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Comparative Study of Quality Changes in Okra *Abelmoschus esculentus* (L) Moench Stored at Different Relative Humidities

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Abstract. Okra *(Abelmoschus esculentus* L*)* pods were stored at the relative humidity of 90% and 100% for up to 10 days. The moisture content, crude fibre, and protein, fat, viscosity, hydrolysable and condensed tannin, total phenol, vitamin C and reducing power of the okra were determined on alternate days. Okra pods stored at 100%RH experienced the least percentage loss in all the determined parameters though the loss of antinutrient was lower at this relative humidity.

Keywords: relative humidity, antioxidant, okra, storage conditions

Introduction

Okra *(Abelmoschus esculentus* (L) Moench) is a tall annual dicotyledonous plant widely grown as vegetable crop in the tropics and subtropics and also in the warmer temperate areas (Kochhar, 1986). It has many different cultivars, varying in many respects. (Tindall, 1986). Okra is traditionally grown in African regions, the most important production regions being Ghana, Burkinafaso and Nigeria (De Lannoy, 2001).

Fresh and green tender fruits of okra are used as vegetable, whereas its mucilage has medicinal applications. Okra has industrial applications as well and is used in confectionary (Siemonsma and Kouame, 2004; Shalau, 2002; Kochhar, 1986).

Okra is a powerhouse of valuable nutrients. Nearly half of its fibre is soluble and half is insoluble which helps to keep the intestinal tract healthy (Shalau, 2002). The fibres from stem and mature pods have a number of uses in papermaking, in textile and other industries. (Siemonsma and Kouame, 2004; Kochhar, 1986). In Nigeria, fresh okra is preferred to dried okra by the majority of the people and as such its consumption is highest in the rainy season when production is at its highest. The sites of okra production are always very far from the market, therefore, post-harvest deterioration of fresh okra results in loss of produce due to poor storage and transportation from the outlying villages to the city markets.

Information regarding optimum environmental conditions for extending post harvest life of okra is not available. Due to the transportation, to long distance, optimum relative humidity might be needed for storage life extension. The aim of this research work is to investigate the quality changes in Akure indigenous okra when stored at the relative humidities (RH) of 90% and 100%. The qualities assessed are nutrients, antinutrients, antioxidants and viscosity.

Materials and Methods

Okra plant (*Abelmoschus esculentus* L Moench) used in this study was of indigenous origin in Akure, Nigeria. Plants were grown on a fallow land of 5 years, measuring 14 m×14 m, located in a farm in Ifon in Ose local Government of Ondo State, Nigeria. The experiment was laid out in randomized complete block design (RCBD). Each experimental unit was planted on the side of ridges. Spacing was 0.9 m between and 0.45 m within rows. Three seeds were planted per hole and thinned to one per stand, two weeks after planting (WAP), giving a plant population of about 24,690 plants/hectare. Each potential okra pod was tagged on the day, the flower dropped and pods free of apparent mechanical injuries, insect damage or diseases were harvested using knife on the 8th day after the flower had dropped.

Pods were randomly divided into two lots and stored at 90% and 100% relative humidities at the temperature of 10 ºC ± 2 ºC for 10 days. The temperature of storage rooms were controlled using a single point thermostat. Relative humidity inside the storage room was manually measured daily using wet bulb/dry bulb hygrometer.

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Okra pods were analyzed five times during the storage period for moisture content, crude fibre, crude protein, fat, viscosity, hydrolysable and condensed tannin, phytate, total phenol, ascorbic acid and reducing power. All determinations were done in triplicate.

Nutrient composition, (moisture, fat and crude fibre) of the fresh and stored okra were determined using standard AOAC (1990) method, the protein content was determined using micro-Kjeldhal method (Nx6.25).

