INTRODUCTION

Vegetables are increasingly becoming 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.,* 1998).

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*., 1981). 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, 1987). An additional constraint to improving this situation is that in most developing countries the number of scientists concerned with post harvest losses is significantly lower than those in production research (F.A.O 1988). It is estimated that about 25 to 40% of vegetables and other respiring fresh commodities produced worldwide each year deteriorates beyond usable qualities (Lioutas, 1988).

Okra (*Abelmoschus 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, 1981). The fruits are consumed as vegetables, raw, cooked or fried in stews, gumbos and cecole dishes together with other vegetable. 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, 1989).

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 the 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 (Siemonsma and Piluck, 1993). The world production of okra as fresh vegetable is estimated at 6 million tonnes per year. In West and Central Africa, production figures are estimated at between 500,000 to 600,000 tones annually (Siemonsma and Hamon, 2000). 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 tonnes (SRID- MOFA, 2007)

Despite all its importance, the crop, like all other fresh vegetables has a problem of short shelf life. The fresh fruits remain in usable quality for only 8 to 10 days 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 temperatures (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. This traditional method however 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.*, 1990).

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, 1988). This helps orderly marketing and may increase the financial gain to the producer. However, farmers do not have adequate storage facilities to reduce losses. There is also the lack of capital so that farmers are unable to acquire and use cold storage facilities even when available. Many growers depend on almost daily sales for their incomes and hence may not store their produce in anticipation of higher prices.

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

LITERATURE REVIEW

Fresh horticultural produce, including vegetables deteriorate after harvest. The rate of deterioration of individual produce depends on its overall rate of metabolism. This has created the need for post harvest techniques that will allow quality to be retained over an increasingly longer period (Wills *et al.,* 1998).

QUALITY OF PRODUCE

The term quality defies complete and objective definition. For the consumer, it is largely a subjective judgment, which will vary between commodities and for a particular commodity will also depend on the position of the recipient in the distribution chain (Arthey, 1975). Quality may therefore be defined in terms of end use based on requirements for market, storage, transport, eating and processing with regard to important factors such as appearance, including size, shape and colour, conditions and absence of defects, texture, flavour and nutritional value (Kapelis, 1987). Appropriate production practices, careful harvesting, proper packaging, storage and transport contribute to good produce quality. Quality therefore cannot be improved after harvest but can only be maintained (Wilson *et al.,* 1995). Production practices therefore have a tremendous effect on the quality of produce at harvest and on post harvest quality and shelf life (Herner, 1989).

POST HARVEST LOSS: Post harvest loss is any change in the quality or quantity of a product after harvest that prevents or alters its intended use or decreases its value (Kays, 1991). Post harvest loss can be classified into two categories:

PHYSICAL LOSS: This arises from structural damage or microbial wastage which can leave produce tissue degraded to a stage where it is not acceptable for presentation, fresh consumption or processing. Physical loss also arises from the evaporation of intercellular water leading to direct loss in weight.

QUALITY LOSS: This is due to physiological and compositional changes that alter the appearance, taste or texture and make produce less desirable aesthetically to the end user (Coursey, 1983).

Loss in quality can be caused by a variety of means, which may be grouped under four main headings: metabolic factors, transpiration, mechanical injury and micro organisms (Kader *et al.,* 1985)

METABOLIC FACTORS

A major metabolic process taking place in harvested produce is respiration. This is an excellent indicator of metabolic activity of the tissue and thus is a useful guide to the potential storage life to the produce. This process, like transpiration continues after harvest. Losses due to respirable substrates and moisture are not replenished leading to deterioration (Douce and Day, 1985).

RESPIRATION

Respiration plays a significant role in the post-harvest life of fresh produce. It results in the biological oxidation of simple sugars in fruits and vegetables. Energy is also liberated as heat at the time of respiration (Roy, 1990). According to the author, the process results in the disappearance of sugars with the uptake of oxygen and the production of carbon dioxide and water. This process does not take place in one step but through a series of reactions. The initial phase of respiration, known as glycolysis is the production of pyruvic acid from glucose. The conversion of pyruvic acid into carbon dioxide and water passes through various organic acids by pathways known as the citric acid cycle or Kreb's cycle. The ratio of Co_2 evolved to O_2 consumed given as Co_2/O_2 is the respiratory quotient of the process. Earlier reports by Roy *et al*., (1972) and Roy and Singh (1980) stated that respiration quotient is useful since it gives us the idea of the substrate used for respiration and the rate of respiration which is a good index of the post harvest life of fruits and vegetables. The authors further stated that, to extend the post harvest life of the produce its respiration rate should be reduced as far as possible (Roy *et al.,* 1972).

