

EFFECTS OF PACKAGING MATERIALS AND STORAGE TEMPERATURE ON QUALITY OF FRESH OKRA (*ABELMOSCHUS ESCULENTUS*) FRUIT

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Abstract

The effect of packaging materials on weight loss, colour, titratable acidity, microbial load, moisture, ascorbic acid, pH and ash contents of okra (*Abelmoschus esculentus*) was studied during storage at room ($28 \pm 2^\circ\text{C}$) and refrigerating condition ($15 \pm 2^\circ\text{C}$) using three different packages (open plastic bowl (which served as control), plastic sieve over-wrapped with low density polyethylene bags, low density polyethylene bags (LDPE) – 15×15 cm). The experiments were set up in a split plot design with storage medium being main plots and packaging material being sub-plots. The results showed that packaging materials had a significant ($p < 0.05$) effect on weight loss, firmness, pH and ascorbic acid. Ash content was better preserved in low density polyethylene (LDPE) bags stored in both storage media. Okra stored in polyethylene followed by plastic sieve container controlled weight loss and delayed senescence significantly ($p < 0.05$). The results of the chemical analysis showed a decrease in pH from 6.7 to 5.5, increase in titratable acidity and decrease in ascorbic acid content under both storage conditions. Ascorbic acid was however more retained in polyethylene at refrigerating condition than its control counter part. Fruit rot was noticed on the twelfth day of storage. Result of total viable count showed growth increase in polyethylene samples during storage than the control under room condition. LDPE packaging material however extended okra marketable life with lowest weight loss up till the ninth day at room temperature and more than 9 days under refrigerating condition. Therefore, our results indicate that LDPE was better than other storage materials in okra storage, with refrigeration better than room condition storage medium.

Key words: okra (*Abelmoschus esculentus*), packaging materials, low density polyethylene, ambient temperature, refrigerating condition, storage period

INTRODUCTION

The importance of fruits and vegetable cannot be overemphasized. The vitamin content in fruits and vegetable is known to be nutritionally superior when compared to many cereal and leguminous crops (FAO, 1992). They are highly perishable due to high water content and thereby susceptible to rapid deterioration soon after harvest, therefore they have to be properly packaged and stored if not consumed immediately. Traditionally, storage materials such as calabash, earthen pots, and basket have been used for the purposes of extending shelf life few days after harvest (Kordylas, 1991).

Okra (*Abelmoschus esculentus*) is one of the most important vegetables grown in Nigeria. It is easy to cultivate and grows well on almost all parts of the countries because of its nutritional content and medicinal potentials (Moreason and Bullard, 1974). Okra left for more than two days tend to become fibrous and unsuitable for direct use, thus proper packaging and storage allows for a better quality and extends shelf life for some days (Schippers, 2000). Inadequate storage of okra results in fading of colour by oxidation and enzymatic activities which affect the commercial value of fresh okra when stored at room temperature (Isiong, 1997). When okra is used for local dishes, it is for the purpose of providing flavour, thickening and colour (Adom et al., 1996). Its stringy gum-like consistency is

particularly desirable in soup and it is believed to be a significant source of protein in the tropics (Constatinides, 1976). It is also a good source of fibre as indicated in the treatment and prevention of many diseases including colon cancer.

Commercially, fresh pods are usually marketed in open streets markets or supermarket without any kind of temperature or humidity control. Consumers identify the loss of fruit quality by the external yellowing and by the toughening or lack of tissue rupture of the apical pod when twisted with fingers (Finger et al., 2008).

Due to increase in demand of fresh fruits and vegetables, there is needed to develop improved method for maintaining product quality and freshness. Loss in quality and limited shelf life are major problems faced in marketing fresh okra in Nigeria due to its high respiration rate at warm temperature. In order to extend the shelf life of okra, it is essential to package it in appropriate packaging materials to reduce the rate of respiration.