The method of Wang and Hwang (1993) was used for the determination of hydrolysable tannin (HT) and condensed tannin (CT). For hydrolysable tannin (HT), phenolic extract (0.5 ml) was diluted with 2 ml distilled water in 10 ml flask. Folin-ciocalteau phenol reagent (1 ml) was added and shaked vigorously. Five ml of 20% Na_2CO_3 was pipetted into the mixture and made up to the mark with distilled water and again shaked vigorously. It was allowed to stand for 20 min for colour development. Absorbance of the sample, standard and the blank were read on spectronic 21D spectrophotometer at a wavelength of 735 nm. For condensed tannin (CT), phenolic extract (0.1 ml) was pipetted into a 30 ml test tube and covered with aluminium foil. Three ml of 4% vanillin (w/v) in methanol was added and the tube was shaken vigorously. Concentrated HCl, 1.5 ml, was added and the tube was shaken again. It was allowed to stand for 20 min for colour development. Absorbance of the sample, standard and the blank were read on spectronic 21D spectrophotometer at a wavelength of 500 nm. Viscosity was measured using Ostwald viscometer as described by AOAC (1990).

For determination of Vitamin C content (AOAC, 1990), 5 g of the sample was extracted with 100 ml H_2O. Twenty five ml of 20% glacial acetic acid was added to 10 ml of the extracted sample and titrated against standardized 2,6 dichloroindophenol (0.05 g/100 ml) solution.

Total phenol was determined by mixing 0.2 ml phenolic extract (0.2 g of okra extracted with 20 ml of 70% acetone) with 0.8 ml Folin-ciocalteau reagent and 2 ml of 7.5% sodium carbonate. The mixture was diluted with 7 ml distilled water and absorbance was measured at 765 nm after 2 h. The result was calculated as gallic acid equivalent (Iqbal *et al.*, 2004).

Reducing power of okra was determined by assessing the ability of okra to reduce $FeCl_3$ solution as described by Pulido *et al.* (2000); briefly, 2.5 ml of okra aliquot (0.5 g of okra homogenized in 20 ml methanol) was mixed with 2.5 ml of 200 mM sodium phosphate buffer (pH 6.6) and 2.5 ml of 1 g/100 ml potassium ferrocyanide. The mixture was incubated at 50 ºC for 20 min and thereafter 2.5 ml of 10 ml/100 ml trichloroacetic acid was added. The mixture was subsequently centrifuged at 650 rpm for 10 min. Five ml of the supernatant was mixed with equal volume of water and 1ml of 0.1 g/100 ml ferric chloride. Absorbance was later measured at 700 nm; higher absorbance indicates higher reducing power.

Statistical analysis. Data collected was subjected to the analysis of variance (SAS, 2002). Mean separation was done, where, there was significant differences using Duncan multiple range test procedure as described in the SAS soft ware; significance was accepted at P>0.05.

Results and Discussion

Physiological activities continue in all plant crops following the harvest. These processes involve changes in the chemical composition and physical characteristics of the plant material and can influence its quality as food, whether it is consumed fresh or used as raw material for subsequent processing operations (Rhodes, 1980).

Storage life of okra pods at the two relative humidities (RH) was determined after 10 days. Okra pods stored at 90% RH and 100% RH differed from the freshly harvested okra pod in the intensity of determined parameters.

The proximate content of okra pods at the two relative humidities are shown in Table 1. At the end of the storage period the proximate contents of pods differed from those of freshly harvested ones and were reduced in storage.

Moisture. The moisture content of pods stored at 90% RH reduced from 89.025% to 86.66% and at 100% RH reduced from 89.02% to 87.02%. Reduction in moisture content could be the result of respiration in the stored pods which releases water to the atmosphere and also due to dehydration of the pods as a result of environmental conditions. There was a significant difference (P>0.05) between the moisture content of pods stored at 90% RH and 100% RH. The pods at 100% RH recorded the least percentage loss of 2.25%. A compromise of about 95% RH is usually used to minimize both water loss and storage rots (Rhodes, 1980). A very high relative humidity (95-100%) is needed to retard dehydration, pod toughening and loss of freshness (Cantwell and Suslow, 2005).