3

When the air supply is restricted and the amount of available oxygen in the environment of a produce falls to about 2% or less, fermentation instead of respiration occurs. Poor ventilation of produce because of restricted air supply leads to the accumulation of Co_2 around produce. When the concentration of carbon dioxide gas rises to between 1 and 5% it ruins produce by causing bad flavour and internal break down (FAO, 1989).

TRANSPIRATION

Transpiration (loss of water) can result in rapid loss in quality, and it is the singular factor that causes deterioration with or without other factors (Hultin and Milner, 1978). Most fresh produce contain 65 to 95% water when harvested. They continue to loose water, leading to shrinkage and loss of weight (FAO, 1989). Post harvest moisture loss causes vegetables and fruits to shrivel (Hurschka, 1977), lose their bright colour and become more susceptible to post harvest decay (Van de Berg and Lentz, 1966, 1978). Transpiration and subsequent water loss can also result in rapid loss of quality as well as direct loss in saleable weight and therefore absolute monetary value. A main quality criterion, appearance, is affected through wilting, shriveling and texture such as loss of crispness in lettuce. Water loss can also affect nutritional quality. Wills *et al.* (1998) reported that vitamin C levels fall rapidly in water-stressed leafy vegetables.

FACTORS AFFECTING TRANSPIRATION RATE

Surface to Volume Ratio

A major factor in the rate of water loss from produce is its surface area to volume ratio. On a purely physical ground, there is proportionally greater loss by evaporation from produce with a higher surface area to unit volume ratio. Generally the rate of moisture loss is proportional to the surface area of the produce and the water vapour pressure deficit (Apeland and Baugerod, 1971), which is determined by the temperature and relative humidity of the surrounding air (Van den Berg, 1987). Differences in size and shape therefore affect moisture loss from fruits and vegetables. Ketsa (1990) later observed that smaller tangerine fruits have a shorter shelf life, due to greater moisture loss from their larger surface areas, compared to larger tangerine fruits. Lownds *et al.* (1994) suggested that differences in the rate of moisture loss from the fruit of nine pepper cultivars may be due to differences in their surface area to volume ratios. In a related experiment on carrots, Apeland and Baugerod (1971) observed that moisture loss per unit surface area from carrots increased as their root size decreased. It is estimated that individual edible leaves have surface area to volume ratio of 50-100cm^2/cm^3, whereas tubers and fruits have ratios of 0.5-1.5cm^2/cm^3. Under the same conditions a leafy vegetable will lose moisture and weight much faster than a fruit (Wills *et al.*, 1998). Rees *et al.* (2002), in a study on keeping qualities of sweet potatoes reported that the main forms of root deterioration were weight loss (primarily water loss) and rotting. It was further suggested, from the relationship between weight

losses and rotting of cultivar, that desiccation increases the susceptibility to rotting, and therefore moisture loss is the driving force for deterioration.

The nature of plant surface and underlying tissues has a marked effect on the rate of water loss. Many fruits and vegetables have waxy coatings (cuticle), which is highly resistant to the passage of water or water vapour. The presence of pores and or cracks, cuticle thickness and epicuticular wax quality; chemistry and distribution on produce surface affect the rate of moisture loss (Lownds *et al.*, 1994).

MECHANICAL INJURY

Mechanical damage greatly accelerates the rate of water loss from produce. Bruising and abrasion damage the surface organization of tissues, thereby allowing much greater flux of water vapour through the damaged areas. Cuts are of even greater importance as they completely break the protective surface layer and directly expose underlying tissues to the atmosphere (Sastry, 1985). Kays (1991) observed that mechanical stress that causes physical injury represents one of the most serious sources of quality loss during the post harvest period. The author further stated that wounding caused increase in respiration and ethylene production and also provides entry sites for decay organisms.

MICRO ORGANISMS

Fungal infestation either from the field or in the storage room can be a cause of deterioration of produce. Benkhemmar *et al.* (1992) identified several fungi species including *Rhizopus stolonifer, Mucor racemosus, Alteernaria alternaria, Botrytis cinero, Aspergillus niger, Penicillium expansum* and other penicillium species as the major causes of deterioration of fresh produce in storage.