In banana, the modified atmosphere generated by wrapping bananas in non perforated polyethylene bags resulted in less visible symptoms of chilling when compared with control fruits (Nguyen et al., 2004)

The present investigation was therefore carried out to develop a modified atmosphere packaging system and investigate the effect of packaging materials on the physical and chemical properties and the micro-flora of okra.

MATERIALS AND METHODS

Freshly harvested okra (47.4 variety) was purchased from a commercial farm at Gambari Village, Surulere Local Government, Ogbomoso, Nigeria. The packaging materials: low density polyethylene bag was obtained from a sachet water company in Ogbomoso and plastic sieve and bowl containers were purchased from a plastic store in Ogbomoso. Fruits of average dimension 50–70 mm long and 12–15 mm diameter were selected for the study. The fruits were sorted for size, colour and physical damage. These were later packaged in low density polyethylene (15/15 cm), plastic sieve type container over wrapped with low density polyethylene and plastic bowl container which was left open as control. Each container contained 20 fruits of okra. The packaged samples were kept at both ambient temperature ($28 \pm 2^\circ\text{C}$) and refrigerating condition ($15 \pm 2^\circ\text{C}$) in a thermostatically controlled fridge.

Analysis

Samples from each treatment were removed from storage every 3 days for assessment. Moisture, ash, pH values and titratable acidity of all samples were determined using the AOAC official methods of analysis (AOAC, 1990).

The colour of okra samples was evaluated using the Jenway colorimeter (model 6051) on the milled samples. The iodine titration method was used to determine the vitamin C content of okra as described by Jacobs (1999).

Weight loss

Weight loss of okra was recorded to an accuracy of 0.01 g using a Mettler balance model P1200 and percentage weight loss was calculated thus

$$\% \text{ Weight loss} = \frac{(\text{Initial weight} - \text{final weight})}{\text{Initial weight}} \times 100$$

Total viable count

Total microbial count was obtained by pour plate method using nutrient agar as the growth medium. 1 ml of the diluent was poured into sterile Petri dishes and

about 10 ml of nutrient agar was gently dispensed on it. The plate was swirled gently and was inverted after it had solidified. The plates were inverted and incubated at 37°C for 24 hours. The colonies were counted and the number of colonies per plate was multiplied by the dilution factor to obtain the total viable counts per ml of the original sample.

Statistical analysis

The experiment was set up in split plot design. Data generated were subjected to analysis of variance (ANOVA) using SAS Software package (SAS Institute, 1985). Significant means were determined with the aid of Fischer's Least significant difference (LSD) at 5% probability level.

RESULTS

Loss in weight

Generally weight loss progressively increased with storage time and was higher in unwrapped bowl samples stored at ambient and refrigeration conditions as shown in Table 1. There was significant difference in weight loss of okra stored in the open bowl and those stored in LDPE and plastic sieve over-wrapped with LDPE. About six percent of the weight was lost by the third day in the control sample while about 3 percent was loss in the polyethylene when stored in the fridge, whereas bowl weight loss was 8.1%, while LDPE weight loss was 1.1% under room condition. At the end of 9 days, the control samples lost 27.3% and 37.2% of their original weight while samples stored in polyethylene lost just 3.9% and 5.8% of their original weight, when stored under fridge and room conditions respectively.

Moisture and ash contents

The trend of moisture content of stored okra is represented in Table 2. Moisture content decreased with storage period, with greater decrease in room condition than fridge. The initial moisture content of okra was about 88%. After nine days of storage, the moisture content of okra ranged between 84.4% and 85.4% for

Tab. 1: Effects of storage medium and packaging material on percentage weight loss of stored okra fruit

