EFFECT OF SOME PROCESSING AND STORAGE METHODS ON THE QUALITY OF OKRA (*ABELMOSCHUS ESCULENTUS*)

ABSTRACT

Three experiments, comprising packaging of fresh Okra for storage, dipping of fresh fruits in hot water before packaging to store and drying of sliced Okra fruits, were carried out on experimental fields sited at the Department of Horticulture, Kwame Nkrumah University of Science and Technology. A portion of plot measuring 14m x 40m was demarcated for planting and drying was done by using a solar cabinet dryer located at the old site of Forestry Research Institute of Ghana, located on the compound of the Kwame Nkrumah University of Science and Technology. Results from the first experiment which involved packing and storing of fresh okra fruits indicated that, Fresh okra fruit packed in both polypropylene and polyethylene bags and store at 7- 9 C can stay up to 24 days with no significant ($p \leq 0.05$) weight lost. However produce packed in perforated polypropylene and polyethylene bags gave a higher salvage of 82.1% compared to 77% from those packed in the imperforated bags of the two packaging materials. The second experiment which involved hot water treatment of okra fruit before packaging for storage indicated a very fast rate of deterioration of fruits, with no fruit being salvaged at the end of the storage period. The third experiment involving slicing and drying of okra fruits in a solar cabinet dryer indicated that samples from both stages of maturity dried for 24hours lost comparatively less weight than those dried for 48hours. This shows that the longer the drying period, the more the lost in weight. From the three experiments it was concluded that packaging and storage of fresh okra fruit enables the fruit to keep longer and remained in the useable state than unpacked storage. Harvesting fruit at 4 and 6days, after setting for storage is appropriate, however those harvested at 6days after setting will come out with greater number of unusable fruit after the storage period. On the choice of packaging material one should prefer polypropylene to polyethylene for bitter results. Also perforation of the chosen material had advantages over the imperforated ones. Hot water treatment of okra fruits can be applied under situations where the fruits may be used within 16 days or less but not longer.

Key words:

- Weight loss in fresh stored okra
- Hot water treatment of fruit and storage
- Solar drying of Okra fruits

INTRODUCTION

Vegetables are increasingly important as produce for domestic and export markets. They have a great potential to improve the nutrition and thereby health of consumers as most are good sources of vitamins, minerals and proteins needed for the proper functioning and development of the human body (Wills *et al.*, 2016).

Post harvest losses of vegetables are particularly high in the tropics and may be in the order of 25% and even higher for more perishable produce (Proctor *et al*., 2017). Losses in fruits and vegetables are more serious in developing countries than the developed ones. In Ghana, it is estimated that about 20% to 30% of fresh food products including vegetables harvested each year never reach the final consumer in the market because they are either lost or damaged during the various stages of the distribution chain (Johnson, 2016). An additional constraint to improving this situation is that in most developing countries the number of scientist concerned with post harvest losses is significantly lower than those in production research (F.A.O 2016). It is estimated that about 25 to 40% of vegetables and other respiring fresh commodities produced worldwide each year deteriorates beyond usable qualities and thus never reach the consumer or marketing centers (Lioutas, 2016) Okra (*Abelmochus esculentus*) is one of the important vegetables with tremendous nutritional values. The edible portion (fresh fruits) contains 86.1% moisture, 9.7% carbohydrates, 2.25% protein, 1.0% fibre, 0.2% fat and 9% ash in addition to vitamins A, B, C and iodine (Kochhar, 2011). The fruits are consumed as vegetables, raw, cooked or fried in stews, gumbos and cecole dishes together with other vegetables. The dried and powdered or dehydrated okra is used in thickening soups, as emulsifier for salad dressing and as flavouring in preparing food products (Nonneck, 2013). Okra's mucilage is suitable for medicinal and industrial applications. It has been used medically as a blood plasma replacement or blood volume expander and also binds cholesterol and bile acid carrying toxins dumped into it by the liver (Siemonsma and Hamon 2000, Zook 2004). The slimmy characteristic of the mucilage soothes and facilitates the comfortable elimination and passage out of the body toxins and excess cholesterol. The fiber in Okra helps to stabilize blood sugar as well as to curb the rate at which sugar is absorbed from the intestinal tract. Nearly half of the fibre is soluble in form of gums and pectins. The soluble fiber helps to lower serum cholesterol thereby reducing the risk of heart diseases. The other half which is insoluble helps to keep the intestinal tract healthy

by absorbing water from it and thereby decreasing the risk of some forms of cancer, especially colorectal cancer and prevents constipation (Zook 2004, Wolford, 2004).

Okra is a potential export item in the Middle East, Thailand, Japan and the Philippines (PROSEA, 2017). The world production of Okra as fresh vegetable is estimated at six (6) million tones per year. In West and Central Africa, production figures are estimated at between 500,000 to 600,000 tones annually (Siemonsma and Hamon, 2000).

Problem Statement

In Ghana Okra is among the non-traditional export crops of importance, contributing 0.02% of Gross Domestic Product (GEPC, 2002). Annual production of Okra in Ghana is estimated between 1,548 to 4,507 metric tones (SRID, MOFA, 2007).

Despite all these importance, the crop, like all other fresh vegetable has a problem of short shelf life. The fresh fruits remain in usable quality for only 8 to 10days if held at 2-13^{o}C at 90% relative humidity. Those held at 0-10^{o}C lasted for only 4 to 6 days and deteriorated rapidly on exposure to higher temperature (20-26^{o}C) (Yamaguchi, 1983).

Large quantities of Okra fruits produced during the main production season are usually left to deteriorate, as they cannot be kept longer. Producers are forced under the circumstances to give their commodities out at very low "take-away" prices. In certain situations market women have no alternative than to throw away Okra fruits in the market to carry their empty baskets or sacks home. This is to avoid paying extra cost on transporting those fruits they could not sell and cannot store till the next market day (Personal observation). Many growers depend mostly on daily sales for their income and hence may be forced to accept a lower price immediately under such situations of glut (FAO, 1988). Even at the lower prices consumers cannot buy large quantities to store, thus paying higher for the fruits during the lean season. Traditionally, Okra fruits have been processed by drying to extend the shelf life well beyond the few weeks when they are in season (Kordylas, 1991). In most cases the fruits are either sliced or smaller whole fruits are sun dried, on racks, trays, concrete floors and on roof tops till they become brittle. However this traditional method has problems associated with it including lack of pretreatment, non uniformity of slice thickness (resulting in uneven drying), direct exposure to dirt, insects and other pests. Thus affecting the nutritional and sensory qualities of the final product (Tindall, 1983, Kordylas, 1991).The final product from drying usually has a brown or

dark- brown colour which is not appealing to the consumer. Both fresh and dried Okra, like other vegetables, for local retailing are usually packed in baskets resulting in over exposure of produce to the weather. These practices lead to quick deterioration as well as contamination of produce (Adegoreye *et al.*, 2014).

At the production level little is done about fresh storage of produce. Storage of fresh fruits and vegetables prolongs their usefulness, checks market gluts, and provides wider selection of fruits and vegetables throughout the year (FAO, 2016). This helps orderly marketing and may increase the financial gain to the producer. However, farmers do not have adequate storage facilities to reduce losses

In view of the problems associated with storability of fresh Okra fruits and the quality of dried fruits, this project was aimed at evaluation and selection of processing and packaging methods for fresh Okra fruits to enhance longer shelf life without marked changes in external and internal qualities.

Research Questions

1. Will packaging and storage of fresh okra in both polypropane and polyethylene bags stored at a temperature of 7 - 9°C stay up to 24 days?
2. What will be the rate of deterioration of hot water treatment of okra fruit before packaging for storage?
3. Will there be a weight loss after slicing and drying okra fruits in a solar cabinet dryer for 24 and 48 hours

Significance of the study

This study is intended to add value to the production of okra by exploring acceptable methods of packaging and storing freshly harvested okra to extend its shelf life.

Limitations of the study

Financial constraints and a steady supply of electricity to ensure the required temperature range was met, was a major limitation. To ensure a steady power supply without any fluctuations which may affect the quality of the okra, the researcher was forced to centre the research on the campus of the Kwame Nkrumah University of Science and Technology, where power supply was constant.

MATERIALS AND METHODS

Three experiments, comprising packaging of fresh Okra for storage, dipping of fresh fruits in hot water before packaging to store and drying of sliced Okra fruits, were set up to study their effects on the storage life and quality of the produce. The experiment involved a fieldwork to produce Okra fruits which were used in the laboratory to study storage of the produce

SITE AND LOCATIONS

The experimental field was sited at the Department of Horticulture Faculty of Agriculture at the Kwame Nkrumah University of Science and Technology. The site falls within the forest area of Ashanti Region of Ghana. The area has a bimodal rainfall regime, with the major rainfall season between March and July and a minor season between September and November.

Laboratory and rooms at the Department of Horticulture were used for handling and keeping of produce at ambient temperatures whilst a refrigerator in the laboratory was used for the storage of produce. Hot water bath at the Pathology laboratory of Crop Science Department of the Faculty of Agriculture was use for the hot water treatment of fruits. Drying of fruits was done by the use of a solar cabinet dryer located at the old site of Forestry Research Institute of Ghana on Kwame Nkrumah University of Science and Technology compound. Proximate analyses of materials (samples) for nutrient content were carried-out in the Bio-chemistry laboratory of Crop Research Institute at Fumesua near Kumasi.

FIELD WORK

Land Preparation and Layout

The experimental plot was ploughed by a tractor with a disc plough and was harrowed after two days.

A portion of plot measuring 14m x 40m was demarcated for planting. The plot was divided into 3 blocks each measuring 4 meters and separated by a path of 1 meter wide. Each block was then divided into smaller

plots of 4meter x 4meter and separated by paths of 0.5m from each other giving a total of 27 plots (9per block)

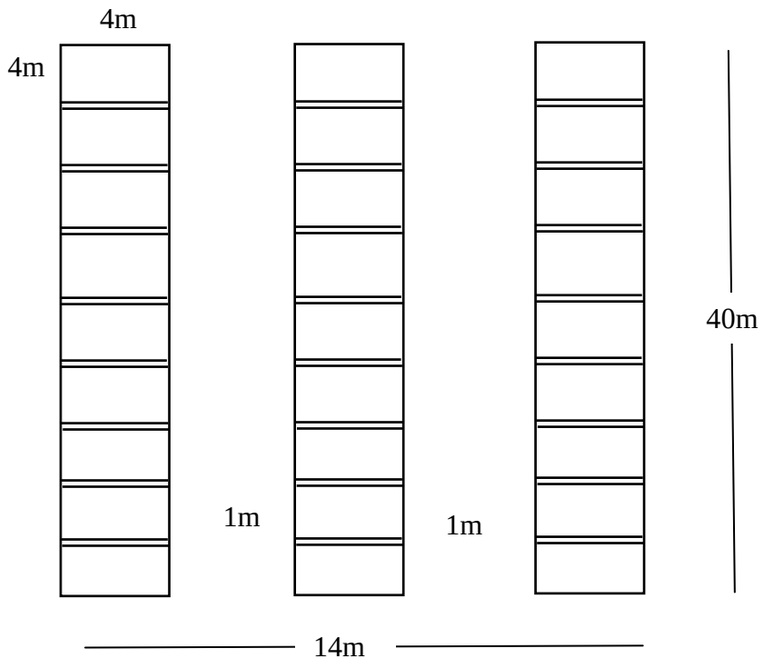

Fig.1; Layout of experimental plot (April to July 2019)

The same layout was used for three successive cropping, October 2017 to February 2018, April to July 2018 and October 2019 to February 2019 respectively. The second, third and fourth crops were grown on plots different from where the first one was planted.

SOURCE OF PLANTING MATERIAL

A variety of Okra, with accession number KNUST/SL1/03, from the Department of Horticulture was grown using seeds selected from a previous cultivation of the crop. The seeds were stored in the pods in the Departments seed store. Selected pods were cracked open by the hand. The seeds were removed and collected in plastic bowls. The seeds were cleaned of debris by winnowing, and further cleaned of. dead, broken and malformed seeds together with more of the debris as they floated when the lot was soaked in water. Selected seeds were then sown in the field using 50 x 50cm interval at 2 to 3 seeds per hill. After germination and emergence they were thinned to one plant per hill

PARAMETERS FOR ASSESMENT

1. DAYS TO 50% EMERGENCE

Counting of merging seedlings started on the fourth day after sowing, on plot by plot bases. The total seedling emerged was worked out as a percentage of the number of hills of seed sown over the plot.

$$\%PE = \frac{(THS-HE)}{THS} \times 100$$

PE = Percent emergence of plant.

THS = Total number of Hills sown

HE = Hills emerged

2. DAYS TO 50% FLOWERING

Percent flowering was worked by counting the number of plants that flowered out of the total number of stand on the field.

$$\%F = \frac{Tp - Fp}{Tp} \times 100$$

%F = Percent flowering.

Tp = Total number of plants

Fp = Flowered plants.

3. DAYS TO FRUIT SET, AFTER PLANTING

When flowers open and closed, plants are observed for actual fruit set. Days to fruit set are then worked with reference to the date of sowing.

SELECTION OF FRUITS FOR HARVESTING: Twenty plants were randomly selected from each plot. Harvesting was done at 2 stages of maturity of fruits: 4days after fruit set and 6 days after fruit set respectively.

COOLING AFTER HARVEST

Okra fruits, harvested from the field, were washed with tap water, to clean the fruits, and then mopped with cotton cloth, to remove water particles from the surface. The fruits thus cleaned were spread on a flat bench for cooling overnight.

RESULTS OF CROP PERFORMANCE PARAMETERS

(1) Days to 50%emergence:

Percent crop emergence is usually used to establish the viability of seeds sown.

Okra seeds sown registered 50% emergence after 5days of sowing. Seedling emergences continued vigorously such that after the sixth day of sowing 80% of the total seeds sown have fully emerged.

