

Effect of Storage Conditions on Some Physico-Chemical and Microbiological Properties of Fresh Okra (*Abelmoschus esculenta*) Fruits

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Abstract: The effects of storage conditions on some physico-chemical and microbiological qualities of fresh okra were determined and compared. Fresh okra fruits were stored in open plates and sealed polyethylene bags in the refrigerator (F_1 , F_2), on the shelf in the laboratory (S_1 , S_2) and in the open sun (O_1 , O_2) respectively for a period of nine (9) days. The moisture content, viscosity, microbiological composition and sensory properties of the stored fruits were determined on a daily basis during the period of storage. The moisture content and viscosity decreased during storage from 92.00% and 700 cP in fresh okra to 35.50% and 100 cP in okra stored in open plates in the sun (O_2) respectively. On the other hand, bacterial count increased from 2.27×10^4 CFU/mL in fresh okra to 2.72×10^5 CFU/mL in okra stored in polyethylene bag in the sun (O_2), while okra stored in open plates on the shelf (S_1) had the highest mould count of 9.0×10^4 CFU/mL. Okra stored in polyethylene bag in the refrigerator (F_2) had the highest moisture content of 84.50%, viscosity of 440 cP and the lowest bacterial and mould counts of 1.15×10^4 and 4.0×10^3 CFU/mL, respectively. Mean sensory scores in respect of colour, smell, texture and general acceptability showed that samples stored in the refrigerator scored higher in all attributes and had higher acceptability at the end of the storage period, which compared favourably with fresh okra fruits.

Keywords: Deterioration, fresh, polyethylene, refrigeration, shelf, viscosity

INTRODUCTION

Stored food products are in constant danger of deterioration from heat, insect infestation and moisture loss. The method of storage will depend on the food product in question, since each crop has an optimum level of temperature and moisture content for best storage (Snowdown, 1992). For example grains store well in a cool dry place while roots and tubers, fruits and vegetables require cool temperature with high humidity (Sargent *et al.*, 2006).

Post-harvest handling and storage of fresh commodities such as fruits and vegetables must therefore aim at reducing the reactions that tend to break down the products. To prolong the shelf life of stored food products, especially fruits and vegetables, it is desirable to reduce the rate of respiration and loss of water by transpiration. Removal of ethylene from the store can have a beneficial effect on the storage life and quality of fruits (Perkins-Veazie and Collins, 2002).

Okra (*Abelmoschus esculenta*), one of the most popular vegetables in Nigeria, is a very nutritious crop, containing a high quantity of sugar, protein, dietary fibre, vitamins, minerals and unsaturated fatty acids. Its protein is of very high quality, with a high content of lysine,

tryptophan and sulphur-containing amino acids (Pavlos *et al.*, 1991). It is a member of the mallow family and is locally known as "Atuur" in Tiv, "Ikpoho" in Idoma "Okuru" in Ibo "Ila" in Yoruba and "Kubewa" in Hausa. It also has a high content of unsaturated fatty acid e.g. linoleic acid, which makes okra seed oil desirable. The vitamin content of fruits and vegetables is nutritionally superior when compared to many cereals and leguminous crops (FAO, 1992).

Fresh okra is available all year round with its peak during the raining season (Ijoyah *et al.*, 2010). It is however highly susceptible to rapid deterioration during storage due to high water content soon after harvest, therefore they have to be properly packaged and stored if not consumed immediately. Thus proper storage and packaging allows for a better quality and extends its shelf life for more days (Schippers, 2000). Inadequate storage of fresh okra fruits at room temperature results in fading of colour by oxidation and enzymatic activity which affects their commercial value (Isiong, 1997).

The objective of this study was therefore, to determine the effect of storage conditions on the moisture content, viscosity, microbiological and sensory properties of fresh okra fruits.

MATERIALS AND METHODS

Source of materials: This study was conducted in the laboratories of the Department of Food Science and Technology, University of Agriculture, Makurdi, Nigeria. Fresh okra (*Abelmoschus esculentus*) fruits were purchased from an okra farm in Idye village in Makurdi, Benue State.