The authors observed also that apart from *Rhizopus stolonifer* and *Aspergillus niger* the rest of the species can grow at 0ºC indicating that cold storage alone is not sufficient to preserve the quality of desert grapes over a long period (Benkhemmar *et al.*, 1992)

Of the bacteria, *Erwirnia* and *Pseudomonas* species are the major causes of post harvest losses of fruits and vegetables (Wills *et al.*, 1998). It was reported that most of these organisms are weak pathogens as they can invade only damaged produce. The authors further stated that a few, such as *Colletotrichum species* are able to penetrate the skin of healthy produce making it possible for weak pathogens to invade afterwards. Most

fruits and vegetable crops retain better quality at high relative humidity (80% to 95%) but at this humidity, disease growth is encouraged (Byczynski and Lynn 1997).

METHODS OF CONTROLLING QUALITY LOSS OF FRESH PRODUCE

In order to maintain the nutritional values and organoleptic properties of fresh produce, technical means of reducing deterioration are used. These methods, classified as physical, chemical and biochemical, are applied to stop the action of deterioration to obtain a desirable quality (Colin, 1992).

(I) PHYSICAL METHODS OF REDUCING DETERIORATION

a. Heating:

Hot water dipping of produce can control surface infections as well as infections that have penetrated the skin. Wastage in papaya, mango, stone fruits and cantaloupe was prevented through hot water dipping at 50-55^{o}c for 4 minutes (Barkai- Goland and Philip, 1991). In a related experiment to control green mould spores, Coates and Johnson (1993), reported that 99% of spores were killed after 1hour exposure to hot water at 50^{O}C. Mould infection and decay in citrus fruits was prevented when the fruits were held at 35^{O}C at 95-99% relative humidity (Eckert and Brown, 1986).

b. Cooling and Cold Storage

Temperature is the single most important factor in maintaining quality after harvest (Hardenburg, 1986). Low temperature storage has become a common practice in reducing weight loss and maintaining quality of fresh produce (Kays, 1991). Thus refrigerated storage has become useful for the storage of most respiring fresh produce, since it helps to stabilize physiological and microbiological qualities (Gorris *et al.*, 1994). Apart from stabilizing physiological and microbiological qualities, chemical composition of fresh produce do not change much under refrigerated storage. Sanjeev and Nath (1993) observed that decay, physiological weight loss and decrease in vitamin C content were lower in *Emblica afficinalis* stored at temperature (8-12^{o}C) and high humidity. The authors further stated that fruits could be stored up to 12 days with acceptable minimum decay and quality loss compared with 4 days at room temperature of 24ºC. Reporting on the chemical composition of stored *Capsicum spp* fruits, Ahmed *et al.* (1996) stated that fruits could be stored for 4 weeks at 8ºC and 85-95% relative humidity with minimum effect on chemical composition.

c. Packaging and Storage

Post harvest losses of fresh and freshly processed agricultural and horticultural produce amount to about 25 to 40% of the total production, and are due to inadequate control of physical, physiological and microbiological deterioration during storage and marketing (Lioutas, 1988). Packaging under modified atmosphere has become increasingly popular as a means to counteract these loses (Day and Gorris, 1993).

With modified atmosphere packaging (MAP), the gas atmosphere inside a package is typically low in oxygen and high in carbon dioxide with equilibrium values in ranges of 2-3% and 5% respectively (Kader *et al.*, 1989). The authors stated that, lower oxygen content stabilizes the product by slowing down respiratory activity of the produce as well as metabolic activity and growth of spoilage micro organisms. The actual gas atmosphere composition within the package is the net result of the initial gas content of the package, gas exchange through the packaging material and respiratory activity of the produce (Gorris and Peppelenbos, 1992). Sankat and Maharaj (1994) reported that weight loss of both packed and unpacked leaves of *Colocasia esculenta* increases almost linearly within storage time. In an experiment on the packaging and storage of *Colocasia* leaves, Sankat and Maharaj (1994), observed that packaging markedly restricted weight loss by 0.3, 0.4, 0.5, and 0.7% respectively against unpacked leaves of 2.7, 3.5, 4.4 and 7.3% per day respectively. Packaging, according to the authors, effectively restricted moisture loss, thus, after 24 days under refrigerated storage all packed samples recorded 1 to 10% weight loss and shriveling. However unpacked samples recorded 50-98% weight loss and shriveling. It was concluded that *Colocasia* leaves could be held for up to 16 days if properly packed and held at10^{o}C.