(2) Days to 50%flower bud initiation:

Flower bud initiation marks the visible stage of the crops' transition from vegetative to reproductive growth. The Okra variety sown took an average of 45days to initiate 50%flower buds across the total plant population.

(3) Days to 50% fruit set:

It took an average of 52days, from the day of sowing, for the crops to register up to 50% fruit setting. Thus Okra fruits were fully set within an average of 7days after bud initiation.

(4) Days to first and second harvests:

The first fruits were harvested at 56 days from the day of sowing; this was 4days after fruit set. The second harvest was done on the58th day after seed sowing, which was 6days after fruit set. Fruits were harvested at these two stages of maturity (4and 6days after setting) for the three experiments of fresh storage, hot water treatment and solar drying.

Plate 1: Fresh okra fruits at first day of harvest.

(A) EXPERIMENT ONE

PACKAGING AND STORAGE OF FRESH OKRA FRUITS

After cooling overnight, two hundred fruits from each maturity were selected for packaging and storage in a refrigerator. Okra fruits of 4 to 6 cm length and 1 to 1.5cm in diameter were selected using a metric plastic ruler and calipers to measure length and diameter respectively. All rated fruits were then packed into two types of bags: Polypropylene (as packaging material one: P_1) and polyethylene (as packaging material two: P_2) measuring 12 x 14cm with each package containing 10 fruits. Some of the bags were perforated with a pin of 1mm diameter making two holes at each side of the bag whilst the rest were not perforated. Twenty fruits were put into two plastic plates as the controls. All the packages were sealed using an electrical hand-operated rubber sealing machine. After sealing each package was weighed and the weight recorded as initial weight before storage and then labeled, as below:

M_1P_1F……four days after fruit set, polypropylene, perforated.

M_1P_1N…… four days after fruit set, polypropylene, not perforated.

M_1P_2F…… four days after fruit set, polyethylene perforated.

M_1P_2N…… four days after fruit set, polyethylene not perforated.

M_2P_1F…… six days after fruit set, polypropylene perforated.

M_2P_1N…… six days after fruit set, polypropylene not perforated

M_2P_2F…… six days after fruit set polyethylene perforated.

M_2P_2N… six days after fruit set polyethylene not perforated

CM_1……control for four days after fruit set.

CM_2…… control for six days after fruit set.

1. External Quality

External quality assessment was based on colour and shriveling.

(a) Shriveling: This affects size and shape of the produce and was scored as:

1…….no shriveling observed

2……1 – 10% shriveling

3……10 – 25% shriveling

4……25 – 50% shriveling

5……50 and above shriveling (after Hirata *e*t *al* 1987).

(b). Colour rating. Selected fruits were rated for colour before packaging and storage. Stored materials were assessed at time interval of 8, 16 and 24 days for colour changes using the colour chart (Kornerup and Wanscher, 1981) as below:

5…… deep green.

4…… apple green.

3…… spinach green.

2…… yellowish green

1……bracken green

0……..oak brown.

2. **Weight loss**

At every stage of assessment the packed samples were weighed by an electronic scale (Sartorius, Germany). Weight loss was calculated as the difference between the initial weight and the weight at the day of observation.

The loss in weight recorded at the end of storage period was worked as the percent loss in weight based on the initial weight.

$$\%WL = \frac{IW - FW}{IW} \times 100$$

Where:

%WL…was Percent weight loss

IW…was Initial weight and

FW…was Final weight

(3). Salvaged materials

The number of fruits that remained in good and useable condition after the third consecutive assessment were recorded as saved materials from the total put into storage. These saved materials were then worked as a percentage over the total put into storage over the period of observation.

$$\%SM = \frac{TS - TR}{TS} \times 100$$

SM = Saved material

TS = Total put into storage

TR = Total Remaining after storage.

4. Determination of Moisture Content

Two grams of sample was accurately weighed into a previously dried and weighed glass crucible. It was then dried in a thermostatically controlled forced convection oven (Gallenkamp, England) at 105^0C overnight to a constant weight. The glass crucibles were removed and transferred into a desiccator for cooling after which they were weighed. Moisture content was determined by difference and expressed as a percentage.

$$\text{Percent moisture Content} = \frac{WFS - WDS}{WFS} \times 100$$

WFS = weight of fresh sample

WDS = weight of dry sample

5. Determination of Ash Content

Two grams sample was accurately weighed into a pre-ignited and previously weighed porcelain crucible, placed in a muffle furnace (Gallenkamp, England) and ignited for 2 hours at 600^0C. After ashing, the crucibles were cooled to about 105^0C in a forced convection oven before cooling them further to room temperature in a desiccator.

The crucibles and their contents were weighed, and the weight reported as percentage ash content.

$$\text{Ash content} = \frac{\text{Weight of Ash}}{\text{Weight of original sample}} \times 100\%$$

6. Determination of Crude Fat Content

Two grams of the dried sample from the moisture determination was transferred into a paper thimble, plugged at the opening with glass wool and placed into a thimble holder. Two hundred milliliters of petroleum ether was measured into a previously dried and weighed round-bottom flask and this was assembled together with the thimble holder and its contents. The Quickfit condenser was connected to the Soxhlet Extractor and refluxed for 16 hours on low heat on a heating mantle. The flask was then removed and the solvent evaporated on a steam bath. The flask containing the fat was heated at 105^0C in an oven for 30 minutes, cooled in a desiccator and the weight of the fat collected determined and expressed as percentage crude fat.

$$\text{Crude Fat} = \frac{\text{Weight of Fat}}{\text{Weight of original sample}} \times 100\%$$

7. Determination of Crude Fibre Content

The sample from the crude fat determination was transferred into a 750ml Erlenmeyer flask and about 0.5g of asbestos added.two hundred milliliters of boiling 1.25% sulphuric acid (H2SO4) was added to the flask and immediately transferred onto a hot plate.

A cold finger condenser was attached to it. The sample was boiled for 30 minutes during which the entire sample was allowed to become thoroughly wetted while any of it was prevented from remaining on the sides of the flask and out of contact with the solvent. After 30 minutes, the flask was removed; its contents filtered through linen cloth in a funnel and washed with boiling water until the washings were no longer acidic. The sample with asbestos was washed back into the flask with 200ml boiling 1.25% sodium hydroxide (NaOH) solution. The flask was reconnected to the condenser and boiled for 30 minutes. The contents were again filtered through linen cloth in a funnel and washed thoroughly with boiling water, then with 15ml alcohol. The residue was transferred into a previously dried and weighed porcelain crucible, dried in an oven at 100^0C for 1 hour, cooled in a desiccator and weighed. The crucible and its contents were ignited in an electric furnace at 600^0C for 30 minutes, cooled and reweighed. The loss in weight was reported as percentage crude fibre.

$$\textbf{Crude Fibre} = \frac{\text{Weight of dry residue} - \text{Weight of ignited residue}}{\text{Weight of original sample}} \times 100\%$$

8. Determination of Nitrogen Content

The Kjeldahl method (AOAC, 1990) was used for the determination.

Digestion:

Two grams sample was placed in a Kjeldahl digestion tube together with a small amount of a selenium-based catalyst and a few anti-bumping granules. Twenty-five milliliters concentrated H2SO4 was added and the tube shaken until the entire sample was thoroughly wet. The flask was placed on a digestion burner in a fume chamber and heated (approximately 410^0C) until the resulting solution was clear. this was then cooled to room temperature and the digested sample solution transferred into a 100ml volumetric flask and made up to the mark.

Distillation

The distillation apparatus was flushed with distilled water for about 10 minutes. Twenty-five milliliters (25ml) of 2% boric acid was poured into a 250ml conical flask and 3 drops of mixed indicator added, turning the solution pink. The conical flask and its contents were placed under the condenser with the tip of the

condenser completely immersed in the boric acid solution. Ten milliliters (10ml) of the digested sample solution and about 20ml of 40% NaOH solution were transferred into the decomposition flask and the funnel stopcock well closed. Ammonia (NH3) liberated during the distillation was collected by the boric acid solution, changing it from pink to bluish-green. The distillate was titrated against 0.1N hydrochloric acid (HCL) solution until the solution changed from bluish-green to pink. The end point was recorded and the titre values obtained were used to calculate the total nitrogen.

$$\text{Percent Total Nitrogen} = \frac{(Va - Vb) \times Na \times 14.01}{\text{Weight of fresh sample}}$$

Where, Va = Volume of standard acid (HCL) used in titration

Vb = Volume of standard acid (HCL) used in blank titration

Na = Concentration of acid (HCL)

9. Determination of Phosphorus (phosphate)

Phosphorus was determined by Ascorbic acid –Molybdate method using Spectrophotometer.

Reagents used:

(a) 0.1M Ascorbic acid

(b) 4% Ammonium molybdate

(c) 2.5M Sulphuric acid solution

(d) 0.28% Potassium Antimonyl titrates.

One hundred milligrams per liter(100mg/L) stock solution of phosphate was prepared and six serial standards were prepared from the stock at 0.50, 1.00, 2.00, 4.00, 6.00 and 8.00mg/L respectively.Colour developing reagent (CDR) was prepared with 50ml of 2.5M Sulphuric acid, 5ml of Potassium Antimonyl Titrate(PAT), 15ml of Ammonium Molybdate(AM) and 30ml of Ascorbic acid(0.1M). Half millilitres (0.5ml) of each serial standard solution and 2.5ml of the colour developing reagent were incubated at room temperature for 20 minutes after which the absorbance was read at 770nM on the Spectrophotometer. A calibration curve was then plotted for absorbance (y) against concentration(x). From the equation of the graph: y = 0.0785x-0.0145 the concentration of the phosphorus in the sample was calculated.

Ammonium molybdate (AM) and potassium antimonyl titrate (PAT) react with phosphate in acid medium to form a complex which on reduction with ascorbic acid yielded an intense blue colour which was measured photometrically(Greenberg *et al*.,1992).

10. Determination of calcium.

Calcium was determined by O –Cresolphthaline complexone method (Norbert, 1986) in which Calcium complexes with a buffer medium of O-cresolphthalein complexone (CPC) to form a deep violet colour which is measured at 570nM on spectrophotometer.

Reagents:

(1) O-cresolphthalein complexone (CPC)

(2) Ethadiol

(3) 2-amino-2-mehtyl-1-propanol (3.5M) –buffer.

(4) 8-Hydroxyl quinoline

(5) Calcium carbonate ($CaCo_3$)

A stock standard solution of 100mg/L was prepared from the $CaCo_3$ by dissolving in 10% hydrochloric acid (HCL) and six (6) serial standards were prepared from the stock. Colour development reagent was prepared using 8ml of Ethadiol, 3ml of buffer, 0.005g of O-cresolphathaline complexone and 0.1g of 8-hydroxylquinoline.

The serial standard measuring 0.05ml and 2.5ml of colour developing reagent were incubated at room temperature for 15 minutes and read absorbance at 750nM on the spectrometer. A calibration curve was then plotted for absorbance (y) against concentration(x). From the equation of the graph: y = 0.1033x-0.013, the concentration of the calcium in the sample was then calculated.

11. Determination of Iron (Fe^{2+})

Standard stock solution of 100ppm was prepared from an analar compound of Ammonium- Iron ll Sulphate [$(NH_4)_2$ Fe $(SO_4)_2$.$6H_2O$].

Serial standards of 1, 2, 4,5and 10ppm were prepared from the stock.

A complex of 1.0ml of the serial standard, 1.0ml of 5% ascorbic acid and0.5ml of1,10-phenonthroline was then incubated at room temperature for 30 minutes and the absorbance read at 520nM on the

spectrophotometer. A calibration curve was then plotted for absorbance (y) against concentration(x). From the equation of the graph: y = 0.067x + 0.0097, the concentration of the Iron in the sample was calculated.

12. Determination of Ascorbic Acid (Vitamin C)

Sample extract in Oxalic Acid was titrated against Sodium 2, 6- dichlorophenolindophenol dye to a faint pink colour which persists for 5 to 10 seconds (Rangana, 1977).

Reagents

1. Indophenol dye (0.04%): Forty milligrams (40mg) of sodium 2,6-dichlorophenolindophenol was weighed and 150ml of hot distilled water and 42ml of Sodium bicarbonate added. The content is then cooled with water kept in refrigerator, making volume up to 200ml.
2. Metaphosphoric acid (3%): Thirty grammes (30g) of metaphosphoric acid were dissolved in water and the volume made up to1000ml
3. Standard ascorbic acid: One hundred milligrams of ascorbic acid was dissolved in 100ml of Oxalic acid and diluted at 10ml to 100ml with metaphosphoric acid.

Standardization of dye. Five milligrams of standard ascorbic acid was added to 5mlof Metaphosphoric acid (HPO_3) and titrated against the dye solution, in a micro burette, to a light pink colour. The dye equivalent was then determined as: Dye equivalent = 0.5/titer.

Ten grams of sample (ashed) was thoroughly mixed with 3% Metaphosphoric acid to make volume up to 100ml and filtered. The sample filtrate was then divided into ten parts of 10ml each and titrated against Sodium 2, 6-dichlorophenolindophenol dye.

Ascorbic acid content was then calculated from the relation as:

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre x dye equivalent x dilution}}{\text{Weight of sample}} \times 100$$

13. Test for viscosity

Twenty grammes (20gm) of sample were weighed by a triple beam balance (Ohaus, U.S.A) into an electronic blender (Monlinex optiblend 2000-France) and 100ml of water added. The blenderwas then connected to an electrical power source and switched on and run for two minutes The blended sample was poured into a funnel lined with 0.5mm sieve supported over a beaker into which the slimmy mucilage was collected. Viscosity is then determined by using "Redwood no.1"viscometer (England), which has a cup with a capillary tube of 1.6mm bore and 10mm length fitted to the base. A discharge valve fitted in the cup controlled the flow of fluid through the capillary. The cup was surrounded by a water jacket having a thermometer inserted through the side.

The mucilage was poured into the cup and allowed to reach the same temperature (30°C) with the surrounding water before the discharge valve was opened for the fluid to flow through the capillary into a collector marked at 50ml under it. The time taken to discharge 50ml of fluid into the collector beneath was noted using an electronic stop-watch.

