INTERACTIVE EFFECTS OF PACKAGING AND STORAGE TEMPERATURES ON THE SHELF-LIFE OF OKRA

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ABSTRACT

A study aimed at evaluating the potential benefits of pre-packaging and storage temperature in extending the shelf life of okra was conducted at Egerton University Horticulture Field and Biotechnology Laboratory. Okra pods were subjected to different combination of packaging and storage temperature. Three levels of packaging were used consisting of perforated (punched) polyfilm bags, non-perforated polyfilm bags (0.03mm thickness) and unpackaged to modifying the storage atmosphere. Pods weighing 100g were put in the various packages and the unpackaged pods were placed on flat cartons. Four levels of storage temperature, 4°C, 8.5°C, 13°C and room temperature storage were used for storing okra pods. The temperatures of 4°C, 8.5°C and 13°C were attained in refrigerators while room temperature was obtained by placing the pods on tables in the open. Pods stored at 4°C were unmarketable 21 days after storage as they were frozen and had the highest electrolyte leakage due to high chilling injury. All unpackaged okra pods stored at all temperatures were also not marketable by day 21 of storage as they were dry and shriveled. These pods had the greatest weight loss (79%) at 13°C compared to weight loss of less than 30% observed in the pods stored at the same temperature (13°C) but kept in perforated packages. The best marketable pods that were not frozen and had the least off odour were those kept at 13°C storage temperature treatment in non perforated and perforated packaging. Blackening was inhibited under these storage conditions resulting in the best visual appearance of okra pods. It is possible that pod discoloration was controlled by atmosphere modification provided by packaging thus resulting in enhanced quality and marketability of the pods for 21 days.

Keywords: okra, packaging, storage temperatures, chilling injury, weight loss, off odour, electrolyte leakage and decay incidence.

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is one of the major vegetables produced in Kenya mainly for export market to the European Union. However, production of the crop has been constrained by the short shelf life of its pods. Okra pods lose quality through blackening, shrivelling and decaying within two days under room temperature conditions leading to heavy postharvest losses. To reduce these losses, traders disinfect fresh produce against decay-causing microorganisms using chlorine solution. However, chlorine has an unpleasant smell and is easily vaporized. Moreover, there is a growing consumer concern on the use of chemicals to manage infections (Salunkhe and Desai, 1984). There has been a strong move towards the use of non-chemical methods, such as packaging and right storage temperature in managing postharvest pathogens (Bauchmann and Earles, 2000).

Temperature management is the most effective tool for extending the shelf life of fresh horticultural produce. Exposure of okra pods to undesirable temperatures will result in bleaching, surface burning or scalding, shrivelling, excessive softening and desiccation (Cantwell and Trevor, 2002). Temperature also influences the effect of ethylene, reduces oxygen, and elevates carbon dioxide levels; affect pathogen spore germination and growth rate. Low temperature will reduce the effects of pathogens on fresh produce. For instance, cooling commodities below 5°C immediately after harvest reduces the incidence of *Rhizopus* rot (Brackett, 1993). However, extremely low storage temperatures can also affect the quality of certain vegetables. Okra is rapidly chill damaged when stored at temperatures less than 7°C for an extended period (Perkin-Veazie and Collins, 1992). The symptoms of chilling injury include surface and internal discoloration (browning), pitting, water soaked areas, off-flavour development, and accelerated incidence of surface moulds and decay especially organisms not usually found growing on healthy tissue (Mitchel and Kader, 1992).
Apart from temperature, water loss from fresh produce will also cause deterioration through wilting and shrivelling, loss of textural quality (softening, flaccidity, limpness, loss of crispness and juiciness), and nutritional quality (Thompson, 1996).

The rate of water loss from fruits and vegetables including okra depends upon the vapour pressure deficit between the commodity and the surrounding air conditions, which is influenced by temperature and relative humidity. At a given relative humidity, water loss increases with the increase in temperature (Shewfelt, 1993 a).