Storage medium	Packaging material	Storage duration (days) \pm		
		3	6	9
Fridge	Bowl	$6.3 \pm 0.0a$	$16.3 \pm 0.0a$	$27.3 \pm 0.0c$
	LDPE	$3.1 \pm 0.0c$	$3.8 \pm 0.0c$	$3.9 \pm 0.0a$
	Sieve	$3.8 \pm 0.0b$	$5.6 \pm 0.0b$	$14.6 \pm 0.0b$
Room	Bowl	$8.1 \pm 0.0a$	$18.3 \pm 0.0a$	$37.2 \pm 0.0c$
	LDPE	$1.1 \pm 0.0c$	4.5 ± 0.00	$5.8 \pm 0.0a$
	Sieve	$5.7 \pm 0.0b$	$12.86 \pm 0.0b$	$22.9 \pm 0.0b$

\pm = standard deviation; Bowl = unwrapped plastic bowl; LDPE = low density polyethylene bags; Sieve = over-wrapped with low density polyethylene bags

For each of the storage medium, means carrying similar alphabets within the column are not significantly different (LSD at 5% probability).

Tab. 2: Effects of storage medium and packaging material on percentage moisture content of stored okra fruit

Storage medium	Packaging material	Storage duration (days)			
		0	3	6	9
Fridge	Bowl	87.8 ± 0.1	87.65 ± 0.2a	85.7 ± 0.1b	84.4 ± 0.2c
	LDPE	87.8 ± 0.1	86.8 ± 0.1b	86.0 ± 0.0a	85.4 ± 0.1b
	Sieve	87.8 ± 0.1	87.6 ± 0.1c	85.4 ± 0.1b	85.0 ± 0.0a
Room	Bowl	87.8 ± 0.1	86.4 ± 0.1b	84.04 ± 0.0a	83.5 ± 0.1b
	LDPE	87.6 ± 0.1	86.8 ± 0.2a	86.0 ± 0.0a	85.2 ± 0.00a
	Sieve	87.6 ± 0.1	86.9 ± 0.07a	86.02 ± 0.09a	85.4 ± 0.00

± = standard deviation; Bowl = unwrapped plastic bowl; LDPE = low density polyethylene bags; Sieve = over-wrapped with low density polyethylene bags

For each of the storage medium, means carrying similar alphabets within the column are not significantly different (LSD at 5% probability).

Tab. 3: Effects of storage medium and packaging material on percentage Ash content of stored okra fruit

Storage medium	Packaging material	Storage duration (days)			
		0	3	6	9
Fridge	Bowl	9.5 ± 0.0a	9.5 ± 0.0a	9.4 ± 0.0a	8.9 ± 0.0a
	LDPE	9.5 ± 0.0a	9.5 ± 0.0a	9.5 ± 0.0a	9.5 ± 0.0a
	Sieve	9.5 ± 0.0a	9.5 ± 0.0a	9.5 ± 0.0a	9.2 ± 0.0a
Room	Bowl	9.5 ± 0.0a	9.5 ± 0.0a	9.0 ± 0.0b	7.9 ± 0.2c
	LDPE	9.5 ± 0.0a	9.5 ± 0.0a	9.4 ± 0.0a	9.3 ± 0.0a
	Sieve	9.5 ± 0.0a	9.4 ± 0.0a	8.4 ± 0.02c	8.3 ± 0.0b

± = standard deviation; Bowl = unwrapped plastic bowl; LDPE = low density polyethylene bags; Sieve = over-wrapped with low density polyethylene bags

For each of the storage medium, means carrying similar alphabets within the column are not significantly different (LSD at 5% probability).

Tab. 4: Effects of storage medium and packaging material on pH of stored okra fruit

Storage medium	Packaging material	Storage duration (days)			
		0	3	6	9
Fridge	Bowl	6.7 ± 0.0a	6.6 ± 0.0a	6.3 ± 0.0b	5.9 ± 0.0b
	LDPE	6.7 ± 0.0a	6.4 ± 0.4b	6.6 ± 0.0a	5.8 ± 0.0b
	Sieve	6.7 ± 0.0a	6.6 ± 0.0a	6.5 ± 0.0a	5.6 ± 0.0a
Room	Bowl	6.7 ± 0.0a	6.5 ± 0.0a	6.0 ± 0.0b	5.9 ± 0.0a
	LDPE	6.7 ± 0.0a	6.5 ± 0.0a	6.3 ± 0.0b	6.0 ± 0.0a
	Sieve	6.7 ± 0.0a	6.6 ± 0.0a	6.5 ± 0.0a	5.9 ± 0.0a