Viscosity was quoted as: $N_{seconds}$ Redwood@T°C

V = $N_{seconds}$ Redwood@T°C.

The more viscous the fluid was the longer the discharge time.

DATA ANALYSIS

Statistical Software (SPSS) package was applied as 2x 2 x 2 factorial in a completely randomized Design (CRD) to test for the interactive effect of packaging material, perforation and stage of maturity on quality of the okra fruits.

(B) EXPERIMENT TWO

HOT – WATER TREATMENT OF FRUITS AND STORAGE

Harvested fruits from the two maturity stages were dipped in hot water. Selected fruits were put into plastic baskets with looped handles fixed to the sides of the basket. Hot-water – bath (Gallenkamp, England) with electric heating coils was filled with tap water up to 5cm below the brim. A long stem thermometer was inserted through a side jacket into the water. The water was heated to 50^0C and a basket of Okra fruits dipped into it and covered for 3 minutes whilst the electricity power was switched off. The water was again heated to 75^0C and another set of fruits were dipped in for 3 minutes.

There were four treatments as shown below:

M_1 50^0C……...fruits harvested 4days after setting, heated at 50^0C.

M_1 75^0C…….. fruits harvested 4days after setting, heated of 75^0C

M_2 50^0C…… fruits harvested 6days after setting, heated at 50^0C.

M_2 75^0C…… fruits harvested 6days after setting, heated at 75^0C.

The heated samples were allowed to cool off under room temperature. Samples after cooling were then packed into polypropylene (P1) and polyethylene (P_2) bags and weighed before put into a refrigerator. Packing increase the sample size to eight, with 2 controls.

M_1 50^0C P_1…...fruits harvested 4days after setting heated at 50^0C and packed in polypropylene

M_1 50^0C P_2…...fruits harvested 4days after setting heated at 50^0C and packed in polyethylene.

M_1 75^0C P_1… fruits harvested 4days after setting heated at 75^0C and packed in polypropylene.

M_1 75^0C P_2… fruits harvested 4days after setting heated at 75^0C and packed in polyethylene.

M_2 50^0C P_1…...fruits harvested 6days after setting heated at 50^0C and packed in polypropylene

M_2 50^0C P_2…...fruits harvested 6days after setting heated at 50^0C and packed in polyethylene.

M_2 75^0C P_1…...fruits harvested 6days after setting heated at 75^0C and packed in polypropylene .

$M_2 75^O C P_2$…… fruits harvested 6days after setting heated at 75^0C and packed in polyethylene

CM_1 …… Control of fruits harvested 4days after setting, unpacked

$CM_{2.....}$ Control of fruits harvested 6days after setting, unpacked

DATA COLLECTED

1. **Weight loss:** This was calculated as the different between the initial weight and the final weight, and worked as percentage of the former.
2. **Shriveling:** Changes in size and shape were scored for as shriveling as follows

   1……no shriveling observed

   2……1 – 10% shriveling

   3……10 – 25% shriveling

   4……25 – 50% shriveling

   5……50 – 100% and above shriveling (after Hirata *et al* 1987).
3. **Fruit colour:** Observable change in colour during storage was score as:

   5……deep green

   4……apple green

   3……spinach green

   2……yellowish green

   1……bracken green

   0……..oak brown (Kornerup and Wanscher, 1981)

Salvaged materials

The number of fruits that remained in good and useable condition after the third consecutive assessment were recorded as saved materials from the total put into storage. These saved materials were then worked as a percentage over the total put into storage over the period of observation.

$$\%SM = \frac{TS - TR}{TS} X100$$

SM = Saved material

TS = Total put into storage

TR = Total Remaining after storage.

Determination of Moisture Content

Two grams of sample was accurately weighed into a previously dried and weighed glass crucible. It was then dried in a thermostatically controlled forced convection oven (Gallenkamp, England) at 105^0C overnight to a constant weight. The glass crucibles were removed and transferred into a desiccator for cooling after which they were weighed. Moisture content was determined by difference and expressed as a percentage.

$$\text{Percent moisture Content} = \frac{\text{WFS} - \text{WDS}}{\text{WFS}} \times 100$$

WFS = weight of fresh sample

WDS = weight of dried sample

Determination of Ash Content

Two grams sample was accurately weighed into a pre-ignited and previously weighed porcelain crucible, placed in a muffle furnace (Gallenkamp, England) and ignited for 2 hours at 600^0C. After ashing, the crucibles were cooled to about 105^0C in a forced convection oven before cooling them further to room temperature in a desiccator.

The crucibles and their contents were weighed, and the weight reported as percentage ash content.

$$\text{Ash content} = \frac{\text{Weight of Ash}}{\text{Weight of original sample}} \times 100\%$$

Determination of Crude Fat Content

Two grams of the dried sample from the moisture determination was transferred into a paper thimble, plugged at the opening with glass wool and placed into a thimble holder. Two hundred milliliters of petroleum ether was measured into a previously dried and weighed round-bottom flask and this was

assembled together with the thimble holder and its contents. The Quickfit condenser was connected to the Soxhlet Extractor and refluxed for 16 hours on low heat on a heating mantle. The flask was then removed and the solvent evaporated on a steam bath. The flask containing the fat was heated at 105^0C in an oven for 30 minutes, cooled in a desiccator and the weight of the fat collected determined and expressed as percentage crude fat.

$$\text{Crude Fat} = \frac{\text{Weight of Fat}}{\text{Weight of original sample}} \times 100\%$$

Determination of Crude Fibre Content

The sample from the crude fat determination was transferred into a 750ml Erlenmeyer flask and about 0.5g of asbestos added.two hundred milliliters of boiling 1.25% sulphuric acid (H2SO4) was added to the flask and immediately transferred onto a hot plate.

A cold finger condenser was attached to it. The sample was boiled for 30 minutes during which the entire sample was allowed to become thoroughly wetted while any of it was prevented from remaining on the sides of the flask and out of contact with the solvent. After 30 minutes, the flask was removed; its contents filtered through linen cloth in a funnel and washed with boiling water until the washings were no longer acidic. The sample with asbestos was washed back into the flask with 200ml boiling 1.25% sodium hydroxide (NaOH) solution. The flask was reconnected to the condenser and boiled for 30 minutes. The contents were again filtered through linen cloth in a funnel and washed thoroughly with boiling water, then with 15ml alcohol. The residue was transferred into a previously dried and weighed porcelain crucible, dried in an oven at 100^0C for 1 hour, cooled in a desiccator and weighed. The crucible and its contents were ignited in an electric furnace at 600^0C for 30 minutes, cooled and reweighed. The loss in weight was reported as percentage crude fibre.

$$\textbf{Crude Fibre} = \frac{\text{Weight of dry residue} - \text{Weight of ignited residue}}{\text{Weight of original sample}} \times 100\%$$

Determination of Nitrogen Content

The Kjeldahl method (AOAC, 1990) was used for the determination.

Digestion:

Two grams sample was placed in a Kjeldahl digestion tube together with a small amount of a selenium-based catalyst and a few anti-bumping granules. Twenty-five milliliters concentrated H_2SO_4 was added and the tube shaken until the entire sample was thoroughly wet. The flask was placed on a digestion burner in a fume chamber and heated (approximately 410^0C) until the resulting solution was clear this was then cooled to room temperature and the digested sample solution transferred into a 100ml volumetric flask and made up to the mark..

Distillation

The distillation apparatus was flushed with distilled water for about 10 minutes. 25ml of 2% boric acid was poured into a 250ml conical flask and 3 drops of mixed indicator added, turning the solution pink. The conical flask and its contents were placed under the condenser with the tip of the condenser completely immersed in the boric acid solution. 10ml of the digested sample solution and about 20ml of 40% NaOH solution were transferred into the decomposition flask and the funnel stopcock well closed. Ammonia (NH3) liberated during the distillation was collected by the boric acid solution, changing it from pink to bluish-green. The distillate was titrated against 0.1N hydrochloric acid (HCL) solution until the solution changed from bluish-green to pink. The end point was recorded and the titre values obtained were used to calculate the total nitrogen.

$$\text{Percent Total Nitrogen} = \frac{(Va - Vb) \times Na \times 14.01}{\text{Weight of fresh sample}}$$

Where, Va = Volume of standard acid (HCL) used in titration

Vb = Volume of standard acid (HCL) used in blank titration

Na = Concentration of acid (HCL)

Determination of Phosphorus (phosphate)

Phosphorus is determined by Ascorbic acid –Molybdate method using Spectrophotometer.

Reagents Required:

(a) 0.1M Ascorbic acid

(b) 4% Ammonium molybdate

(c) 2.5M Sulphuric acid solution

(d) 0.28% Potassium Antimonyl titrates.

One hundred milligrams per liter(100mg/L) stock solution of phosphate was prepared and six serial standards were prepared from the stock at 0.50, 1.00, 2.00, 4.00, 6.00 and 8.00mg/L respectively.Colour developing reagent (CDR) was prepared with 50ml of 2.5M Sulphuric acid, 5ml of Potassium Antimonyl Titrate(PAT), 15ml of Ammonium Molybdate(AM) and 30ml of Ascorbic acid(0.1M). Half millitres (0.5ml) of each serial standard solution and 2.5ml of the colour developing reagent were incubated at room temperature for 20 minutes after which the absorbance is read at 770nM on the Spectrophotometer. A calibration curve is then plotted for absorbance (y) against concentration(x). From the equation of the graph: $y = 0.0785x-0.0145$ the concentration of the phosphorus in the sample is calculated.

Ammonium molybdate (AM) and potassium antimonyl titrate (PAT) react with phosphate in acid medium to form a complex which on reduction with ascorbic acid yields an intense blue colour which is measured photometrically(Greenberg *et al*,1992).

Determination of calcium.

Calcium was determined by O –Cresolphthaline complexone method (Norbert, 1986) in which Calcium complexes with a buffer medium of O-cresolphthalein complexone (CPC) to form a deep violet colour which is measured at 570nM on spectrophotometer.

Reagents:

(1) O-cresolphthalein complexone (CPC)

(2) Ethadiol

(3) 2-amino-2-mehtyl-1-propanol (3.5M) –buffer.

(4) 8-Hydroxyl quinoline

(5) Calcium carbonate ($CaCo_3$)

A stock standard solution of 100mg/L is prepared from the $CaCo_3$ by dissolving in 10% hydrochloric acid (HCL) and six (6) serial standards are prepared from the stock. Colour development reagent is prepared using 8ml of Ethadiol, 3ml of buffer, 0.005g of O-cresolphathaline complexone and 0.1g of 8-hydroxylquinoline.

The serial standard measuring 0.05ml and 2.5ml of colour developing reagent were incubated at room temperature for 15 minutes and read absorbance at 750nM on the spectrometer. A calibration curve is then plotted for absorbance (y) against concentration(x). From the equation of the graph: y = 0.1033x-0.013, the concentration of the calcium in the sample is calculated.

Determination of Iron (Fe^{2+})

Standard stock solution of 100ppm is prepared from an analar compound of Ammonium- Iron ll Sulphate [$(NH_4)_2$ Fe $(SO_4)_2$.$6H_2O$].

Serial standards of 1, 2, 4,5and 10ppm were prepared from the stock. A complex of 1.0ml of the serial standard, 1.0ml of 5% ascorbic acid and0.5ml of1,10-phenonthroline is then incubated at room temperature for 30 minutes and the absorbance read at 520nM on the spectrophotometer. A calibration curve is then plotted for absorbance (y) against concentration(x). From the equation of the graph:

y = 0.067x + 0.0097, the concentration of the Iron in the sample is calculated.

Determination of Ascorbic Acid (Vitamin C)

Sample extract in Oxalic Acid is titrated against Sodium 2, 6- dichlorophenolindophenol dye to a faint pink colour which persists for 5 to 10 seconds (Rangana, 1977).

Reagents

1. Indophenol dye (0.04%): Forty milligrams of sodium 2,6-dichlorophenolindophenol was weighed and 150ml of hot distilled water and 42ml of Sodium bicarbonate added. The content is then cooled with water kept in refrigerator, making volume up to 200ml.
2. Metaphosphoric acid (3%): Thirty grammes (30g) of metaphosphoric acid were dissolved in water and the volume made up to1000ml
3. Standard ascorbic acid: One hundred milligrams of ascorbic acid was dissolved in 100ml of Oxalic acid and diluted at 10ml to 100ml with metaphosphoric acid.

Standardization of dye.

Five milligrams of standard ascorbic acid was added to 5mlof Metaphosphoric acid (HPO_3) and titrated against the dye solution, in a micro burette, to a light pink colour. The dye equivalent is then determined as:

Dye equivalent = 0.5/titer. Ten grams of sample (ashed) was thoroughly mixed with 3% Metaphosphoric acid to make volume up to 100ml and filtered. The sample filtrate was then divided into ten parts of 10ml each and titrated against Sodium 2, 6-dichlorophenolindophenol dye. Ascorbic acid content is then calculated from the relation as:

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titer x dye equivalent x dilution}}{\text{Weight of sample}} \text{ X100}$$

Test for viscosity

Twenty grammes (20gm) of sample were weighed by a triple beam balance (Ohaus, U.S.A) into an electronic blender (Monlinex optiblend 2000-France) and 100ml of water added. The blender is then connected to an electrical power source and switched on and run for two minutes The blended sample is poured into a funnel lined with 0.5mm sieve supported over a beaker into which the slimy mucilage is collected. Viscosity is then determined by using "Redwood no.1"viscometer (England), which has a cup with a capillary tube of 1.6mm bore and 10mm length fitted to the base. A discharge valve fitted in the cup controls the flow of fluid through the capillary. The cup is surrounded by a water jacket having a thermometer inserted through the side. The mucilage was poured into the cup and allowed to reach the same temperature (30°C) with the surrounding water before the discharge valve was opened for the fluid to flow through the capillary into a collector marked at 50ml under it. The time taken to discharge 50ml of fluid into the collector beneath is noted using an electronic stop-watch.