Crude fibre. At the end of the storage period, crude fibre reduced from 10.93% to 8.83% at 90% RH and from 10.93% to 9.57% at 100% RH; the reduction in crude fibre might be the result of conversion of cellulose to carbohydrates, used during respiration; however at every stage of the storage, there was no significant difference (P>0.05) between the crude fibre of the pod at the two relative humidities but pods at 100% RH recorded the percentage loss of 12.44% against 19.21% at 90% RH. Decrease in the crude fibre observed in this study

Table 1. Nutrient composition of Akure okra (%)

Parameters	Day	90% RH*	100% RH*
Moisture	0	89.02±0.031[a]	89.02±0.031[a]
content	2	88.45±0.044[a]	88.40±0.044[a]
	4	87.73±0.044[b]	88.24±0.051[a]
	6	87.44±0.053[b]	87.92±0.044[a]
	8	87.01±0.044[b]	87.56±0.053[a]
	10	86.66±0.044[b]	87.02±0.035[a]
Loss (%)	-	2.65	2.25
Crude	0	10.93±0.062[a]	10.93±0.062[a]
fiber	2	10.33±0.026[b]	10.40±0.026[a]
	4	10.18±0.010[a]	10.28±0.026[a]
	6	9.77±0.026[a]	10.00±0.029[ab]
	8	9.39±0.011[a]	9.72±0.026[a]
	10	8.83±0.026[ab]	9.57±0.026[ab]
Loss (%)	-	19.11	12.38
Crude	0	15.17±0.026[a]	15.17±0.026[a]
protein	2	13.73±0.026[a]	13.76±0.026[a]
	4	13.37±0.026[f]	13.59±0.026[c]
	6	13.12±0.026[c]	13.18±0.026[b]
	8	12.57±0.026[b]	12.76±0.026[a]
	10	12.22±0.026[bc]	12.03±0.026[a]
Loss (%)	-	19.17	20.41
Fat	0	9.97±0.010[a]	9.97±0.010[a]
	2	8.99±0.017[a]	9.03±0.017[a]
	4	8.50±0.036[c]	8.88±0.026[a]
	6	8.47±0.017[c]	8.65±0.036[a]
	8	7.96±0.026[d]	7.78±0.017[f]
	10	7.38±0.017[d]	7.25±0.036[e]
Loss (%)	-	25.98	27.28

* = values represent means of triplicate tests; values with the same alphabet in the same row are not significantly different (p> 0. 05).

does not conform to the findings of Oti and Mgbolu (1987) who reported increase in crude fibre of the two varieties of Nigerian ginger during storage. Amusa *et al.* (2002) also reported increase in crude fiber of the breadfruit with increase in the storage time.

Crude protein: Crude protein of the pods reduced with the increase in the storage period, from 15.17% to 12.22 at 90% RH and from 15.17% to 12.34% at 100% RH; this could be attributed to the breaking down of proteins after harvest and recycling of the component amino acid. This result conforms with the findings of Omueti and Adepoju (1988) about okra. Agbor-Egbe and Rickard (1990) also reported decrease in crude protein of aroid stored for 14 days. A significant difference (P>0.05) between the crude protein at the two relative humidities was noted at every stage of the storage period, percentage loss in crude protein being the least (18.72%) at 100% RH.

Fat. Fat content of the okra pod at the two relative humidities decreased as the storage period increased; at 90% RH it reduced from 9.97% to 7.38%, while at 100%, from 9.97% to 7.25%. This could be the result of recycling of the carbon stored as triacyclglycerols into lipids through the action of the enzyme lipase. This result agrees with the findings of Amusa *et al.* (2002), regarding the bread fruit but contrary to the report of Udoessien and Ifon (1984) about the increase in fat content of the flesh of stored pepper fruit. There was a significant difference (P>0.05) between the fat content at the two relative humidities with 90% RH having the least loss of 25.98%.

Tannin. The tannin content of okra pod reduced with the storage period (Fig. 1) which could be attributed to the action of polyphenol oxidase enzyme.