In fresh produce like okra, water loss is influenced by internal factors (morphological and anatomical characteristics, surface area-to-volume ratios, surface injuries, and maturity stage) and external or environmental factors (temperature, relative humidity, air movement, and atmospheric pressure) (Crisosto, 1993). Evaporation of water from the plant tissues is a physical process that can be controlled by applying treatments to the commodity. Treatments to overcome these factors may include waxes, other surface coatings and wrapping with plastic films, or manipulating the environment such as maintenance of high relative humidity and control of air circulation (Sargent, *et al*., 2000).

One of the most common and obvious symptoms of deterioration in fresh produce results from the activity of various fungi including grey moulds (*Botrytis cinere*) (Snowdown, 1992). For example, Baxter and Waters (1990) associated decay, the most common okra problem, with *Alternaria Spp*. However, the level of attacks by most pathogenic organisms follow stresses from sunscald, physical injury or physiological disorders that lower resistance of the commodity (Wills, *et al*., 1998).

Weight loss is very high in immature okra pods hence relative humidity (95-100%) is needed to reduce dehydration, pod toughening and loss of fresh appearance. Modified atmosphere, a technique of sealing actively respiring produce in polymeric film packages to modify oxygen and carbon dioxide concentrations within the package has been associated with improved moisture retention and enhanced metabolism and activities of decay-causing microorganisms. The technique also reduces browning of damaged surfaces of produce thus increasing storability of a wide range of fresh produce. Due to high respiration rate, okra pods bleach and may develop off-flavours when stored in poorly ventilated containers for prolonged periods (over 24 hours). Due to excessive heating (heat of respiration), and high relative humidity (condensation) this promotes decay (Medlicott, 1990). In addition, temperature inside the package affects storability by influencing the film permeability and hence composition of O_2 and CO_2.

Storage temperature and humidity are most important as they influence the senescent phases of fresh vegetables by regulating the rate of all associated physiological and biochemical processes (Salunkhe and Desai, 1984). Similar findings have been made with bell peppers stored in perforated packaging which had a lower decay incidence than in non perforated packaging (Yehoshua *et al.,* 1998). It was also found that pods in perforated packaging had less off odour than those in non perforated packaging. This finding is also similar to a study carried out on parsley where perforated packaging retained flavour and aroma better than in non perforated packaging (Heyes, 2004). In storage, ventilation is very important to avoid build up of carbon dioxide and heat as non perforation permits slow gas exchange combined with vapour and heat build up leading to rapid deterioration. The objective of this study was to develop post-harvest management options that will delay senescence so as to optimize marketing of okra pods without loss of quality.

MATERIALS AND METHODS

Experimental Site

The research was carried out at Egerton University horticultural research field. The field is located at altitude 0°23 South, longitude 35°35 East and 2,225m above sea level. The area receives moderate, mean rainfall of 1012 mm, mean maximum temperature of 22°C with minimum night temperature range of 5 to 10°C. The soils are Vintric Mollic Andosols with pH of 5.5 - 6.5.

Establishment of okra in the field

Okra seeds of 'Pusa Sawani' purchased from Kenya Seed Co. LTD was planted at a depth of 3 cm as recommended by Jambhale and Nerker, (1990). Planting beds (1.2 m wide and 30 cm high) were prepared to a fine tilth before laying the irrigation tubes and polyethylene mulch for supplementary water application. At planting, 120 kg NPK/ha (17.17.0) equivalent of 2 g/plant was applied. Calcium Ammonium Nitrate (CAN-26%N) was topdressed at 70 kg N/ha (68 g/plant) when plants were 15 to 20 cm in height and repeated 2 to 3 weeks later (HCDA, 1996). The most common pests observed during the period of research were aphids and ants and these were managed by the use of endosulfan (Duzyaman, 1997). Harvesting commenced within 10 weeks of planting, 4-7 days after the flower had opened. Well formed, straight, tender pods with a fresh appearance and a colour typical of the cultivar (generally bright green) and free of defects were harvested with at least 1cm long stalk. The pods were handled carefully to prevent physical damage such as surface friction, impact and vibration bruising (Medlicott, 1990). Harvested pods were immediately transferred to a cool room to dissipate field heat. Pods 5-8 cm in length, which are preferred by consumers, were used for the experiment. Pods were further sorted to select only those with good appearance and without seeds protruding through the skin (Perkins-Veazie and Collins, 1992).