± = standard deviation; Bowl = unwrapped plastic bowl; LDPE = low density polyethylene bags; Sieve = over-wrapped with low density polyethylene bags

For each of the storage medium, means carrying similar alphabets within the column are not significantly different (LSD at 5% probability).

samples stored under refrigerating condition. For samples stored in the room temperature ($28 \pm 2^\circ\text{C}$), moisture contents ranged between 83.5% and 87.8%, with lowest moisture content observed in okra stored in bowl for 9 days. Result of the ash content is shown in Table 3 which ranged from 7.9–9.5%. There were changes in chemical composition during refrigeration and ambient temperature storage of okra, with best result obtained in LDPE and poorest retention of chemical composition observed in bowl under both storage conditions.

pH and titratable acidity

Storage duration made okra to be slightly acidic; however, the difference due to storage condition was

not significant. The pH of samples stored in polyethylene bags after 3 days had value of 6.4 which was lower than values of other samples stored in bowl and plastic sieve containers under refrigeration condition (Table 4). The titratable acidity of all samples increased with storage time and control bowl samples in fridge had the least value (Table 5).

Effect on vitamin C

Table 6 showed the effect of storage and packaging on vitamin C level of okra. The initial vitamin C content of fresh okra was 43.5 mg/100 g. The ascorbic acid of all samples decreased during storage. Though, there was no significant difference in the ability of LDPE

Tab. 5: Effects of storage medium and packaging material on percentage titratable acidity of stored okra fruit

Storage medium	Packaging material	Storage duration (days)			
		0	3	6	9
Fridge	Bowl	3.0 ± 0.0a	3.0 ± 0.0b	3.2 ± 0.0c	3.4 ± 0.0c
	LDPE	3.0 ± 0.0a	3.4 ± 0.0a	3.8 ± 0.1a	4.0 ± 0.0a
	Sieve	3.0 ± 0.0a	3.0 ± 0.0b	3.5 ± 0.0b	3.6 ± 0.0b
Room	Bowl	3.0 ± 0.0a	3.2 ± 0.0b	3.7 ± 0.0b	4.3 ± 0.1a
	LDPE	3.0 ± 0.0a	3.5 ± 0.1a	3.9 ± 0.0a	4.0 ± 0.0b
	Sieve	3.0 ± 0.0a	3.3 ± 0.1b	3.9 ± 0.0a	4.0 ± 0.0b

± = standard deviation; Bowl = unwrapped plastic bowl; LDPE = low density polyethylene bags; Sieve = over-wrapped with low density polyethylene bags

For each of the storage medium, means carrying similar alphabets within the column are not significantly different (LSD at 5% probability).

Tab. 6: Effects of storage medium and packaging material on vitamin C (mg/100 g) of stored okra fruit

Storage medium	Packaging material	Storage duration (days)			
		0	3	6	9
Fridge	Bowl	43.5 ± 0.1	43.2 ± 0.1c	42.2 ± 0.0c	42.5 ± 0.0b
	LDPE	43.5 ± 0.1	43.5 ± 0.0b	43.4 ± 0.0b	43.3 ± 0.0a
	Sieve	43.5 ± 0.1	43.4 ± 0.0a	43.3 ± 0.0a	43.3 ± 0.0a
Room	Bowl	43.5 ± 0.1	43.0 ± 0.0b	41.2 ± 0.0b	40.2 ± 0.00
	LDPE	43.5 ± 0.1	43.4 ± 0.0a	42.4 ± 0.1a	42.5 ± 0.0a
	Sieve	43.5 ± 0.1	43.4 ± 0.0a	42.2 ± 0.0a	41.3 ± 0.0b

± = standard deviation; Bowl = unwrapped plastic bowl; LDPE = low density polyethylene bags; Sieve = over-wrapped with low density polyethylene bags

For each of the storage medium, means carrying similar alphabets within the column are not significantly different (LSD at 5% probability).