The hydrolysable tannin (HT) is more important nutritionally because it can be readily hydrolyzed into carbohydrate and phenols (Osagie, 1998; Bullard *et al*., 1981). The hydrolysable tannin reduced from 0.480% to 0.268% at 90% RH and from 0.480% to 0.280% at 100% RH. There was no significant difference (P>0.05) at every stage of storage of the okra pod at the two relative humidities, but 90% RH recorded the high-

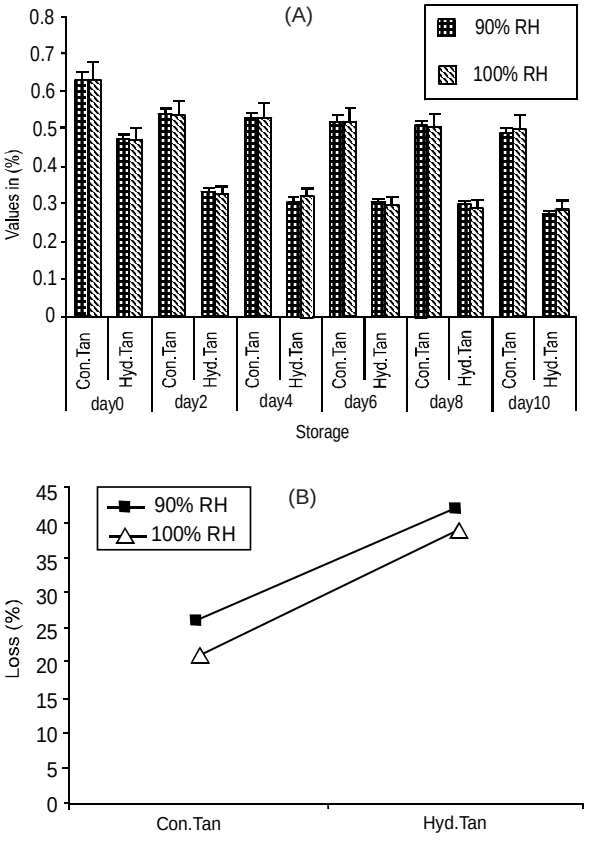

Fig. 1. Condensed tannin and hydrolysable tannin. (A) Content (%); (B) Loss (%).

est percentage loss (44.09%) at the end of the storage period which makes much of the HT not available. Condensed tannins (CT) are complex flavanol polymers which cannot be hydrolyzed to simple components; they have limited solubility and extractability and hence may have little nutritional significance (Osagie 1998; Mehansho *et al.*, 1987). Condensed tannin reduced from 0.630% to 0.484% at 90%RH and from 0.630% to 0.501%, at 100%RH with the former having the highest percentage loss of 23.06% at the end of the storage period, making much of the CT unavailable. Fleck (1988) reported decrease in tannin level during storage of four acorn species.

Viscosty. The viscosity reduced during storage at the two relative humidities Fig. 2. At 90% RH, the viscosity of Akure okra pod reduced from 63.27 cp to 51.38 cp and at 100% RH, from 63.27 cp to 51.26 cp. The highest percentage loss of 18.95% was recorded at 100% relative humidity and there was a significant difference (P>0.05) at every stage of the storage at the two relative humidities. This could be attributed to the loss of moisture in the okra through metabolic activities.

Total phenol. Total phenol reduced as the storage period increased (Table 2). This conforms with the findings of Ose *et al.* (1997) who reported decreas in total phenol content of water convolvulus leaves during the storage. Lim *et al.* (2006) reported decrease in total phenol content of guava. Total phenol of okra pods at 90%RH reduced from 0.098 to 0.063 mg/g gallic acid equivalent (GAEg) while 100% RH from 0.098 to 0.071 mg/g GAE; this could be attributed to the oxidation of phenols by phenolase to quinones (Kays, 1991). There was a significant difference (P>0.05) at every level of storage of the pods at the two relative humidities. The relative humidity of 100% recorded the lowest percentage loss of total phenol (27.54%), which means it conserves more of this antioxidant and makes them available.

