are used, the fruit's shelf life can be increased as well. Failure to follow these best practices has led to significant losses, particularly in developing nations.

Although most okra handlers in developing countries may lack high-tech postharvest technologies for resolving postharvest losses in okra, it has been discovered that learning simple and optimal postharvest procedures is advantageous. Harvesting/handling, cleaning/sorting, grading, packing, shipping, and storage techniques all had a part in preserving quality and prolonging the shelf life of okra pods after harvest. The employment of proper postharvest treatment procedures, such as heat treatment, 1-methylcyclopropene (1-MCP)/modified atmospheric packaging (MAP), calcium chloride ($CaCl_2$) application, edible coating, and sanitizing chemicals, was also discovered to be essential. As a result, postharvest losses in okra will continue to be a big concern for its handlers in developing world like Nigeria unless these easy postharvest procedures are implemented. It is suggested that the government, NGOs, and private groups focus on raising awareness and educating local farmers (okra handlers) about simple postharvest measures to decrease losses and provide food security by making okra available even during off seasons. This paper concludes that by simply employing suitable postharvest handling procedures and treatment technologies, the quality of harvested fruits will be preserved and shelf life increased. 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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