Tab. 7: Effects of storage medium and packaging material on microbial load (cfu/ml) of stored okra fruit

Storage medium	Packaging material	Storage duration (days)			
		0	3	6	9
Fridge	Bowl	6.0 × 10 ⁶	6.0×10 ⁸	8.5×10 ⁸	8.0×10 ⁸
	LDPE	6.0 × 10 ⁶	3.5×10 ⁸	6.0×10 ⁸	9.5×10 ⁸
	Sieve	6.0 × 10 ⁶	1.9×10 ⁹	9.0×10 ⁸	1.2×10 ⁹
Room	Bowl	6.0 × 10 ⁶	6.0×10 ⁷	6.2×10 ⁷	3.4×10 ⁸
	LDPE	6.0 × 10 ⁶	3.9×10 ⁸	1.8×10 ⁹	1.2×10 ⁹
	Sieve	6.0 × 10 ⁶	3.9×10 ⁸	6.0×10 ⁸	1.0×10 ⁹

Bowl = unwrapped plastic bowl; LDPE = low density polyethylene bags; Sieve = over-wrapped with low density polyethylene bags; cfu = Colony forming unit

and sieve in terms of vitamin C retention when okra was stored in the refrigerator, LDPE was a better storage material than sieve under room storage condition.

Microbial count

Microbial load of okra samples increased with storage period under both storage conditions. LDPE performed better than other packaging materials at 4–8 days in fridge. After 8 days, the performance of LDPE was poorer than bowl. Under room condition however, the performance of LDPE was quite poor, having higher microbial count than what was obtained in sieve and bowl (Table 7).

DISCUSSION

Weight loss progressively increased with storage time and it was higher in unwrapped bowl samples. Weight loss of okra packed in LDPE was lower and linearly increased from day 3 to day 9. Weight loss was higher in samples stored in bowl at room temperature than samples stored in polyethylene and the plastic sieve container under ambient condition and the difference was significant at $P < 0.05$. This was due to uncontrolled water loss and food reserve loss from tissues of okra due to biochemical activities such as transpiration and respiration (Santi et al., 1992). Batu and Thompson

(1998) reported weight loss in tomatoes stored in films to be related to film permeability due to transmission rates of water vapour and this could also be associated with lower losses recorded in okra stored in polyethylene bags and plastic sieve containers. Samples stored at $15 \pm 2^\circ\text{C}$ had the weight of okra better preserved than samples stored under ambient condition. This agreed with findings of Finger et al. (2008) who reported that lowering the temperature of storage room decrease the weight loss in both poly vinyl chloride (PVC) wrapped and control fruits with a lower rate at 5°C .

Variation in moisture content of fresh okra (87.7%) to the one reported by the Ihekoronye and Ngoddy (1985) could be due to environmental and varietal difference. The moistures content of all samples decreased with the storage time, the changes were however not significantly different until the sixth day of storage. The moisture loss in all packaging materials at the two storage conditions was however significant ($p < 0.05$) after the sixth day of storage. Samples stored in LDPE retained moisture better than the control bowl samples. This could be attributed to the property of the low density polyethylene which exhibited good barrier to water vapour loss (Zagory, 1995) and also had the ability to reduce respiration rate of vegetables which in turn reduced moisture loss as reported by Lee et al. (1995). Finger et al. 2008 also reported that relative water content of the fruit pericarp of okra was maintained through out in the storage while at 25°C the high weight loss was associated with significant reduction of the water. Considering the samples stored under ambient condition, moisture loss was greater in the control bowl samples. Plastic sieve samples retained more and a little above polyethylene which was not significant. Decrease in moisture content which was more pronounced in the control samples was similar to findings of Amati et al. (1989) who reported moisture loss in fruit and vegetables to be due to post-harvest physiological processes such as respiration and transpiration. The ash content of produce was not affected by storage and packaging material until the sixth day of storage (Table 3). The LDPE bags retained ash content better than plastic sieve