Sample preparation: The okra fruits were washed clean using distilled water and allowed to drain. They were then divided into two sets of three samples each, in open plates and sealed polyethylene bags (to mimic the different ways in which okra fruits are usually displayed in the market for sale). These sets were then replicated and stored in the refrigerator (8-10°C), on the shelf in the laboratory (28-32°C) and in the sun (38-45°C) for a period of nine (9) days, from where samples were taken for analysis every 24 h.

Analyses: While moisture content was determined by the method of AOAC (2005), viscosity was determined by the method described by Woolfe *et al.* (1997), microbiological composition by the method described by Frazier and Westhoff (2010) and sensory evaluation was carried out using the 9-point hedonic scale quality analysis as described by Mellgard *et al.* (2007).

Statistical analysis: Analysis of Variance (ANOVA) was carried out on the sensory scores obtained using a prepackaged computer analytical tool (MINITAB 15).

RESULTS

Moisture content: The moisture content of stored okra is shown in Fig. 1. The results show that moisture content decreased as storage period increased with a greater decrease in okra stored outside compared to storage in the refrigerator. A similar trend is shown for storage in open bowls as compared to storage in polyethylene bags. Okra stored in a polyethylene bag in a refrigerator (F₂) showed the least loss of moisture as it reduced from 92.00% in the fresh okra to between 87.50-84.50% during the storage period. Okra stored in a polyethylene bag in the sun (O₂) had a moisture range of 85.50-77.50%, while those stored in open plates in the refrigerator (F₁) had moisture range of 82.50-77.50%. This was followed by okra stored in a polyethylene bag on the shelf (S₂) had a moisture range of 86.9-76.1%. Samples stored in polyethylene bags showed lower moisture loss compared to samples in open bowls.

Viscosity: The viscosity of the okra samples during storage is presented in Fig. 2. There was generally a reduction in viscosity with increase in storage period.

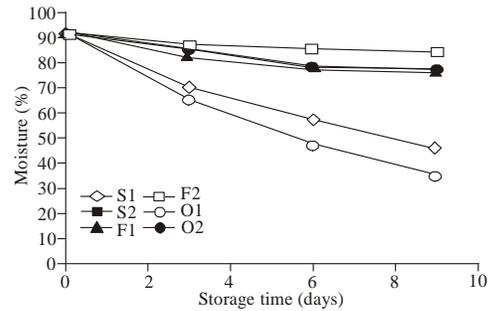


Fig. 1: Moisture content of okra fruits during storage
 S₁: Fresh okra stored in an open plate on the shelf; S₂: Fresh okra stored in a polyethylene bag on the shelf; F₁: Fresh okra stored in an open plate in a refrigerator; F₂: Fresh okra stored in a polyethylene bag in a refrigerator; O₁: Fresh okra stored in an open plate in the sun; O₂: Fresh okra stored in a polyethylene bag in the sun

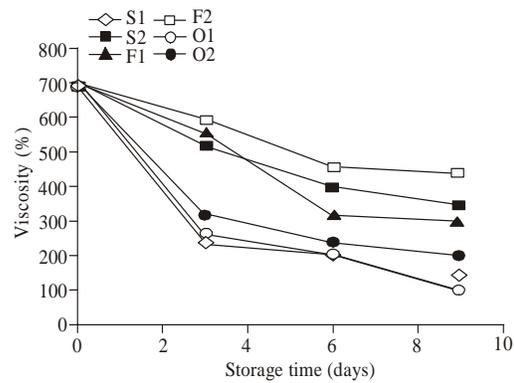


Fig. 2: Viscosity of okra fruits during storage
 S₁: Fresh okra stored in an open plate on the shelf; S₂: Fresh okra stored in a polyethylene bag on the shelf; F₁: Fresh okra stored in an open plate in a refrigerator; F₂: Fresh okra stored in a polyethylene bag in a refrigerator; O₁: Fresh okra stored in an open plate in the sun; O₂: Fresh okra stored in a polyethylene bag in the sun