Post-harvest treatments

The selected pods were subjected to treatment effects of three levels of packaging and four levels of storage temperature. The packaging effects investigated were perforated (punched) polyfilm bags, non-perforated polyfilm bags (0.03mm) and unpackaged (free packaging) to modify the storage atmosphere, while the temperature levels used were 4°C, 8.5°C, 13°C and room temperature storage (Salunkhe and Desai, 1984). The temperatures of 4°C, 8.5°C and 13°C were attained in refrigerators.

Experimental design

A split plot experiment embedded in a completely randomised design (SPCRD) was used to test the effects of the treatments on various parameters of okra pods. The treatments were repeated six times. Storage temperatures treatments were the main factor investigated while the packaging were sub factor. The pods were stored for a maximum period of three weeks (21 days). The experiment was repeated twice. The first trial ran from November 25th–December 15th, 2005 and second trial from December 26th–January 15th, 2006.

Variable Assessments

The variables investigated were assessed first when the non-packaged pods stored at open room environment started showing signs of wilting or shrivelling. Among the variables assessed were: visual appearance, off odour, incidence of chilling injury, electrolyte leakage, weight loss (%) and incidence of decay, The assessment of weight loss and visual appearance were carried out on the 3rd day (excellent), 7th day (relatively good), 14th day (maximum) and 21st day (not published) of storage (Duzyaman, 1997).

Visual appearance was evaluated when green pods started changing colour using of the pods were based on the changes in the skin colour of okra pods. The evaluation was done using a hedonic scale from 7-excellent (bright green), 5-good (dull green), 3-acceptable (yellowing) and 1-not acceptable (dark).

Off odour was evaluated using a hedonic scale of 7-Excellent, 5-good, 3-acceptable, and 1-not acceptable. Then percentage average divided by 7 and calculated per package. Off odour = (No of packages in scale/No of total packages) 100%.

Incidence of chilling injury (IC) was calculated by counting the number of pods with symptoms (PS) as a percentage of the total number of pods per bag (TP). Incidence of chilling injury was determined at the end of 21 days and after exposing the produce to room conditions for the symptoms discoloration, pitting, water-soaked lesions and increased decay to be expressed. IC (%) = [(PS/TP)*100]

Electrolyte leakage was determined by rinsing cut pieces of okra with water. The pieces of 5g were picked from the lot then soaked in water for 15 min and the electroconductivity of the water determined using a Hanna electroconductivity meter

Weight loss: Weight of pods per bag (WP) were determined using an electric weighing balance and weight loss (WL) calculated on the basis of the initial weight (IW) at the start of the experiment and the final weight (FW) at the end of the experiment WL (%) = [(IW-FW/IW] * 100

Incidence of decay (ID) was calculated based on number of pods showing symptoms of decay (D) to the total number of pods per bag (TP) at the end of 21 days of storage. ID (%) = [(D/TP)*100].

Statistical analyses

Data collected was subjected to analysis of variance (ANOVA) at $p \leq 0.05$. The analysis of treatment means was done using the Mixed Models procedure of SAS V9.1 statistical package (SAS Institute, 2002). The UNIVARIATE procedure of SAS was used to check that the data were normally distributed before performing the analysis.

RESULTS AND DISCUSSIONS

Visual appearance

The best visual appearance was observed in pods kept in perforated packages and stored either at room storage temperature or 13°C (Table-1). Blackening was inhibited under this storage condition resulting in the best visual appearance of okra pods. It is possible that pod discoloration was controlled by atmosphere modification provided by packaging. Pods kept either in perforated or non perforated packages and stored at 8.5°C had the worst visual appearance.

Table-1. Interactive effects of storage temperature and packaging on visual appearance of Okra.

	Storage temperatures (°C)			
Treatments	4	8.5	13	RT[w]
	Visual appearance			
Free pod packaging	2.9b[x]	2.4b	3.0b	3.0b
Perforated packaging	3.1b	1.3d	5.2a	5.5a
Non perforated packaging	3.0b	1.3d	3.0b	4.8a

[x]Means followed by the same suffix are not significantly different in all columns at DMRT $P \leq 0.05$

[w]Room temperature (RT) varied between 15-20°C. Hedonic scale used is 7 (excellent) to 1 (not acceptable).