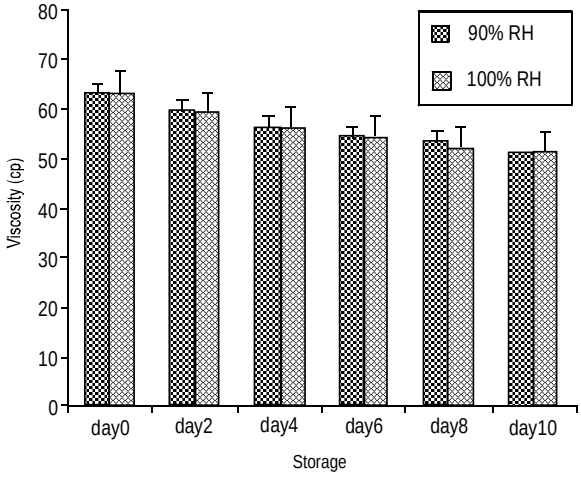

Fig. 2. Viscosity of okra (cp) during storage.

Reducing power. Reducing power of okra followed the trend of the total phenol and reduced during storage (Table 2). At 90% RH, it reduced from 1.16 to 0.65 and at 100% RH, from 1.16 to 0.71 at absorbance of 700 nm. However, there was no significant difference (P>0.05) at every stage of storage at the two relative humidities. The least percentage loss of 38.79% was recorded at the relative humidity of 100% RH.

Vitamin C. Vitamin C contributes to the antioxidant properties of vegetables by protecting the erythrocyte membrane, maintaining the blood vessel flexibility and improving the blood circulation in the arteries as well as facilitating the absorption of iron in the body (Oboh, 2005). Vitamin C content (Table 2) reduced during storage at the two relative humidities. Evensen (1983) reported loss of vitamin C in the musk melon during storage. Vitamin C in Okra pods reduced from 48.73 mg/100 g to 16.52 mg/100 g at 90% RH and from 48.73 mg/100 g to 18.92 mg/100 g at 100% RH, which could be attributed to the conversion of ascorbic acid to dehydro ascorbic acid in stored produce by the enzyme, ascorbate oxidase. At every stage of storage, there was a significant difference (P>0.05) between the vitamin C content of the stored

Table 2. Total phenol, reducing power and vitamin C content of 'Akure' okra

Parameters	Day	90% RH*	100% RH*
Total	0	0.098±0.003^{a}	0.098±0.003^{a}
phenol	2	0.088±0.003^{a}	0.089±0.003^{a}
(mg/GAEg)	4	0.082±0.003^{ab}	0.085±0.003^{a}
	6	0.076±0.003^{ab}	0.080±0.003^{a}
	8	0.070±0.003^{b}	0.078±0.008^{a}
	10	0.063±0.003^{b}	0.071±0.003^{a}
Loss (%)	-	35.70	27.54
Reducing	0	1.16±0.052^{a}	1.16±0.052^{a}
power	2	0.82±0.026^{a}	0.85±0.026^{a}
	4	0.80±0.026^{a}	0.81±0.026^{a}
	6	0.76±0.026^{a}	0.78±0.026^{a}
	8	0.73±0.026^{a}	0.75±0.026^{a}
	10	0.65±0.026^{bc}	0.71±0.026^{a}
Loss (%)	-	43.96	38.79
Vitamin C	0	48.73±0.029^{a}	48.73±0.029^{a}
(mg/100 g)	2	21.86±0.012^{b}	22.84±0.026^{a}
	4	20.59±0.032^{a}	20.46±0.015^{b}
	6	19.78±0.044^{b}	20.01±0.040^{a}
	8	16.64±0.040^{b}	19.75±0.023^{a}
	10	16.52±0.023^{c}	18.92±0.038^{a}
Loss (%)	-	64.42	59.62

* = values represent means of triplicate tests; values with the same alphabet along the same row are not significantly different (p> 0. 05).

pod at the two relative humidities with 100% RH having the lowest percentage loss (61.17%).

Conclusion

It is concluded from the observations presented that though in a few of the parameters observed, there was no significant difference (P>0.05) in "Akure" okra pods stored at 90% RH and 100% RH but the pods stored at 100% recorded more acceptable percentage loss. Thus for storage of okra, 100% RH at the temperature of 10 ºC ± 2 ºC is recommended.

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