Okra stored in open plates in the sun (O₁) and on the shelf (S₁) showed the highest reduction in viscosity with values ranging from 240-100 and 260-140 cP respectively compared to 700 cP for fresh okra. This was followed by the okra stored in a polyethylene bag in the sun (O₂) whose viscosity ranged between 320-200 cP. Okra stored in a polyethylene bag on the shelf (S₂) had viscosity values ranging from 520-350 cP, while okra stored in a polyethylene bag in the refrigerator (F₂) showed the least reduction in viscosity with values ranging from 600-440 cP followed by okra stored in open plates in the refrigerator (F₁) whose viscosity ranged from between 560-300 cP.

Microbial composition: The result of the microbial analysis of stored fresh okra is shown in Fig. 3 and 4.

Table 1: Mean sensory scores of stored okra samples

Attributes	F ₀	S ₁	S ₂	F ₁	F ₂	O ₁	O ₂	LSD
Colour	7.40 ^a	2.60 ^d	3.80 ^c	6.70 ^b	7.00 ^a	2030 ^d	2.70 ^a	0.55
Smell	7.30 ^a	6.50 ^a	1.70 ^c	6.10 ^b	6.10 ^b	6.70 ^a	1.90 ^c	1.00
Texture	7.20 ^a	1.70 ^c	3.70 ^d	5.70 ^b	5.70 ^a	1.60 ^e	4.50 ^c	0.70
General acceptability	7.70 ^a	2.00 ^e	2.70 ^d	5.10 ^c	6.70 ^b	1.70 ^e	2.80 ^d	0.80

Means with the same superscript within the same row are not significantly different ($p > 0.05$); F₀: Fresh okra; S₁: Fresh okra stored in an open plate on the shelf; S₂: Fresh okra stored in a polyethylene bag on the shelf; F₁: Fresh okra stored in an open plate in a refrigerator; F₂: Fresh okra stored in a polyethylene bag in a refrigerator; O₁: Fresh okra stored in an open plate in the sun; O₂: Fresh okra stored in a polyethylene bag in the sun

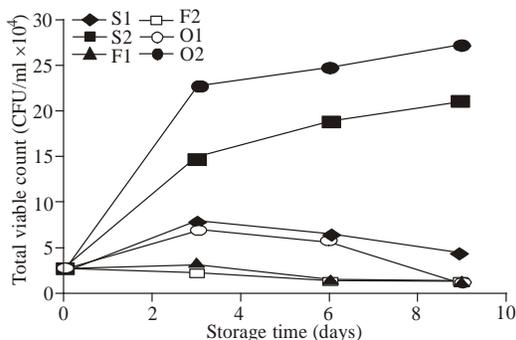


Fig. 3: Total Viable Count (TVC) of okra fruits during storage S₁: Fresh okra stored in an open plate on the shelf; S₂: Fresh okra stored in a polyethylene bag on the shelf; F₁: Fresh okra stored in an open plate in a refrigerator; F₂: Fresh okra stored in a polyethylene bag in a refrigerator; O₁: Fresh okra stored in an open plate in the sun; O₂: Fresh okra stored in a polyethylene bag in the sun

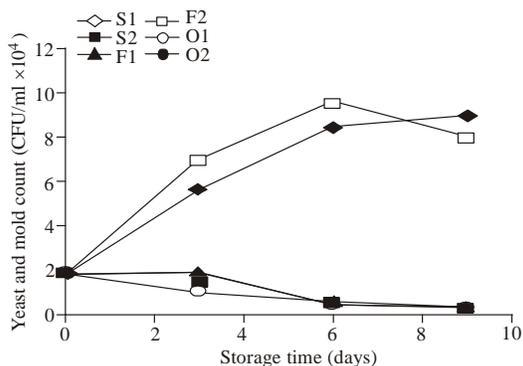


Fig. 4: Yeast and mould count of okra fruits during storage S₁: Fresh okra stored in an open plate on the shelf; S₂: Fresh okra stored in a polyethylene bag on the shelf; F₁: Fresh okra stored in an open plate in a refrigerator; F₂: Fresh okra stored in a polyethylene bag in a refrigerator; O₁: Fresh okra stored in an open plate in the sun; O₂: Fresh okra stored in a polyethylene bag in the sun