Viscosity is quoted as: $N_{seconds}$ Redwood@T°C

V = $N_{seconds}$ Redwood@T°C.

The more viscous the fluid was the longer the discharge time.

DATA ANALYSES

Statistical Software package (SPSS) in 2 x 2 x 2 factorial CRD was applied to test for effects of stage of maturity, water temperature and packaging material on quality of fruits.

(C) EXPERIMENT THREE:

SOLAR DRYING OF OKRA FRUITS.

METHODOLOGY:

Fresh Fruits selected and harvested at 2 stages of maturity (4 and 6days after setting) were washed and allowed to cool off at room temperature. The fruits were then sliced into thickness sizes of 0.5cm 1.0cm and 1.5cm using an adjustable pair of knife cutter designed by the Department of Agricultural Engineering, Kwame Nkrumah University of Science and Technology. The sliced fruits were then weighed and the weights recorded as initial weight (weight before drying) and graded for colour using the colour chart by Kornerup and Wanscher (1981) The sliced fruits were dried by using a solar cabinet dryer for 24 and 48 hours. There were 12 treatments replicated three times.

Treatments:

M_1 0.5 D_1…….Fruits harvested 4days after setting, sliced 0.5cm thick, dried for 24hours

M_1 0.5 D_2……. Fruits harvested 4days after setting, sliced 0.5cm thick, dried for 48hours.

M_2 0.5 D_1…… Fruits harvested 6days after setting, sliced.0.5cm thick, dried for 24hours.

M_2 0.5 D_2…… Fruits harvested 6days after setting, sliced 0.5cm thick, dried for 48hours.

M_1 1.0 D_1……. Fruits harvested 4days after setting, sliced 1.0cm thick, dried for 24hours

M_1 1.0 D_2……. Fruits harvested 4days after setting, sliced 1.0cm thick, dried for 48hours.

M_2 1.0 D_1……. Fruits harvested 6days after setting, sliced 1.0cm thick, dried for 24hours.

M_2 1.0 D_2…… Fruits harvested 6days after setting, sliced 1.0cm thick, dried for 48hours.

M_1 1.5 D_1……. Fruits harvested 4days after setting, sliced 1.5cm thick, dried for 24hours

M_1 1.5 D_2……. Fruits harvested 4days after setting, sliced 1.5cm thick, dried for 48hours.

M_2 1.5 D_1……. Fruits harvested 6days after setting, sliced 1.5cm thick, dried for 24hours.

M_2 1.5 D_2……. Fruits harvested 6days after setting, sliced 1.5cm thick, dried for 48hours.

DATA COLLECTED

1. **Weight loss**: These were calculated as the difference between the weight after the drying (WAD) and the initial weight IW, and worked as a percentage of the former.

$$\%WL = \frac{IW - WAD}{IW} \times 100$$

%WL = Percent weight loss

IW = Initial weight

WAD = Weight after drying

2. **Colour:** Changes in colour was recorded, using the chart by Kornerup and Wanscher (1981), as a deviation from initial score for colour before drying and the colour after drying.

3. **Nutrient content**: Fresh materials were analyzed for nutrient content by the proximate analyses method before and after drying. The dried materials were packed in polythene and polypropylene bags and stored for 3 months. After the storage period, proximate analyses were carried on to check for nutrient content.

4. **Data analyses:** Statistical software package (SPSS) was used to test for the effect of maturity, slice thickness and drying time in a 2 x 3 x 2 factorial CRD on quality of dried samples.

Determination of Moisture Content

Two grams of sample was accurately weighed into a previously dried and weighed glass crucible. It was then dried in a thermostatically controlled forced convection oven (Gallenkamp, England) at 105^0C overnight to a constant weight. The glass crucibles were removed and transferred into a desiccator for cooling after which they were weighed. Moisture content was determined by difference and expressed as a percentage.

$$\text{Percent moisture Content} = \frac{WFS - WDS}{WFS} \times 100$$

WFS = weight of fresh sample

WDS = weight of dry sample

Determination of Ash Content

Two grams sample was accurately weighed into a pre-ignited and previously weighed porcelain crucible, placed in a muffle furnace (Gallenkamp, England) and ignited for 2 hours at 600^0C. After ashing, the crucibles were cooled to about 105^0C in a forced convection oven before cooling them further to room temperature in a desiccator. The crucibles and their contents were weighed, and the weight reported as percentage ash content.

$$\text{Ash content} = \frac{\text{Weight of Ash}}{\text{Weight of original sample}} \times 100\%$$

Determination of Crude Fat Content

Two grams of the dried sample from the moisture determination was transferred into a paper thimble, plugged at the opening with glass wool and placed into a thimble holder. Two hundred milliliters of petroleum ether was measured into a previously dried and weighed round-bottom flask and this was assembled together with the thimble holder and its contents. The Quickfit condenser was connected to the Soxhlet Extractor and refluxed for 16 hours on low heat on a heating mantle. The flask was then removed and the solvent evaporated on a steam bath. The flask containing the fat was heated at 105^0C in an oven for 30 minutes, cooled in a desiccator and the weight of the fat collected determined and expressed as percentage crude fat.

$$\text{Crude Fat} = \frac{\text{Weight of Fat}}{\text{Weight of original sample}} \times 100\%$$

Determination of Crude Fibre Content

The sample from the crude fat determination was transferred into a 750ml Erlenmeyer flask and about 0.5g of asbestos added.two hundred milliliters of boiling 1.25% sulphuric acid (H2SO4) was added to the flask and immediately transferred onto a hot plate. A cold finger condenser was attached to it. The sample was boiled for 30 minutes during which the entire sample was allowed to become thoroughly wetted while any of it was prevented from remaining on the sides of the flask and out of contact with the solvent. After 30

minutes, the flask was removed; its contents filtered through linen cloth in a funnel and washed with boiling water until the washings were no longer acidic. The sample with asbestos was washed back into the flask with 200ml boiling 1.25% sodium hydroxide (NaOH) solution. The flask was reconnected to the condenser and boiled for 30 minutes. The contents were again filtered through linen cloth in a funnel and washed thoroughly with boiling water, then with 15ml alcohol. The residue was transferred into a previously dried and weighed porcelain crucible, dried in an oven at 100^0C for 1 hour, cooled in a desiccator and weighed. The crucible and its contents were ignited in an electric furnace at 600^0C for 30 minutes, cooled and reweighed. The loss in weight was reported as percentage crude fibre.

$$\textbf{Crude Fibre} = \frac{\text{Weight of dry residue} - \text{Weight of ignited residue}}{\text{Weight of original sample}} \times 100\%$$

Determination of Nitrogen Content

The Kjeldahl method (AOAC, 1990) was used for the determination.

Digestion:

Two grams sample was placed in a Kjeldahl digestion tube together with a small amount of a selenium-based catalyst and a few anti-bumping granules. Twenty-five milliliters concentrated H2SO4 was added and the tube shaken until the entire sample was thoroughly wet. The flask was placed on a digestion burner in a fume chamber and heated (approximately 410^0C) until the resulting solution was clear. this was then cooled to room temperature and the digested sample solution transferred into a 100ml volumetric flask and made up to the mark..

Distillation

The distillation apparatus was flushed with distilled water for about 10 minutes. 25ml of 2% boric acid was poured into a 250ml conical flask and 3 drops of mixed indicator added, turning the solution pink. The conical flask and its contents were placed under the condenser with the tip of the condenser completely immersed in the boric acid solution. 10ml of the digested sample solution and about 20ml of 40% NaOH solution were transferred into the decomposition flask and the funnel stopcock well closed. Ammonia (NH3) liberated during the distillation was collected by the boric acid solution, changing it from pink to bluish-green. The distillate was titrated against 0.1N hydrochloric acid (HCL) solution until the solution changed

from bluish-green to pink. The end point was recorded and the titre values obtained were used to calculate the total nitrogen.

$$\text{Percent Total Nitrogen} = \frac{(Va - Vb) \times Na \times 14.01}{\text{Weight of fresh sample}}$$

Where, Va = Volume of standard acid (HCL) used in titration

Vb = Volume of standard acid (HCL) used in blank titration

Na = Concentration of acid (HCL)

Determination of Phosphorus (phosphate)

Phosphorus is determined by Ascorbic acid –Molybdate method using Spectrophotometer.

Reagents Required:

(a) 0.1M Ascorbic acid

(b) 4% Ammonium molybdate

(c) 2.5M Sulphuric acid solution

(d) 0.28% Potassium Antimonyl titrates.

One hundred milligrams per liter(100mg/L) stock solution of phosphate was prepared and six serial standards were prepared from the stock at 0.50, 1.00, 2.00, 4.00, 6.00 and 8.00mg/L respectively.Colour developing reagent (CDR) was prepared with 50ml of 2.5M Sulphuric acid, 5ml of Potassium Antimonyl Titrate(PAT), 15ml of Ammonium Molybdate(AM) and 30ml of Ascorbic acid(0.1M). Half millitres (0.5ml) of each serial standard solution and 2.5ml of the colour developing reagent were incubated at room temperature for 20 minutes after which the absorbance is read at 770nM on the Spectrophotometer. A calibration curve is then plotted for absorbance (y) against concentration(x). From the equation of the graph: $y = 0.0785x-0.0145$ the concentration of the phosphorus in the sample is calculated.

Ammonium molybdate (AM) and potassium antimonyl titrate (PAT) react with phosphate in acid medium to form a complex which on reduction with ascorbic acid yields an intense blue colour which is measured photometrically(Greenberg *et al*,1992).

Determination of calcium.

Calcium was determined by O –Cresolphthaline complexone method (Norbert, 1986) in which Calcium complexes with a buffer medium of O-cresolphthalein complexone (CPC) to form a deep violet colour which is measured at 570nM on spectrophotometer.

Reagents:

(1) O-cresolphthalein complexone (CPC)

(2) Ethadiol

(3) 2-amino-2-mehtyl-1-propanol (3.5M) –buffer.

(4) 8-Hydroxyl quinoline

(5) Calcium carbonate ($CaCo_3$)

A stock standard solution of 100mg/L is prepared from the $CaCo_3$ by dissolving in 10% hydrochloric acid (HCL) and six (6) serial standards are prepared from the stock. Colour development reagent is prepared using 8ml of Ethadiol, 3ml of buffer, 0.005g of O-cresolphathaline complexone and 0.1g of 8-hydroxylquinoline.

The serial standard measuring 0.05ml and 2.5ml of colour developing reagent were incubated at room temperature for 15 minutes and read absorbance at 750nM on the spectrometer. A calibration curve is then plotted for absorbance (y) against concentration(x). From the equation of the graph: y = 0.1033x-0.013, the concentration of the calcium in the sample is calculated.

Determination of Iron (Fe^{2+})

Standard stock solution of 100ppm is prepared from an analar compound of Ammonium- Iron ll Sulphate [$(NH_4)_2$ Fe $(SO_4)_2$.$6H_2O$].

Serial standards of 1, 2, 4,5and 10ppm were prepared from the stock.

A complex of 1.0ml of the serial standard, 1.0ml of 5% ascorbic acid and0.5ml of1,10-phenonthroline is then incubated at room temperature for 30 minutes and the absorbance read at 520nM on the spectrophotometer. A calibration curve is then plotted for absorbance (y) against concentration(x). From the equation of the graph: y = 0.067x + 0.0097, the concentration of the Iron in the sample is calculated.

Determination of Ascorbic Acid (Vitamin C)

Sample extract in Oxalic Acid is titrated against Sodium 2, 6- dichlorophenolindophenol dye to a faint pink colour which persists for 5 to 10 seconds (Rangana, 1977).

Reagents

1. Indophenol dye (0.04%): Forty milligrams of sodium 2,6-dichlorophenolindophenol was weighed and 150ml of hot distilled water and 42ml of Sodium bicarbonate added. The content is then cooled with water kept in refrigerator, making volume up to 200ml.
2. Metaphosphoric acid (3%): Thirty grammes (30g) of metaphosphoric acid were dissolved in water and the volume made up to1000ml
3. Standard ascorbic acid: One hundred milligrams of ascorbic acid was dissolved in 100ml of Oxalic acid and diluted at 10ml to 100ml with metaphosphoric acid.

Standardization of dye. Five milligrams of standard ascorbic acid was added to 5mlof Metaphosphoric acid (HPO_3) and titrated against the dye solution, in a micro burette, to a light pink colour. The dye equivalent is then determined as: Dye equivalent = 0.5/titer.

Ten grams of sample (ashed) was thoroughly mixed with 3% Metaphosphoric acid to make volume up to 100ml and filtered. The sample filtrate was then divided into ten parts of 10ml each and titrated against Sodium 2, 6-dichlorophenolindophenol dye.

Ascorbic acid content is then calculated from the relation as:

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titer x dye equivalent x dilution}}{\text{Weight of sample}} \text{X100}$$

Test for viscosity

Twenty grammes (20gm) of sample were weighed by a triple beam balance (Ohaus, U.S.A) into an electronic blender (Monlinex optiblend 2000-France) and 100ml of water added. The blender is then connected to an electrical power source and switched on and run for two minutes The blended sample is poured into a funnel lined with 0.5mm sieve supported over a beaker into which the slimy mucilage is collected. Viscosity is then determined by using “Redwood no.1”viscometer (England), which has a cup with a capillary tube of 1.6mm bore and 10mm length fitted to the base. A discharge valve fitted in the cup

controls the flow of fluid through the capillary. The cup is surrounded by a water jacket having a thermometer inserted through the side. The mucilage was poured into the cup and allowed to reach the same temperature (30°C) with the surrounding water before the discharge valve was opened for the fluid to flow through the capillary into a collector marked at 50ml under it. The time taken to discharge 50ml of fluid into the collector beneath is noted using an electronic stop-watch.

Viscosity is quoted as: $N_{seconds}$ Redwood@T°C

V = $N_{seconds}$ Redwood@T°C.