Off odour

There was no off odour in pods kept at 4°C storage temperature and in free pod packaging. The pods at 4°C were frozen, while those in free pod packaging were dry and hence did not decay. Pods in non perforated and perforated packaging and stored at 8.5°C had the worst off odour. The best marketable pods that were not frozen and had the least off odour were those kept at 13°C storage temperature treatment in non perforated packaging (Table-2). Yehoshua *et al.* (1998) also found that pods in perforated packaging had less off odour than those in non perforated packaging. This finding is also similar to a study carried out on parsley where perforated packaging retained flavour and aroma better than in non perforated packaging (Heyes, 2004). In storage, ventilation is very important to avoid build up of carbon dioxide and heat as non perforation permits slow gas exchange combined with vapour and heat build up leading to rapid deterioration.

Table-2. Interactive effects of storage temperature and packaging on off odour.

	Storage temperatures (°C)			
Treatments	4	8.5	13	RT[w]
	Off odour			
Free pod packaging	5.0a[x]	5.0a	5.0a	5.0a
Perforated packaging	5.0a	1.3d	4.0bc	3.9bc
Non perforated packaging	5.0a	1.2d	4.3b	3.5c

[x] Means followed by the same suffix are not significantly different in all columns at DMRT P ≤ 0.05
[w] Room temperature (RT) varied between 15-20°C. Hedonic scale used is 7 (excellent) to 1 (not acceptable).

Chilling injury

Results show that there was no chilling injury of okra pods stored at 13°C and at room temperatures (Table-3). However, low storage temperature caused chilling injury in okra pods across all the packaging methods tested. The pods were more susceptible to chilling injuries at lower temperatures probably due to the fact that okra is of tropical origin. Paull and Chen (1990) reported that many fruits, vegetables, and ornamentals of tropical or subtropical origin are sensitive to low temperatures. These crops are injured after a period of exposure to chilling temperatures below 10 to 13 °C, but above their freezing points (Wang, 2001). Crops which are susceptible to chilling injury often have a short storage life as low temperatures cannot be used to slow deterioration and pathogen growth. The primary cause of chilling injury is thought to be damage to plant cell membranes. The membrane damage sets off a cascade of secondary reactions, which may include ethylene production, increased respiration, reduced photosynthesis, interference with energy production, accumulation of toxic compounds such as ethanol and acetaldehyde and altered cellular structure.

Table-3. Effect of packaging and storage temperature on okra chilling injury after 21 days of storage.

	Storage temperatures (°C)			
Treatments	4	8.5	13	RT[w]
	Chilling injury (%)			
Free pod packaging	100.0a[x]	100a	0.0b	0.0d
Perforated packaging	100.0a	86.1c	0.0d	0.0d
Non perforated packaging	100.0a	93.2d	0.0d	0.0d

[x] Means followed by the same suffix are not significantly different in all columns at DMRT P ≤ 0.05
[w] Room temperature (RT) varied between 15-20°C. Hedonic scale used is 7 (excellent) to 1 (not acceptable).

Electrolyte leakage

Regardless of packaging, storage temperature at 4°C had the highest electrolyte leakage (Table-4). In free pod packaging, least electrolyte leakage was observed on pods stored at room temperature, while in perforated and non perforated packages, the least electrolyte leakage was observed in pods kept at 13°C and room storage temperature (Table-4). This suggested that packaging at higher storage temperatures greatly reduced electrolyte leakage. Pods stored at 4°C and 8.5°C were very susceptible to high electrolyte leakage. This could be an indication that the pod membrane was damaged, therefore, causing solute leakage. Thompson (1996) reported that the lower the temperature the longer the storage duration. For okra this does not agree with Thompson's (1996) observations since results showed that the optimal temperature is between 13°C and 18°C where the best quality of pods was achieved, as okra is a tropical vegetable.

Table-4. Interactive effects of storage temperature and packaging on electrolyte leakage ($EC.m^S/cm$) of okra pods.