During the storage period, the okra stored in a polyethylene bag in the sun (O₂) had the highest bacterial count of 2.72×10^5 but a low yeast and mould count of 1.1×10^4 . This was followed by okra stored in a polyethylene bag on the shelf (S₂) with a bacterial count

of 2.1×10^5 and yeast and mould count of 1.52×10^4 . Okra stored in open plates on the shelf (S₁) had a bacterial count of 8.0×10^4 and high yeast and mould count of 5.7×10^4 , while the one stored in the sun had a bacterial count of 7.0×10^4 and yeast and mould count of 7.0×10^4 . Okra stored in a polyethylene bag in the refrigerator (F₂) had the least microbial count with a bacterial count of 1.15×10^4 , and a yeast and mould count of 1.15×10^4 . This was followed by okra stored in an open bowl in a refrigerator (F₁) which had a bacterial count of 3.2×10^4 and yeast and mould count of 1.96×10^4 .

Sensory analysis: Table 1 shows the mean sensory scores of the stored okra fruits. At the end of the storage period okra stored in open bowls on the shelf and in the sun showed a drastic significant ($p < 0.05$) colour loss from a mean sensory score of 7.10 in fresh okra (F₀) to 2.30 (O₁) and 2.60 (S₁). Okra stored in polyethylene in the sun and on the shelf had a slower colour loss than those stored in open plates with mean sensory scores of 2.70 (O₂) and 3.80 (S₂). Samples stored in the refrigerator still had acceptable colour at the end of the storage period especially the one in a polyethylene bag with mean sensory scores of 6.70 (F₁) to 7.00 (F₂). Okra stored in polyethylene in the sun and on the shelf had off-odours with mean sensory scores of 1.90 (O₂) and 1.70 (S₂) which were significantly different ($p < 0.05$) from fresh okra (F₀) and okra stored in the refrigerator (F₁ and F₂).

DISCUSSION

Moisture content: That moisture content decreased with increase in storage time could be due to transpiration, evaporation and respiratory activities of the okra samples in order to attain equilibrium with their surroundings. This agrees with the results of Santi *et al.* (1992). The finding that okra stored in polyethylene in the refrigerator lost the least amount of moisture is in agreement the findings of Finger *et al.* (2008) who reported that lowering of temperature reduces moisture loss in okra fruits with lower rates at 5°C.

In all cases okra stored in polyethylene bags retained more moisture. This could be attributed to the property of the polyethylene bag which exhibited a 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). This is also in agreement with the findings of Batu and Thompson (1998) who reported that reduced moisture loss in tomatoes stored in a film was related to poor loss of water vapour through the film. Also, that okra stored in open plates on the shelf (S₁) and in the sun (O₁) showed the highest moisture loss with a moisture range of 70.30-46.00 and 65.50-35.50% respectively, could be due to high temperatures which increased respiration and transpiration rates thus causing drying of the okra fruits.

Viscosity: The reduction in viscosity with increase in storage period could be attributed to the utilization of carbohydrates (okra mucilage) during metabolism while in storage. While refrigeration temperatures could control metabolic processes of the okra after harvest, room and sun temperatures could not, thus leading to the breakdown of polysaccharides, causing greater reduction in viscosity in samples in the sun and on the shelf than in the refrigerated samples. This is similar to the findings of Woolfe *et al.* (1997) who reported that at high temperatures there will be a reduction in viscosity in okra mucilage as de-polymerization of polysaccharide will occur. The smaller reduction in the viscosity of refrigerated and polyethylene packaged samples compared to samples in open bowls on the shelf and in the sun could also be due to the influence of humidity. Adetuyi *et al.* (2008) reported that storage of Benin indigenous okra at 100% humidity recorded minimal reduction in the viscosity of the okra.