The more viscous the fluid was the longer the discharge time.

RESULTS AND DISCUSSION

(A) EXPERIMENT ONE:

weight Loss of fresh Okra stored in polypropylene and polyethylene bags at 7 to 9°C

Table 1: Mean weight of fresh fruits stored in polypropylene and polyethylene bags at 7 to 9°C

Treatment	Initial Weight(g	Weight afte 8days(g)	Weight afte 16days(g)	Weight afte 24days(g)	Total weigh Loss(g)	Mean wei Loss(g)
M_1P_1F	89.50	86.48	86.40	85.36	10.26	3.42
M_1P_1N	87.80	85.50	84.80	84.40	8.70	2.90
M_1P_2F	90.50	88.36	87.30	87.00	8.84	2.95
M_1P_2N	91.60	89.60	88.50	88.45	8.25	2.75
M_2P_1F	98.70	97.50	96.40	95.35	6.85	2.28
M_2P_1N	95.10	93.97	92.95	92.70	5.65	1.89
M_2P_2F	92.40	90.40	90.36	90.00	6.44	2.15
M_2P_2N	90.80	89.76	88.50	88.35	5.79	1.93
CM_1	87.40	67.25	57.30	52.36	85.29	28.43*
CM_2	98.30	73.30	72.50	63.30	85.80	28.60*

Note:

M_1P_1F……four days after fruit set, polypropylene bag perforated.

M_1P_1N…… four days after fruit set, polypropylene bag not perforated.

M_1P_2F…… four days after fruit set, polyethylene bag perforated.

M_1P_2N…… four days after fruit set, polyethylene bag not perforated.

M_2P_1F…… six days after fruit set, polypropylene bag perforated.

M_2P_1N…… six days after fruit set, polypropylene bag not perforated

M_2P_2F…… six days after fruit set, polyethylene bag perforated.

M_2P_2N… six days after fruit set, polyethylene bag not perforated

CM_1……control for four days after fruit set.

CM_2…… control for six days after fruit set.

Mean for the parameters: M_1=3.00g, M_2= 2.06g, P_1= 2.78g, P_2= 2.44g, F =2.85g and N=2.38g.

Fresh Okra fruits packed in polypropylene and polyethylene bags were weighed and put into a refrigerator at temperature of 7-9^{o}C.The weight of the samples were checked at time intervals of 8. 16 and 24 days during the storage period.

Changes in weight (weight loss) that were observed was used to determine how the under listed parameters had influenced the shelf life of the Okra fruits during storage as compared to the unpacked samples (controls):

(a) Stage of maturity,

(b) Type of packaging material,

(c) Perforation and imperforation of packaging material.

Total weight loss was the cumulative values observed at 8, 16 and 24days of storage.

The two controls were significantly different from all the other treatments ($p<0.01$) There is no significant different between them. The highest weight loss (3.42g) in packed samples compared to the lowest (28.43g) in the controls gave 87.99% saving on weight by packaging. This suggests that packaging plays a significant role in restricting respiratory and transpiratory activities of samples, thus impeding moisture loss that will lead to subsequent weight loss. Loss of moisture through transpiration is known to be responsible for rapid loss of weight in fresh Horticultural produce (Hultin and Milner, 1978). Sankat and Maharaj (1994) stated that packaging of *colocassia* leaves restricted weight loss by 0.3-0.7% compared to 2.7-7.3% in unpacked ones per day. They further reported that, after 24 days under refrigerated storage all packed samples recorded1 to 10% weight loss whilst unpacked samples recorded 50 to 100%weight loss.

Effect of packaging material on weight of produce.

There is no significant difference ($P<0.05$) between the mean (2.78g), weight loss of Okra fruits packed in polypropylene bags and that (2.44g) of those packed in polyethylene bags after 24 days of storage(Table 1).

It is probable that the two materials have almost the same functional ability to impede and control moisture loss from the fruits held in them. Di Pentima *et al* (1996)observed a similar phenomenon in a study on storage of broccoli, spinach leaves and asparagus packed in polyethylene and polypropylene, and reported that there is no difference in general appearance wilting (due to moisture loss) and colour of samples packed in the two materials. Percent weight loss for produce packed in both polypropylene and polyethylene bags ranges between1.3 to 3.6% whilst the controls (unpacked) gave between 18.4 to 28.8% losses. Thus Okra fruits can be held for up to24days if properly packed and held at 7-9°C with a minimal loss in weight.

Table2: Least significant Different Test (Lsd)

	M_1P_1F	M_1P_1N	M_1P2F	M_1P_2N	CM_1	M_2P_1F	M_2P_1N	M_2P_2F	M_2P_2N	CM_2
M_1P_1F										-
M_1P_1N	0.53NS									-
M_1P_2F	0.47NS	0.04NS								-
$M1P_2N$	0.67NS	0.15NS	0.19NS							-
CM_1	25.29**	25.53**	25.49**	25.68**						-
M_2P_1F	1.13NS	0.62NS	0.68NS	0.46NS	26.14**					-
M_2P_1N	1.52NS	1.01NS	1.05NS	0.86NS	26.54**	0.39NS				-
M_2P_2F	1.27NS	0.76NS	0.80NS	0.61NS	26.29**	0.14NS	0.25NS			-
M_2P_2N	1.49NS	0.97NS	1.02NS	0.82NS	26.50**	0.36NS	0.04	0.22NS		-
CM_2	25.19**	25.69**	25.66**	25.85**	0.17NS	26.31**	26.71**	26.46**	26.67**	

Lsd (0.05):2.04 x 2.49 =5.08 NB: NS……Means difference not significant

Lsd (0.01):2.75 x 2.49 = 6.89 **……Means difference significant at 1%

Perforated and Non- perforated packaging materials

Statistically there is no significant difference ($p<0.05$) between the mean weight loss (2.85g) of samples in perforated packages and the mean (2.73g) of those in non perforated packages, Table1. It is probable that the cooling effect on produce packed in the two types of packaging material resulted in nearly the same rate of

reduction in water loss regardless of type, perforation and non perforation. Cooling, according to Daryl and Brain (1994), reduces the vapour pressure of liquid water in produce and therefore the propensity for water loss resulting to weight loss.

Stage of Maturity and weight loss.

Materials from maturity stage one (M_1-4days after fruit set) loss comparatively more weight (3.00g) than those from the second stage of maturity (M_2-6days after fruit set) which loss 2.60g (Table 1). Statistically there is significant difference (P>0.05) between the two stages. It is probable the M_1contained much water than M_2 samples, which might be converting its soluble matter contents into lignified materials. Iremiren *et al* (1991) reported from a study on the effect of age of harvesting, after pod set, on okra, that increasing age results in increase in crude fiber and reduction in moisture. Losses due to respirable substrate and moisture are not replenished (Douce and Day, 1985) leading to shrinkage and loss of weight (FAO, 1989).

Per cent salvage and shriveling

Table 3. Per cent salvage and shriveling of fresh Okra fruits stored at 7-9^{o}C for 24 days.

Treatment	% Salvage	% Shriveling
M_1P_1F	73.3	10
M_1P_1N	76.7	10
M_1P_2F	88.3	10
M_1P_2N	68.3	10
M_2P_1F	85.0	10
M_2P_1N	93.3	10
M_2P_2F	86.7	10
M_2P_2N	70.0	10
CM_1	1	50and above
CM_2	3	25- 50

Results after 24days of storage gave the following trend for salvage and shriveling of

Okra fruits (Table 3). The highest salvage of 93.3%was recorded for fruits harvested at 6days after setting and packed in unperforated polypropylene bags, whilst the lowest of 68.3%was recorded for samples harvested at 4day after setting and packed in polyethylene bags. Per cent salvage for the rest of the packed samples ranged between 70-88.3%.
The control for samples harvested at 4days after fruit set
recorded 1% salvage whist those harvested at 6days after fruit set recorded 3%.
Shriveling was 10% for all the packed samples, whilst that for control samples harvested at 4days after setting was 50%and above and 25-50%for samples harvested at 6days after setting.

Table 2 shows per cent fruits salvaged and shriveling. Packaging enabled the saving of 68.3 to 93.3% of fresh fruits whilst the unpacked samples (controls) gave up to 3% salvage of fruits after the storage period of 24 days. Fruits harvested four days after setting (M_1) gave a lower mean of 76.7% salvage compared to 83.7% from those harvested six days after setting (M_2).Though the controls (unpacked) gave a far lower saving of produce, compared to packed ones, more was saved from samples harvested six days after setting(3%) compared to 1% from those harvested at four days. These indicated that deterioration was faster in the younger fruits than the older ones. The younger fruits probably contain much moisture and soluble respirable substances that were lost faster compared to the relatively older ones that were reaching the stage of increasing crude fiber, protein and ashes and a reduction in moisture content.

Succulence, according to Oyolu (2014), is an important factor where Okra pod is used as a table vegetable but pods harvested at an advanced age have the advantage of high fiber content, less moisture whilst the seeds which contain the bulk of the minerals, oils and proteins has also grown considerably at that stage and can be stored longer. Produce packed in both perforated polypropylene and polyethylene bags gave a higher average salvage of 82.1% compared to 77% from those packed in unperforated bags. Most common vapour barriers, such as polypropylene and polyethylene, are hydrophobic and this influence the behavior of condensed water resulting in accumulation of water on their surfaces as droplets rather than a continuous film. This process tends to increase the likelihood that free water will contact fruits packed in these materials and damage them causing deterioration (Kell, 1972).It is probable, therefore, that accumulation of water droplets within the unperforated bags caused damage to fruits packed in them resulting from contact with

water hence the relatively lower salvage. Perforation on the other hand is an approach to condensation control that prevents the problem of surface tension and droplet formation. Damage due to contact of fruits to water is therefore minimized or completely eliminated (Irtwange, 2006).In a related experiment on the conditions produced in film packages by fresh fruits and vegetables and their effect on storage life; Tomkins (2000) observed that perforation established high CO_2 and low O_2 atmosphere in the packages. This retards respiration activity and deterioration is also retarded resulting in longer shelf life.

In sufficient concentration, CO_2 may also have a fungistatic effect, thus reducing microbial damage (El-Kazzaz *et al.* 1983; Agar *et al.* 1990; Chambroy *et al.* 2015).

VISCOSITY

Table 4.Viscosity of fresh Okra fruits stored at 7-9^{o}C

Treatment	8days of storage	16 days of storage	24days of storage	Mean
M_1P_1F	4:13	3:28	2:51	3:31
M_1P_1N	5:10	4:13	2;25	3:83
M_1P_2F	4:42	3:39	2:51	3:44
M_1P_2N	4:34	3:41	3:01	3:59
M_2P_1F	4:12	3:18	2:25	3:18
M_2P_1N	3:49	2:37	2:51	2:79
M_2P_2F	4:01	3:13	2:54	3:23
M_2P_2N	4:16	3:25	2:42	3:28
CM_1	3:09	2:15	0:40	2:82
CM_2	3:00	2:10	0:37	1:82

Initial Viscosity: M_1=9.33, M_2=8.52

Viscosity, an indicative measure of the sliminess of Okras' mucilage was tested for fresh fruit samples before packaging and storage. During the storage period samples were tested for their viscosity at 8, 16 and 24 days and the results are shown in table 4 above.

The highest mean viscosity (3:81 seconds $_{Redwood}$) was recoded for Okra fruit samples harvested at 4days after fruit set and packed in unperforated polypropylene bags (M_1P_1N).These samples lost 58.9% of their viscosity after 24 days of storage from the initial viscosity of 9:33seconds $_{Redwood}$.

The second highest mean viscosity of 3:59 seconds $_{Redwood}$ was recorded for samples from the same stage of maturity and packed in unperforated polyethylene bags. These samples lost 61.5% viscosity compared to the initial value. Generally unperforated packages of both polypropylene and polyethylene bags gave higher viscosity values than the perforated ones. Packed samples harvested at 4days after setting gave mean viscosity of 3:81, 3:59, 3:44 and 3:31seconds $_{Redwood,}$ whilst those harvested at 6days after setting gave means of 3:28, 3:23, 3:18, and 2:79 seconds $_{Redwood.}$ Okra fruits harvested at 4days after fruit set gave comparatively higher viscosity values than those harvested at 6days after setting. Similarly the control (unpacked) samples from fruits harvested 4days after setting recorded a mean of 2:82 seconds $_{Redwood}$ and those harvested at 6days after setting recorded 1:82seconds Redwood.

The initial viscosity of fresh Okra fruits, harvested at 4days after fruit set, was 9:33 seconds $_{Redwood}$ and that of fruits harvested 6days after fruit set was 8:52 seconds $_{Redwood}$ at30^0C before packaging and storage (Table 4). Eight days after storage viscosity of fruits harvested at 4days after fruit set decreased from the initial 9:33 to 4:49 seconds $_{Redwood}$, indicating a loss of 49 .6% viscosity. This value decreased further to 3.55 seconds $_{Redwood}$ by the sixteenth day after storage registering a loss of 59% viscosity. Up to the end of the storage period of 24days the fruits' viscosity dropped to 2:57seconds $_{Redwood}$ indicating a loss of 69.1% of the initial viscosity.

The viscosity of fruits harvested at 6days after fruit set decreased from the initial 8:52 to 4.35 seconds $_{Redwood}$ after eight days of storage, registering a loss of 48.3%. Sixteen days after storage the value further decreased to 3:38seconds $_{Redwood}$ representing a loss of 59% in viscosity. Up to the end of the storage period of 24 days viscosity of the fruits harvested at 4days after fruit set was 2.57 seconds $_{Redwood}$, giving a total loss of 69.1% of the initial value. Those harvested at 6days after fruit set dropped to 2:46seconds $_{Redwood,}$ losing 68.8% of the initial value. Fruit samples from both stages of maturity, 4days and 6days after setting, lost a greater proportion (49.6 %and 48.3% respectively) of their viscosity during the first eight days of storage. Thus materials from both stage of maturity loss nearly half of their initial viscosity within 8days of storage. The results indicate that viscosity of the okra mucilage decreases with increasing storage time.