and the bowl control samples. Ash content of samples stored in the three packaging materials differed significantly at 5% probability level with LDPE retaining ash content better. This was followed by samples stored in plastic sieve over wrapped with LDPE and the loss was higher in control bowl samples. Reason for the loss in ash content was not known. Titratable acidity with storage time increased and bowl samples in the fridge were less acidic. For samples stored in the room condition, the increase in titratable acidity for all packaging materials was not significant.

There was reduction in the pH of all samples which implies that fresh okra turned more acidic with increase in storage period. LDPE samples stored in the fridge had the value of 5.8 at 9 days of storage and this may be attributed to increase in total acids which increased the hydrogen ion concentration (Pantastico, 1975). Samples stored in low density polyethylene and plastic sieve in fridge retained vitamin C better than those stored in ambient condition and this was similar to what Weichmann (1987) reported that ascorbic acid content of stored produce generally decrease more rapidly at higher storage temperature since it is thermo labile. Greater loss of vitamin C in samples stored in bowl at $28 \pm 2^\circ\text{C}$ was due to the fact that it was exposed to oxygen and light which affected the stability of vitamin C.

Okra colour changed rapidly after the first 3 days of storage and later at a slower rate over the next 6 days. Fruit sealed in LDPE changed colour more slowly than those stored in plastic sieve container and bowl although the difference was not significant. However colour of samples stored in fridge at $15 \pm 2^\circ\text{C}$ was better retained. Rapid colour loss in bowl samples stored at room temperature could be attributed to exposure of samples to atmosphere gases which results in fading out of greenish colour (Salunkhe, 1991).

The microbial load of okra samples increased during the storage time of all packaged samples. The microbial load showed significant differences as storage time increased. The trend continued for the rest of the experimental study with the room polyethylene samples having the highest microbial load. This could be due

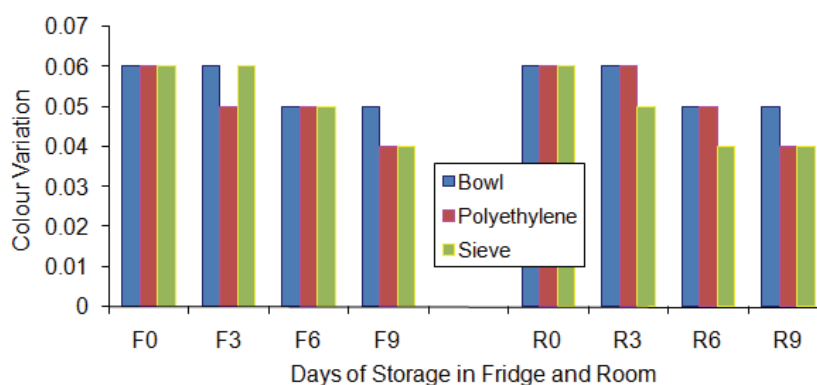


Figure 1: Effect of storage medium and packaging material on colour variation of Okro monitored between 0 and 9 days

to the heat of respiration in the packaging material at the early period of storage.

CONCLUSIONS

The results of this work suggest that the storage medium, the method of storage and packaging material had significant effect on quality of okra. The moisture content, ash and vitamin C in LDPE bags, followed by plastic sieve over wrapped with LDPE were better preserved. It may therefore be suggested that okra should be packaged in low density polyethylene and stored at room temperature for optimum period of nine days and more than nine days in a thermostatically controlled refrigerator at $15 \pm 2^\circ\text{C}$. Plastic sieve materials can be employed when okra is freshly harvested from farm after appropriate cooling and can be over-wrapped with low density polyethylene rather than conventional raffia basket used in developing countries which can also cause mechanical damage to produce. However, further studies are still needed on pre-treatment of fresh okra samples prior to storage.

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