Microbial composition: The result of microbial composition shows that there was a reduction in microbial load of refrigerated samples during the storage period. This is in agreement with the findings of Ngure *et al.* (2009) who reported that storage of fresh okra at temperatures between 10-20°C reduces microbial load. The samples stored in open plates on the shelf and in the sun showed high microbial contamination with a decrease in bacteria growth but increase in yeast and mould growth. This could be because of the drying process (loss of moisture) that took place thus lowering the water activity and making conditions conducive for yeast and mould growth. This is in agreement to the findings of Katende and Namirembe-Ssonkko (2005) who reported decrease in bacterial growth with decrease in moisture content. Komolafe and Idah (2008) also reported that if moisture content is not low enough it will still permit activities of moulds which hasten the spoilage of okra.

Okra samples stored in polyethylene bags both on the shelf and in the sun gave low yeast and mould count, but very high bacteria counts. This could be because of high moisture content (high water activity level) which gave room for more bacterial growth than yeast and moulds.

This is in conformity with the findings of Babarinda and Fabunmi (2009) who reported that the microbial load of okra samples packaged in polyethylene and kept outside the refrigerator during their study all increased. High microbial load in these samples could be due to high heat of respiration in the polyethylene bag at the early period of storage.

Sensory analysis: The drastic loss of colour of the okra stored in open plates the sun could be due to chemical activities (bleaching, oxidation and enzymatic activities) consistent with the exposure of the okra fruits. Salunkhe *et al.* (1991) reported that rapid loss of colour of fruits and vegetables was attributed to their exposure to atmospheric gases with resultant fading out of their greenish colour. In addition to their unacceptable colour okra fruits stored in polyethylene in the sun became slightly rotten and had off-odours. Komolafe and Idah (2008) also made a similar finding and attributed it to the growth and activities of microorganisms and poor ventilation. This is also in agreement with Ngure *et al.* (2009) who reported that okra stored in packages and not refrigerated had off-odours due to decay. Samples stored in open plates in the sun and on the shelf also had no significant ($p < 0.05$) off-flavours. This could be because drying and proper ventilation of the exposed okra in open bowls prevented decay. As drying proceed the samples in open plates in the sun and on the shelf even developed pleasant smells competing with fresh okra.

That samples stored in the refrigerator still had acceptable colour at the end of the storage period was consistent with Ngure *et al.* (2009), who reported that okra pod blackening was inhibited by refrigeration temperatures especially when it is packaged. Finger *et al.* (2008) also reported that the rate of chlorophyll degradation was diminished by reduction in temperature and by wrapping in PVC film. The lack of off-flavours in the refrigerated fruits could be due to controlled biochemical activity which prevented decay.

Okra stored in open plates in the sun and on the shelf had the highest textural changes compared to all other samples. This was because of loss of moisture in the samples leading to loss of textural qualities making the samples to become fibrous. This is similar to the findings of Bantu and Thompson (1998) who reported that apart from temperature, moisture loss can also cause fresh produce to deteriorate through wilting, shriveling and loss of textural qualities (softening, flaccidity, limpness, loss of crispness and juiciness).

Though samples stored in open plates in the sun and on the shelf had nice smell at the end of the storage period, they became fibrous, dry and had brownish colour, while samples in polyethylene bags on the shelf retained their high moisture content but also lost colour and had

slight off odours. Only the refrigerated samples were generally accepted at the end of the storage period, because they maintained all their sensory attributes at the end of the storage period.

CONCLUSION

This study has shown that fresh okra stored in a polyethylene bag in a refrigerator retained its quality attributes for a longer period. At the end of nine (9) days storage, it had the highest moisture content, highest viscosity, lowest microbial count and the best and most acceptable sensory attributes compared to the other stored samples. Okra stored in open plates on the shelf and outside lost so much moisture that they become dry and had the highest yeast and mould contamination during storage. Okra stored in polyethylene bags on the shelf and in the sun had high moisture content; but the highest bacteria count.

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