Figure 2: **Relation between viscosity and storage time.**

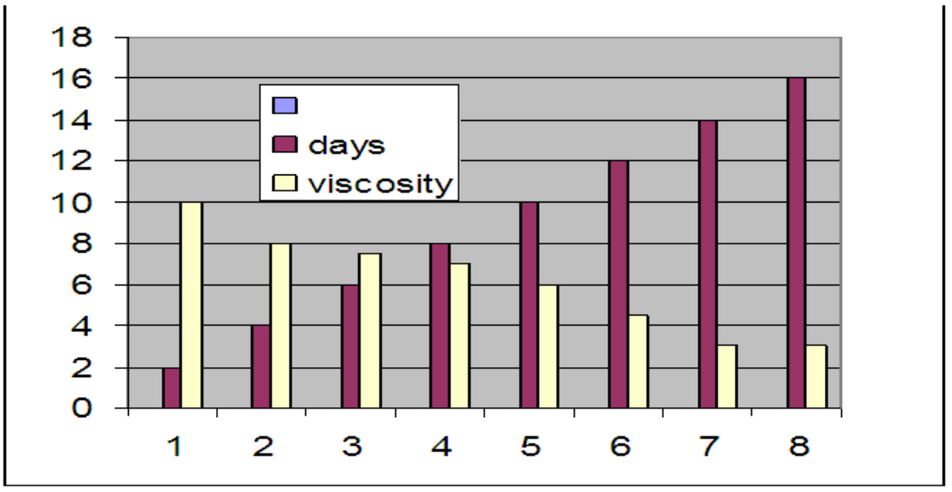

Figure 1 above shows the relation between storage time and viscosity of the fresh Okra fruits observed for 16days of storage. For the first two days of storage viscosity of the fruits was 10 seconds $_{Redwood.}$ There was a steady decrease in viscosity as storage period increases such that by the 14th day of storage the value fell from 10 to3.1seconds$_{Redwood.}$

(ii) EFFECT OF PACKAGING ON VISCOSITY.

The mean viscosity of Okra fruits harvested 4days after fruit set (M_1) and packed in Polypropylene bags (M_1P_1) eight days after storage was 4:46 seconds $_{Redwood.}$ The mean value for the same fruits packed in Polyethylene bags (M_1P_2) during the same storage period was 4:36 seconds $_{Redwood}$, whilst that of the control (CM_1) which was not packed was 3:09seconds $_{Redwood}$. The results indicated that within eight days of storage fruits harvested at 4days after setting and packed in Polypropylene lost 52.2% of its initial viscosity whilst those packed in Polyethylene lost 53.3%with the control losing 66.9% of their respective initial viscosity.Okra fruits harvested at 6days after fruit set (M_2) and packed in Polypropylene (P_1) and Polyethylene (P_2) had viscosities of 4:28 and 4:29 seconds $_{Redwood}$ respectively after 8days of storage whilst the control (CM_2) was

3:00seconds $_{Redwood}$. Thus fruits packed in Polypropylene lost 49.6% of their initial viscosity, those packed in Polyethylene lost49.9% and the control 66.2% after 8days of storage.

After 16 days of storage, fruits harvested 4days after setting (M_1) and packed in Polypropylene (P_1) have their viscosity reduced to 3:24seconds $_{Redwood,}$ indicating a loss of 65% of the initial viscosity. Those packed in Polyethylene (P_2) have their viscosity reduced to 3:30 seconds $_{Redwood}$ being 64.6% of the initial viscosity whilst that of the control (CM_1) was 2:15seconds $_{Redwood}$ indicating a fall of 76.9% from the initial value. Okra fruits harvested at the second stage of maturity (M_2), six days of fruit set, packed in Polypropylene (P_1) and Polyethylene (P_2) had viscosity of 2:84 and 3:34seconds $_{Redwood}$ respectively after 16 days of storage. During the same period of storage the control samples (CM_2) have their viscosity reduced to 2:10second $_{Redwood.}$ The losses from the initial viscosity were 66.7% for samples packed in Polypropylene, 60.8% for

Polyethylene packed samples and 75.4% for the controls after 16 days of storage.

Further decreases in viscosity were observed up to the 24th day of storage. Fruits harvested at the first stage of maturity (M_1) and packed in Polypropylene and Polyethylene registered final viscosity of 2:48 and 2:81seconds $_{Redwood}$ respectively with the control at 0:40seconds $_{Redwood}$. Thus after 24days of storage Okra fruits harvested 4days after setting and packed in Polypropylene recorded 73.4% those packed in Polyethylene recorded 69.9% and the control 95.7% decrease from the initial viscosity.

During the same period, samples harvested at the second stage of maturity (M_2) recorded 2:42seconds $_{Redwood}$ for Polypropylene, 2:76seconds $_{Redwood}$ for Polyethylene packed samples and 0.37second $_{Redwood}$ for the control Final decreases in viscosity were 71.6%, 67.6 % and 95.7% respectively for Polypropylene and Polyethylene packed fruits and the control samples.

(iii). EFFECTS OF PERFORATED AND UNPERFORATED PACKAGING ON VISCOSITY

The mean viscosity of fruits packed in perforated Polypropylene bags was 4:13seconds $_{Redwood}$ after 8days in storage and that of unperforated bags was 4:30seconds $_{Redwood}$. During the same storage period means recorded for fruits packed in perforated and unperforated Polyethylene bags were 4:22and 4:25 seconds $_{Redwood}$ respectively.

Comparing these values to the initial viscosity of 8:52 seconds $_{Redwood,}$ the lower for the fresh fruits before packaging and storage, it was observed that the Okra fruits loss 50% of their viscosity within 8days of storage.

After 16days of storage viscosity for fruits packed in the various materials have reduced as follows: Fruits packed in perforated Polypropylene bags reduced from 4:13 to 3:23second$_{Redwood}$ whilst those packed in the unperforated bags reduced from 4:30 to 3:25second $_{Redwood}$. These gave decreases of 21.8% and 24.4% respectively for the perforated and unperforated Polypropylene packed fruits between day 8 and day16 storage periods. Fruits packed in perforated Polyethylene bags have their viscosity reduced from 4:22 to 3:26 second $_{Redwood}$, and that of unperforated bags also reduced from 4:25 to 3:33 second $_{Redwood.}$ Thus recording decreases of 22.7% and 21.6% respectively for the perforated and unperforated Polyethylene packed fruits between the 8th and 16th days of storage.

At the end of the storage period of 24 days fruits packed in perforated and unperforated Polypropylene bags had viscosity values of 2:38 and 2:51second $_{Redwood}$ respectively, recording a further decrease of 26.3% and 22.8% between the 16th and 24th days of storage. Fruits packed in perforated and unperforated Polyethylene bags also had their viscosity reduced to2:53 and 2.27 second $_{Redwood}$ respectively within 24days of storage. These gave a reduction of 22.4% and31.8% between the16th and 24th day of storage respectively for perforated and unperforated Polyethylene bag. Viscosity of Okra fruits packed in perforated and unperforated packages of Polypropylene and Polyethylene was found to be decreasing irrespectively as storage time increases.

NUTRIENT CONTENT

Table 5. Mean Nutrient content of fresh Okra fruits stored at 7-9^{o}C**.**

Treatment	Calcium g/100g	Phosphorus g/100g	Iron g/100g	Ash. g/100g	Fats g/100g	Fiber g/100g	Protein %	Carbohydrate %	Ascorbic acid g/100g
M_1P_1F	17.0a	0.77a	0.07a	1.25a	0.13a	0.02a	2.49a	6.45b	17.0b
M_1P_1N	19.3a	0.79a	0.05a	1.28a	0.13a	0.02a	2.14a	7.99a	16.0b
M_1P_2F	19.3a	0.78a	0.07a	1.19a	0.14a	0.01b	2.44a	6.76ba	17.0b
M_1P_2N	17.3a	0.81a	0.07a	1.28a	0.17a	0.01b	2.32a	6.66b	15.9b
M_2P_1F	20.0a	0.80a	0.07a	1.25a	0.13a	0.01b	2.37a	6.79ba	15.0b
M_2P_1N	19.0a	0.81a	0.06a	1.30a	0.14a	0.01b	2.14a	7.11ba	14.8b

M_2P_2F	21.0a	0.80a	0.07a	1.30a	0.16a	0.01b	2.21a	6.69ba	15.7b
M_2P_2N	20.0a	0.79a	0.07a	1.28a	0.13a	0.02a	2.18a	7.34ba	14.8b
CM_1	18.7a	0.80a	0.07a	1.23a	0.14a	0.02a	2.51a	7.02ba	4.4a
CM_2	19.3a	0.83a	0.07 a	1.37a	0.14a	0.01b	2.17a	6.99ba	4.2a

NB: Means with the same letter(s) are not significantly different: Duncan's multiple test range

One of the important qualities of Okra is its potential to improve the nutrition of consumers since it is a good source of vitamins, proteins and several minerals.

The nutrient content of Okra fruit samples was checked before packaging and storage and then at the end of the storage period to ascertain any variation. At the end of the storage period of 24 days results of the final produce salvage were as shown in table below (Table 6).

Mean calcium content of fresh Okra fruits harvested at 4days after fruit set was 20.50g/100g and that for fruits harvested at 6days after fruit set was21.00g/100g before packaging and storage. After the storage period of 24days the control sample (unpacked) of fruits harvested 4days after setting have their mean calcium content reduced to 18.7g/100g and 19.3g/100g for the control (unpacked) sample of fruits harvested 6 days after setting. The mean calcium content of Okra fruits from the two maturity stages packed in Polypropylene and Polyethylene bags ranged between 17.00 and 21.00g /100g after 24 days of storage.

Statistically there was no significant difference among the means for calcium content of the samples before and after storage. This indicated that stage of maturity, packaging in perforated and unperforated Polypropylene and Polyethylene bags have no significant effect on the calcium content of the Okra fruits. Similarly the calcium content was not significantly affected by storage time.

The mean phosphorus content for fresh Okra fruits harvested at 4days after fruit set was 0.83g/100g and 0.81g/100g for those fruits harvested at 6days after setting before they were packaged for storage. After the storage period of 24days the mean Phosphorus content for the controls (unpacked samples) was 0.80g/100g for fruits harvested 4days after setting and 0.83g/100g for those harvested 6days after setting. For the packed samples, the highest mean Phosphorus content, after 24days of storage was 0.81g/100g and the lowest 0.77g/100g.There were, statistically, no significant differences ($P<0.05$) between the means of the fresh fruits,

(before packaging), the controls and the packed samples. Thus the mean Phosphorus content for all fruits from the two stages of maturity, packed in perforated and unperforated Polypropylene and Polyethylene bags were not significantly different. Therefore, storage time, packaging material (perforated or unperforated) and the stage of maturity have no significant effect on the Phosphorus content of Okra fruits.

The mean Iron content of fresh Okra fruits from both stages of maturity was 0.07g/100g before packaging and storage. Fruits harvested at 4days and 6days after setting and packed in perforated and unperforated Polypropylene bags recorded mean values of 0.05g and 0.06g/100g Iron respectively after 24 days of storage. All the other treatments, including the controls had values of 0.07g/100g which were not significantly different ($P<0.05$) from the two earlier means. . Therefore, storage time, packaging material (perforated or unperforated) and the stage of maturity have no significant effect on the Iron content of Okra fruits.

Mean Protein content, before packaging and storage, for fresh Okra fruits harvested 4days after fruit set was2.51% and 2.40% for fruits harvested at 6days after fruit set. After 24days of storage the controls (unpacked) samples of Okra fruits harvested at 4 and 6days after setting recorded mean values of 2.51 and 2.17% respectively which were not significantly different. The highest mean Protein content recorded was 2.49% for Okra fruits samples harvested at 4days after setting and packed in perforated Polypropylene bags. Okra fruits samples from the two stages of maturity packed in unperforated Polypropylene gave the lowest mean Protein content of 2.14%.

The means for the rest of the treatments, in percentages, were 2.18, 2.21, 2.32, 2.37 and 2.44. Though there were observable differences in the means, statistically these differences were not significant. These results indicated that all the parameters studied during the storage period did not significantly affect the protein content of Okra fruits stored at 7-9^{o}C for 24days.

Carbohydrate content of fresh Okra fruits harvested at 4 and 6days after fruit set were 8.61 and 8.82% respectively, before packaging and storage. After 24days of storage at 7-9o C, samples harvested at 4days after fruit set and packed in unperforated Polypropylene bags registered the highest mean carbohydrate content of 7.99% .The lowest mean carbohydrate content of 6.45% was registered for samples from the same fruits harvested at 4days after setting and packed in perforated Polypropylene bags. Both means were significantly

different ($P<0.05$) from each other as well as the initial means before storage. Another lower mean of 6.66% registered for samples harvested 4days after setting and packed in unperforated Polyethylene bags was not significantly different from the lowest mean of 6.45%.The rest of the treatments, including the controls, registered percentage mean carbohydrate contents of 6.69, 6.76, 6.79, 6.99, 7.02, 7.11and 7.34 which were not significantly different from each other.

Generally there was a significant decrease in the carbohydrate content of the Okra fruits after storage comparing the final means to the means of the fresh produce, 8.61 and 8.82%, before packaging and storage.

However the non significant differences among the means of a greater portion of the stored samples suggested that reduction in carbohydrate content was very minimal and probably ceased after some period. The marked reduction in carbohydrate content observed might probably be due to respiration activity of the produce during packaging and shortly before reaching an equilibrium temperature after they were put into the refrigerator.