	Storage temperatures (°C)			
Treatments	4	8.5	13	RT[w]
	Electrolyte leakage ($EC.m^S/cm$)			
Free pod packaging	12.0b[x]	10.0cd	8.8d	5.9e
Perforated packaging	12.3b	11.8b	2.5f	5.3e
Non perforated packaging	11.3bc	14.3a	2.6f	5.7e

[x] Means followed by the same suffix are not significantly different in all columns at DMRT $P \leq 0.05$
[w] Room temperature (RT) varied between 15-20°C. Hedonic scale used is 7 (excellent) to 1 (not acceptable).

Weight loss

There was a general gradual increase in weight loss at every packaging level and with increase in storage temperature (Figure-1). Lowest weight loss of 0% to 6.3% was observed in the pods stored in non perforated polyfilm tubes (0.03mm) across all the storage temperatures. However, there was no weight loss in the pods stored at 4C as the pods were frozen and therefore had very low metabolic processes. Packaging treatments compared to the other treatments had more effect on weight suppression. For example, the greatest weight loss (79%) was in unpackaged pods stored at temperature of 13°C for 21 days, compared to maximum weight loss of 30% observed in the pods stored at the same temperature (13°C) but in perforated packages. This may explain why unpackaged okra pods stored at all temperatures were not marketable by day 21. In a similar study, storing apples at 0°C in modified atmosphere storage increased firmness, maintained quality and decreased weight loss due to low temperatures and high humidity (Brackman and Bortoluzzi, 2001), thus supporting the findings and observations in this okra study. Perforated packaging had better storing ability than non perforated packaging

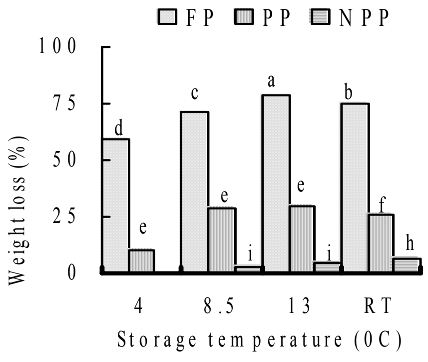

Figure-1. Interactive effects of storage temperature and packaging on weight loss.

Decay incidence

All the okra pods kept at 4°C storage temperature were frozen irrespective of the treatment. These pods had no decay, but had severe chilling injury. Most the decay was observed in pods kept in perforated and non perforated packages and stored at 8.5°C indicating that these conditions are unsuitability for okra storage. But as the storage temperature was increased (Figure-2) there was a substantial reduction in decay incidence on the pods. Pod blackening was inhibited as the storage temperatures were increased above 13°C in both packages. Packaging might have improved moisture retention, and reduced exposure to microorganisms and contaminants (Figure-2). Similar findings have been made with bell peppers stored in perforated packaging which had a lower decay incidence than in non perforated packaging (Yehoshua *et al.,* 1998). There was no decay incidences recorded on the non packaged pods, these pods dried out long before the 21st day of storage.

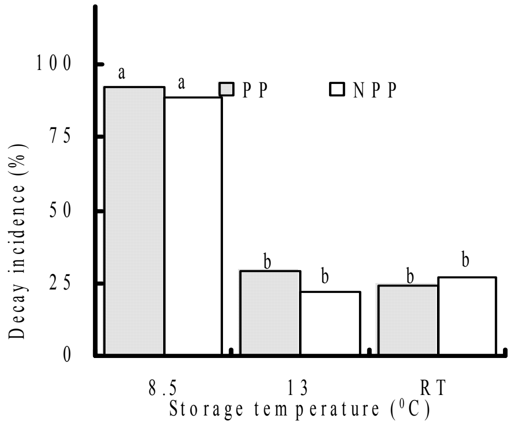

Figure-2. Interactive effects of storage temperature and packaging on decay incidence in okra pods stored for 21 days after harvesting.

CONCLUSIONS

Storage temperature and packaging greatly affected quality of okra pods. However, among the treatments investigated in this work, the best post-harvest treatment combination to manage okra quality was where okra pods were packaged in perforated polyfilm bags and stored at room temperature of 15-20°C. The pods subjected to this treatment combination had good visual appearance, least off odour, low decay, low electrolyte leakage, no chilling injury and limited weight loss. The pods stored under these conditions were of high quality and optimal marketability. The treatment combination suppressed pod quality deterioration and improved shelf life for 21 days.

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