The mean Vitamin C (ascorbic acid) content for the fresh Okra fruits harvested at 4days after fruit set was 24.4g/100g and that of fruits harvested at 6days after fruit set was 24.2g/100g before packaging and storage. After the storage period of 24 days fruits harvested at 4days after setting and packed in perforated and unperforated Polypropylene bags recorded 17.0 and 16.0g/100g mean Vitamin C content respectively. The same samples packed in perforated and unperforated Polyethylene bags recorded 17.0 and15.9g/100g of Vitamin C respectively. After the same period of storage Okra fruits harvested at 6days after setting and packed in perforated and unperforated Polypropylene bags recoded mean Vitamin C contents of 15.0 and 14.8g/100g respectively. Those samples packed in perforated and unperforated Polyethylene bags recorded 15.7 and 14.8g/100g mean Vitamin C content respectively.

All the recorded mean values were statistically not different ($P<0.05$) from each other however they were significantly different from the initial mean values of 24.4 and 24.2 g/100g recoded for the fresh samples before packaging and storage. The controls (unpacked) recorded 4.4 and 4.2g/100g respectively for samples harvested at 4and 6days after fruit set. Though these values were not significantly different from each other, they were significantly different from the initial values recorded before storage and the values recorded for the packed samples after storage. The unpacked samples (controls) loss 82-83% of their Vitamin C after 24days of storage

whilst the packed samples loss 30-39% of their Vitamin C over the same storage period .The above results indicated that packaging combined with low temperature storage was more effective in reducing loss of Ascorbic acid from the stored Okra fruits. Works from some authors reported that conditions favourable to water loss after harvest also accounts for the loss of Vitamin C. Seung and Kader (2000) concluded that an attempt to reduce water loss from harvested produce will as well reduce Vitamin C loss. Low temperature storage and wrapping (packaging) have been found to be practices that minimized loss of Ascorbic acid from harvested produce. Zeppelin and Elvehjein (1949) reported that vegetables stored at low temperatures loss less Vitamin C compared to those held at high temperatures. In an experiment on leafy vegetables they reported that samples held at 6^{o}C lost 10% of their Vitamin C in 6days while those held at room temperature lost 20% in only 2days.Losses of Vitamin C in Kale were accelerated at higher temperatures. Similar results were obtained with Spinach, Cabbage and Snap beans by Ezell and Wilcox (1959).

In an experiment on Strawberry Nunes *et al* (1998) reported that wrapping which prevented water loss reduced Ascorbic acid loss as well. They further concluded that the total Ascorbic acid content of wrapped Strawberries changed little during storage for 8days at 10^{o}C while losses in total Ascorbic acid content of unwrapped samples even at 1^{O}C ranged from 20-30% over 8days. Packaging therefore has a significant influence on the Vitamin C content of Okra by reducing the rate of loss in packed fruits compared to the unpacked ones. The type of packaging material, Polypropylene and Polyethylene, show no significant difference in the Vitamin C content of fruits packed in them. There were no significant differences also in the perforated and unperforated packages of both materials.

Stage of maturity and nutrient content

Maturity is one of the major factors that determine the compositional quality of fruits and vegetables upon detaching from the parent plant. Comparatively the less mature fruits, harvested 4days after setting, retained more of their Vitamin C (15.9-17.0g/100g) than those harvested at 6days after setting which had means of 14.8-15.7g/100g. Vitamin C retention was 65.2-69.7% for fruits harvested at 4days after setting and 61.2-64.9% for those harvested at 6days after setting. Vitamin C content was found to be varied for vegetables at various stages of maturity. Howard et al (1994) reported that total Vitamin C content of red pepper was about30% higher than that of green pepper.

In earlier reports variously on their works on Tomato, Kader et al, and Bentacourt et al (1977) stated that fruits at breaker stage contain less Vitamin C than those at table ripe stages. They concluded that fruits analyzed at the breaker stage contain only 69% of their potential Ascorbic acid concentration. Contrary to their reports, Lee et al (1982) reported that large and more mature Peas contained less ascorbic acid than smaller and less mature ones. This assertion agreed with an earlier report by Nagy (1980), that immature citrus fruits contain the highest concentration of Vitamin C whereas the matured fruits contain the least. He further stated that the concentration of Vitamin C in fruits and vegetables decreases with maturity. The maturity factor probably, might have contributed to the comparatively higher Vitamin C retained by the less mature Okra fruits that were harvested 4days after setting as against those harvested at 6days.

Plate 2: Fresh okra fruits stored for 24days

Fruits harvested 4 days after setting

Fruits harvested 6 days after setting

(B) EXPERIMENT TWO:

Weight Loss of Okra fruits dipped in hot water at 50 and 75^{o}C

Observations on weight changes of Okra fruits during the storage period, after dipping them in hot water at 50 and 70^{o}C, indicated a more stable weight for all the samples except the controls. The results were shown in Table 6 below:

Table 6: Mean weight of Okra fruits dipped in hot water at 50 and 75^{o}C

Treatments	Initial mean weight(g)	Mean weight after 8days(g)	Mean weight after 16days(g)	Mean weight after 24days(g)
$M_1 50^{O} CP_1$	44.15	44.05	43.55	43.15
$M_1 50^{O} CP_2$	43.50	43.50	43.50	43.30
$M_1 75^{O} CP_1$	50.70	50.70	50.50	50.40
$M_1 75^{O} CP_2$	52.60	52.40	52.10	52.10
$M_2 50^{O} CP_1$	64.84	64.80	64.70	64.70
$M_2 50^{O} CP_2$	66.20	66.10	66.00	65.90
$M_2 75^{O} CP_1$	78.90	78.70	78.10	78.10
$M_2 75^{O} CP_2$	68.90	68.90	68.70	68.50
CM_1	57.40	38.10	22.00	11.40
CM_2	60.70	41.30	26.10	12.70

The highest mean weight loss of 1.0g among the packed samples was recorded for fruits harvested 4days setting, dipped in water at 50^{O}C and in Polypropylene bags. This gave 2.27%loss in weight from the original weight of 44.15g. The lowest weight loss of 0.14g was recorded for samples harvested at 6days after setting,

dipped in water at 50^{o}Cand packed in polypropylene bags. This gave 0.22%loss in weight from the initial weight of 64.84g. Values for the rest of the packed samples were between 0.30-0.80g.All these values, for the packed samples, were statistically not different from each other (P>0.05). The control samples lost 43g and 54g for fruits harvested at 4and 6 days after setting respectively. The percentage lost was 79 for samples harvested at 4days after setting and 81for those harvested at 6days after setting. Values for the two controls (unpacked) were not significantly different (P>0.05) from each other but different from all the other treatments which were packed in polypropylene and polyethylene bags. The two types of materials however did not indicate any different influence on weight loss.

Packaging in this regard help to restrict weight loss to a significant level in packed samples compared to unpacked ones. In a related experiment on packaging of *colocasia* leaves, Sankat and Maharaj (1994) reported that packaging markedly restricted weight loss by 0.3-0.7% per day in packed leaves compared to 2.7-7.3%in unpacked ones. Packaging, according to the authors, have the advantage of longer shelf life over non-packaging.

Shilvering

Okra fruit samples harvested at 4days after setting showed a greater degree of shilvering than those harvested at 6days after setting. After 8days of storage the mean score for samples harvested at 4days after setting was 3(10-25%shilvering) and 2(1-10% shilvering) for those harvested at 6days after setting and dipped in hot water at 50^{o}C. Mean shilvering scored for samples dipped in hot water at 75^{o}C was the same, for the two maturity stages after 8days of storage, as that at 50^{o}C water temperature. From the 16th to the 24th day of storage there were no observable shilvering in all the hot water treated samples. The control samples scored 5(50% and above shilvering) and 4(25-50% shilvering) for samples harvested at 4 days and 6days after setting respectively by the 24th day of storage.

Colour change.

The colour of the fresh fruit samples were score 4(apple green) before dipping into hot water at 50and 70^{O}C. After the 8th day of storage materials heated at 75^{o}C deviated to 3(spinach green) whilst those heated at 50^{o}C remained at 4(apple green). The control samples scored 2(yellowish green) for both stages of maturity. Up to

the 16th day of storage all the samples from both maturity stages and dipping temperatures scored 0(oak brown) with grayish water coming from them. All the samples deteriorated completely beyond usable state by the 24th day of storage.

Percent Salvage: There was a complete deterioration of all samples at the end of the storage period hence no material was salvaged at the end.

VISCOSITY

Table 7 Viscosity of Okra fruits dipped in hot water at 50 and 75^{O}C, stored for 24 days at 7-9^{o}C

Treatment	Viscosity after 8days of storage	Viscosity after 16days of storage	Viscosity after 24days of storage	Mean Viscosity
M_1 50^{o}C P_1	4:20	2:15	-	3.18
$M_1$50^{O}C P_2	4:15	2:10	-	3.13
$M_1$75^{O}C P_1	4:22	2:12	-	3.17
$M_1$75^{O}C P_2	4:34	2:30	-	3.32
$M_2$50^{o}C P_1	4:15	2:15	-	3.15
$M_2$50^{o}C P_2	3:40	1:35	-	2.38
$M_2$75^{O}C P_1	4:10	1:15	-	2.63
$M_2$75^{O}C P_2	4:15	1:25	-	2.70
CM_1	3:09	2:15	-	2.62
CM_2	3:00	2:10	-	2.55

Initial mean viscosity: M_1=9:33, M_2=8:52

Table 7 above showed the changes in viscosity observed in Okra fruits dipped in hot water at 50 and 75^{O}C, packed in Polypropylene and Polyethylene bags and stored at 7-9^{o}C over a period of 24days. Okra fruit samples harvested at 4days after setting lost 53-55% of their viscosity after 8days of storage whilst those harvested at 6days after setting lost 51-60% of their viscosity during the same period. The control for samples harvested at 4and 6 days after setting lost 66 and 65% of their viscosity respectively after the 8days of storage.

At the end of 16days of storage lost in viscosity ranged between 88.7-98.4% for all the samples harvested at 4days after setting and dipped in hot water at 50 and 75^{o}C. Samples harvested at 6days after setting lost between 88.3-98.2% of their viscosity during the same period. The controls for samples harvested at 4 and 6days after setting lost77 and 75.3% of their respective viscosities. Samples deteriorated completely by the 24th day of storage hence were not further tested for viscosity.

Okra fruit samples harvested at 4days after setting lost 53-55% of their viscosity after 8days of storage whilst those harvested at 6days after setting lost 51-60% of their viscosity during the same period. The control for samples harvested at 4and 6 days after setting lost 66 and 65% of their viscosity respectively after the 8days of storage.

At the end of 16days of storage lost in viscosity ranged between 88.7-98.4% for all the samples harvested at 4days after setting and dipped in hot water at 50 and 75^{o}C. Samples harvested at 6days after setting lost between 88.3-98.2% of their viscosity during the same period. The controls for samples harvested at 4 and 6days after setting lost77 and 75.3% of their respective viscosities.

The loss in viscosity was very high, 88.7-98.4%, among all the hot water treated samples regardless of age at harvesting, dipping temperature and packaging material. The controls (unpacked samples) also demonstrated the same high level of viscosity lost which were not different from the packed samples. The mucilage of okra is known to be composed of long -chain carbohydrate molecules and very highly soluble in water (Tomoda *et al*., 1980). It is likely that the heating process might have interfered into the structure of the carbohydrate molecules leading to its breakdown. Heating might have also increased the solubility of the mucilage and couple with hydrolysis will lead to reduction in viscosity of the fruits during storage.

Plate 3: Hot water treated fruits

Fruits heated at 50^{0}C

Fruits heated at 75°C

Fruits heated 50°C stored 16 days

Fruits heated 75°C stored 16 days

NUTRIENT CONTENT

At the end of the stipulated storage period of 24days, all the stored samples deteriorated beyond their useable states. It was therefore not possible to check their nutrient status at the end of the storage period. However results from nutrient content analysis, up to the 16th day of storage, indicated a complete loss of vitamin C and about 50% loss of carbohydrates. Protein, Calcium, Fiber, Iron, Fats, Phosphorus and Ash mostly remained unchanged or showed very marginal change up to the 16th day of storage.

(C) EXPERIMENT THREE:

WEIGHT LOSS IN SLICED OKRA FRUITS AFTER DRYING

Table 8 WEIGHT LOSS IN SLICED OKRA FRUITS AFTER DRYING.

Treatment	WBDg.	WAD g.	Weight loss (WBD-WAD)g.	%Weight loss
M_1 0.5 D_1	949.3	131.8	817.5	86.1
M_1 1.0 D_1	1298.1	163.3	1134.8	87.4
M_1 1.5 D_1	1064.1	131.7	932.4	87.6
M_1 0.5 D_2	255	26.8	229	89.5
M_1 1.0 D_2	392.4	38.3	354.1	90.2
M_1 1.5 D_2	363.2	329.5	33.7	90.7
M_2 0.5 D_1	949.3	131.8	817.5	86.1
M_2 1.0 D_1	1298.1	163.3	1134.8	87.4
M_2 1.5 D_1	1064.1	131.7	932.4	87.6
M_2 0.5 D_2	205.7	21.7	184	89.8
M_2 1.0 D_2	363.6	37.2	326.4	89.8
M_2 1.5 D_2	385.2	37.2	348	90.3

NB: WBD = Weight Before Drying, WAD = Weight After Drying.

Table 8 shows the loss in weight for the various sliced Okra fruits after drying for 24 and 48 hours. The highest percent weight loss of 90.7 was recorded for Okra fruit samples harvested at 4days after fruit set, sliced 1.5cm thick and dried for 48 hours.

Lowest percentage weight loss of 86.1was recorded for two treatments from samples harvested at 4and 6days after fruit set which were both sliced 0.5cm thick and dried for 24 hours.

Differences in slice thickness among samples from the same stage of maturity dried for the same time period have very little influence on the degree of weight loss. Thus slice thickness of 0.5, 1.0 and 1.5cm did not show marked differences on weight loss for the samples from the two stages of maturity of 4 and 6days after fruit set. The observed differences in weight after drying is due to the drying period rather than slice thickness.The loss in weight is the direct effect of moisture loss during drying indicating that longer drying time resulted into more moisture loss and a subsequent loss in weight.

In an experiment on the drying of Okra, Adom *et al* (1995) reported that during solar drying of Okra moisture content decreases significantly and this is influence by slice thickness and drying time.

The highest percent weight loss of 90.7 was recorded for Okra fruit samples harvested at 4days after fruit set, sliced 1.5cm thick and dried for 48 hours.

Lowest percentage weight loss of 86.1was recorded for two treatments from samples harvested at 4and 6days after fruit set which were both sliced 0.5cm thick and dried for 24 hours.

Generally samples dried for 48 hours from both stages of maturity loss much weight compared to those dried for 24 hours irrespective of slice thickness. The percent mean weight loss for all the samples dried for 24hours ranged between 86.1-87.6 whilst that of samples dried for 48 hours ranged between 89.5-90.7%.

Differences in slice thickness among samples from the same stage of maturity dried for the same time period have very little influence on the degree of weight loss. Thus slice thickness of 0.5, 1.0 and 1.5cm did not show marked differences on weight loss for the samples from the two stages of maturity of 4 and 6days after fruit set.

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NUTRIENT CONTENT OF DRY OKRA FRUITS

Table 9 Mean nutrient content of dry okra fruits

Treatment	PROTEIN%	FATS g/100g	ASH g/100g	FIBER g/100g	CARBO. %	VITC. g/100g
$M_1 0.5D_1$	2.68 a	0.10 b	1.25 bc	1.22 ba	7.01 a	11.4b
M_1 1.0D_1	2.52 ba	0.11 b	1.07 bd	1.13 ba	6.95 ba	11.6b
M_1 1.5D_1	2.70 a	0.11 b	1.27 bc	1.31 a	6.88 ba	11.3b
M_1 0.5D_2	2.28 bd	0.09 b	1.14 bc	0.92 c	6.20 ba	9.6c
M_1 1.0D_2	2.20 cd	0.09 b	0.94 b	1.02 bc	6.25 ba	9.9c
M_1 1.5D_2	2.09 cd	0.09 b	0.91 b	1.03 bc	5.64 b	9.7c
M_2 0.5D_1	1.93 c	0.09 b	0.91 b	0.95 c	6.48 ba	11.2b
M_2 1.0 D_1	2.19 cd	0.09 b	1.08 bd	1.04 bc	6.27 ba	10.9b
M_2 1.5D1	2.32 bd	0.39 a	1.02 bd	1.11 ba	6.26 ba	10.7b
M_2 0.5 D_2	2.29 bd	0.09 b	0.97 b	0.99 c	6.40 ba	9.8c
M_2 1.0 D_2	2.12 cd	0.09 b	0.92 b	0.91 c	5.94 b	9.5c
M_2 1.5 D_2	2.29 bd	0.10 b	1.05 bd	0.98 c	6.85 ba	9.3c
CM_1	2.57 ba	0.11 b	1.45 a	0.02 d	7.10 a	24.4a
CM_2	2.09 cd	0.15 b	1.33 a	0.01 d	7.00 a	24.2a

Duncan's multiple range tests

Means with the same letter are not significantly different**.**

The highest mean protein content of 2.70% was recorded for materials harvested at 4days after fruit set sliced 0.5cm and thick and dried for 24 hours. Also material harvest at 4days after fruit set sliced 1.5cm thick dried for 24 hours gave the next highest percent protein content of 2.68. These two were not significantly different from each other (P< 05). The control (fresh material) harvest at 6days after fruit set is

not significantly different from samples harvested at 4days after fruit set sliced 1.5cm thick dried for 48hours and those harvested at 6days after fruit set, sliced 1.0cm thick and dried for 24 and 48hoursrespectively.

Observed difference among treatments indicated that slice thickness, drying time and stage of maturity have not significantly affected the protein content of okra fruit.

Also drying in general does not alter the protein content to a significant level. Schippes (2000) reported from an experiment on drying *solanum scarbum* that the level of crude protein and minerals nutrient were not affected by drying.

Material harvested at 6days after maturity, sliced 1.5cm thick and dried for 24hours gave the highest fat content of 0.39 g/100g. This value is significantly different ($P< 0.5$) from all the other treatments, which had values ranging from 0.09 to 0.11, which were not significantly different from each other. The value of 0.39 g100/g for this only treatment might be due to unexplained circumstances. Generally it is observed that stage of maturity, slice thickness and drying time do not significantly affects the fat content of okra. However drying resulted in the reduction of the fat content of samples between 18-40% compared to the fresh stage.

Carbohydrate content for fresh fruits (controls) from both stages of maturity was 7.10 and 7.00%.These were significantly different ($P< 0.05$) from all the samples after drying. Materials from samples harvest 4days after fruit set sliced 0.5cm thick and dried for 24hours have carbohydrate content which was not different significantly from the controls. Two treatments, one from samples harvested at 4 days after fruit set, sliced 1.5cm thick and the other from samples harvested at 6days after fruit set, sliced 1.0cm thick were also significantly different from the remaining treatments. The rest of the treatments were not different from each other. The highest percentage (20.6%) decrease in carbohydrate from the fresh samples after drying was recorded by fruits harvested at 4days after setting, sliced 1.5cm thick and dried for 48hours.

The other treatments show less than 20% fall in carbohydrate over the drying periods of 24 and 48 hours. Decrease in carbohydrate across the rest of the treatments ranges between 12.8-16.3%

Despite the variations observed in carbohydrate content drying have very little effect on carbohydrate content of Okra fruits. The carbohydrates are known to be mainly present in the form of mucilage which is highly soluble in water (Siemonsma and Hamon (2002)

It is therefore possible that a lot of the carbohydrates were present in the much water contained in the fresh succulent fruits. Upon drying this become concentrated with less marginal decreases. Drying, according

Jules Janick (1986), remove water form tissues and the resultant produce is a highly concentrated material of enduring quality as natural deterioration of produced by respiration is stopped because of enzyme inactivation and lack of free water protects the dried products from decay by micro- organisms.

VISCOSITY OF SLICED OKRA FRUITS AFTER DRYING

Table 10 Viscosity of sliced and dried Okra fruits stored for 90days.

Treatment	Before storage	30 Days	60 Days	90 Days
M_1 0.5 D_1	8.01	7.16	7.05	6.42
M_1 1.0 D_1	8.20	7.29	7.17	6.45
M_1 1.5 D_1	8.13	8.04	7.34	7.21
M_1 0.5 D_2	8.11	8.01	7.37	7.19
M_1 1.0 D_2	8.21	8.01	7.29	7.08
M_1 1.5 D_2	8.14	8.01	8.08	7.42
M_2 0.5 D_1	7.31	7.01	6.48	6.08
M_2 1.0 D_1	7.42	7.27	7.04	6.32
M_2 1.5 D_1	7.55	7.34	7.11	6.41
M_2 0.5 D_2	7.45	7.37	7.31	7.29
M_2 1.0 D_2	7.35	7. 11	6.40	6.30
M_2 1.5 D_2	7.38	7.26	6.52	6.44

NB: Viscosity of fresh Okra fruit on the day of harvest for M_1= 9:33 and M_2= 8:57

Viscosity of fresh Okra fruits harvested at 4 and 6 days after setting was 9:33 and 8:57 seconds $_{\text{Redwood}}$ respectively. After slicing and drying for 24 hours samples from materials harvested at 4days after setting gave a lower viscosity of 8:01seconds $_{\text{Redwood}}$ for fruits sliced 0.5cm thick. The highest viscosity of 8:20seconds $_{\text{Redwood}}$ was recorded for samples sliced1.0cm thick. The loss in viscosity, from the initial fresh values, registered after 24 hours of drying were 14.15 and 12.11%, for the lower and the highest values respectively. After 90 days of

storage, the loss in viscosity from the initial fresh stage was 31.20% for the lower value and 30.87%for the highest.

Samples from materials harvested at 4days after setting and dried for 48 hours gave a low viscosity of 8:11seconds $_{Redwood}$ whilst the highest was 8:21seconds $_{Redwood.}$ These gave reduction of 13.08 and 12.00%, for the lowest and the highest values respectively, from the initial viscosity of the fresh fruits. The final loss in viscosity after 90days of storage were 24.12and 23.00%for the less and more viscous samples respectively. For Okra fruit samples that were harvested at 4days after setting, slice thickness have a very little influence on viscosity after drying for 24 and 48 hours.

It was however observed that samples dried for 24 hours were less viscous than those dried for 48 hours. Indicating that, the longer drying period the more viscous the product becomes

Okra fruit samples harvested at 6days after setting and dried for 24 hours gave a highest viscosity of 7:45 seconds $_{Redwood}$ and the lowest being 7:35seconds $_{Redwood.}$

These gave a reduction of 13.04and 14.24% respectively from the initial viscosity of 8:57seconds $_{Redwood}$. After 90 days of storage the highest and the lowest viscosities were 7:29and 6:30seconds $_{Redwood}$ respectively, registering a reduction of 15.00and 26.50% from the initial fresh state value. Samples dried for 48 hours gave the highest viscosity of 7:55and the lowest of 7:31seconds $_{Redwood.}$ Registering reductions of 12.00 and 14.70% respectively. After 90 days of storage the percentage loss in viscosity was 25.20 and 29.05 for the highest and the lowest values respectively

Generally it was observed that samples dried for 24 hours from both stages of maturity were less viscous than those dried for 48 hours irrespective of slice thickness. It is probable that the samples dried for a shorter period still have some of the mucilage in solution of moisture retained in the sample. Whilst those dried for a longer might have loss more moisture resulting in the mucilage becoming more concentrated hence the more viscous product. The mucilage is known to be soluble in water, but the water is loss through evaporation during the process of drying resulting in more concentrated mucilage as moisture is removed. Viscosity is therefore caused by mucilage which becomes concentrated in the product as moisture is removed. There was a negative correlation($r = \sim 0.96$) between viscosity and moisture content confirming that increased viscosity was the result of concentration effect (Adom *et al*, 1999).

Though viscosity was found to have decreased initially in the dried products compared to their fresh stages, it has become more stable even over long period of storage. This may be the consequence of increase crystallinity in the structure of the mucilage as a result of continual decrease in moisture content (Holdsworth, 1971, Fennema, 1985). Viscosity is an important attribute of Okra which serves for consumer appeal and from the results of this experiment the best effect is given by samples harvested at 4days after fruit set and dried for 48 hours.

Plate 4: Sliced okra fruits

Fresh sliced okra fruits

Okra fruits harvested after 4 days dried for 24 hours

Okra fruits harvested after 4 days dried for 48 hours

Okra fruits harvested after 6 days dried for 24 hours

Okra fruits harvested after 6 days dried for 48 hours

CONCLUSION

The three experiments were carried out with the view of finding out a suitable post harvest processing method that can help extend the shell life of okra fruits without affecting their useable qualities. Results from the first experiment which involved packing and storing of fresh okra fruits indicated the following. Fresh okra fruit packed in both polypropylene and polyethylene bags and store at 7- 9 C can stay up to 24 days with no significant ($p \leq 0.05$) weight lost.

Perforation and imperforation of the polypropylene and polyethylene bags used for packaging showed no significant effect on the weight of the stored fruits. Okra fruits harvested at four days after fruit set lost comparatively more weight than those harvested at six days after fruit set. Percent fruit salvage was higher (68.3-93.3%) for package samples compare to the very low (1-3%) for unpacked (control) samples.

However produce packed in perforated polypropylene and polyethylene bags gave a higher salvage of 82.1% compared to 77% from those packed in the imperforated bags of the two packaging materials. Viscosity of all stored samples decreased with increasing storage period. By the end of 24days of storage fruits harvested at 4days after fruit set lost 69.1% of their viscosity and those harvested at 6days lost 68.8% of their viscosity. Perforation or imperforation of packaging material has no effect on the viscosity lost in okra fruits. Polypropylene packed fruit lost 71.6%, polyethylene packed fruits lost 67.6%, and the unpacked fruits lost 95.7% of their respective viscosity.

Apart from vitamins C which recorded a significant reduction all the other nutrients elements tested did not reduced in the fruit samples significantly over the storage period.

The second experiment involves hot water treatment of okra fruit before packaging for storage. Result of this experiment show a very fast rate of deterioration of fruits. Though the weight of stored produced was quite stable, no fruit was salvage at the end of storage the period.

Experiment three involves slicing and drying of okra fruits in a solar cabinet dryer, for 24 and 48 hours. Results showed that samples from both stages of maturity dried for 24hours lost comparatively less weight than those dried for 48hours indicating that, the longer the drying period, the more the lost in weight. Generally weight lost by the dried samples ranged between 86.1-90.7% making the dried material light and convenient to carry.

Plant nutrient content of the okra fruit were not significantly affected by the drying process except vitamin C which recorded52.5-60.7% lost from the produce after drying. Drying resulted in a stable colour of samples which remained unchanged up to 90days of storage.

Judging from the results of these three experiments I wish to conclude that: packaging and storage of fresh okra fruit enables the fruit to keep longer and remained in the useable state than unpacked storage.

Harvesting fruit at 4 and 6days, after setting for storage is appropriate, however those harvested at 6days after setting will come out with greater number of unusable fruit after the storage period. On the choice of packaging material one should prefer polypropylene to polyethylene for bitter results. Also perforation of the chosen material had advantages over the imperforated ones.

Hot water treatment of okra fruits can be applied under situations where the fruits may be used within 16 days or less but not longer. Dying invariable should be considered as the best method of processing large volumes of okra fruits and for longer storage period. When properly done large quantities of okra fruits that will other wise go waste can be saved during the peak season. Also for bulk haulage to distant markets, drying provides the convenient of lighter load weight and easy handling.

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Recommendations

It is therefore recommended that a further studies be carried out on the hot water treatment of okra fruit considering different heating and storage temperature levels.

It is recommend that solar cabinet dryers that would be use in future drying experiments be provided with temperature measuring and control gadget to enable one to work towards the appropriate drying temperature for quality produce. Also further work can be done on fresh okra fruits storage using other packaging material and different temperature levels.

Finally I recommended a workable collaboration to carry out these experiments in some selected okra growing communities with farmers participating.

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