In a study on the storage of Rambutan fruits, Ketsa and Klaewkasetkorn (1995) observed that fruits in sealed polyethylene bags with ventilation holes stored significantly longer than those under other conditions. It was further reported by the authors that sealed bags with 1, 2 and 3 ventilation holes stored at 12^{o}C lasted for 18, 16 and 13 days respectively whilst those in open polyethylene bags under the same conditions stored for 7 days and those in open baskets lasted for 5 days. Packaging and packaging material however contributes a significant cost to the produce industry.

For fruits and vegetables, packaging is one of the most important steps in the long and complicated journey from grower to consumer (Ashby, 1987). Apart from ensuring safety of produce during transport, packaging also helps to keep quality of produce.

A survey by Kwaa (1993) showed that packaging positively influenced the shelf life of perishable food produce.

It has been reported that the protection and preservation function of a package are against mechanical, chemical, environmental and biological hazards (Packaging code, 1989). Roy (1990) also observed that packaging has a significant effect in reducing wastage and providing protection from mechanical damages and pathological deterioration during storage, transport and marketing. The primary function of a package therefore is to keep the produce clean and provide a barrier against dirt and other forms of contamination that favours pathogenic attack (Paine and Paine, 1983).

d. Drying

Some fruits and vegetables have traditionally been processed by drying to extend their shelf life and quality well beyond the few weeks when they are in season (Kordylas, 1991). Thus crop drying is essential to enhance the storage life of certain horticultural produce. Andzono (1996) observed that harvested fruits of *Dacryolis edulis* (sofou), which cannot be preserved for more that 3 days due to pulp softening, were processed through drying and the quality after drying was more acceptable to consumers.

The method of drying can have effect on the final quality of the produce. Comparing open sun drying and shade drying of Baobab leaves, Modibo (2000) reported that sun drying reduced vitamin A content by 50%, however vitamin C, iron and zinc were not affected and hence recommended shade drying as the best. Itodo *et al.* (2002) observed that apart from loss in nutritional value of crops, sun drying method is reported to have other disadvantages including low drying rate, unhygienic exposure to various forms of contamination and infestation by insects and other animals. On the other hand solar drying (cabinet) has the advantage of higher air temperature drying. In addition microbial and insect infestations are prevented resulting in better hygienically dried produce due to the enclosed structure. Reporting on the efficiency of solar and open air-sun drying, Arinze (1985) stated that over 50% saving in time was gained when solar drying was used against the traditional sun drying.

Tulasidas *et al*., (1993) observed and reported that microware drying reduced drying time resulting in comparable product quality of grapes. It was further suggested that, air temperature of 50ºC was the optimum for modified microwave drying. Lower maximum temperatures, reduced intensity of sunlight and higher atmospheric humidity

led to slower drying, fruit (sliced) darkening and the risk of moulding (Birgita *et al*., 1998)

e. Waxing

The outer surfaces of fruits have a natural waxy layer which is partly removed during handling and washing. An extra layer of wax applied artificially provides the necessary protection against decay organisms (Roy, 1989).

The practical benefit from wax coating is usually a reduction in evaporation and respiration. It has been reported that where refrigerated storage facilities are not available protective skin coating with wax is one of the methods developed for increasing the storage-life of fresh fruits (Srivastava, 1962; Dalal *et al.,* 1971)

Coatings can to some extent reduce the decay of produce. In many cases, coated fruits had less decay and longer storage life than uncoated samples (Ben-Yehoshua, 1967; Curtis, 1988). El-Ghaouth *et al.* (1991) however, reported that chitosan coating could control the decay of strawberry, cucumber and bell pepper fruits. Waxed or coated Orblanco fruits (*Citrus grandis x Citrus ponadisi)* had significantly lower chilling injury incidence than unwaxed samples when stored at 1°C for 40days (Meheriuk and Lau,1988). Reporting on the effects of coating on the quality of fruits and vegetables, Ahmad and Khan (1987) and Faroogi *et al.* (1988) found that, firmness, colour, texture, acid concentration and ripening process are influenced to different extents. The magnitude of effects is related to the degree of atmosphere modification, and may also be cultivar and temperature dependent (Drake *et al.*, 1991)

f. Irradiation

Investigations have shown that ionizing radiation has the potential to extend the shell life of perishables. Gamma radiation not only helps in the destruction of microorganisms but also alters the physiology of fruits (Salunkhe, 1961). Dharkar and Sreenivasa (1968) reported that ripening of mangoes can be retarded by the application of ionizing radiation. A dosage of 0.50kGy was found effective for disinfestations of mango from fruit flies (Manoto and Blanco, 1982). The potential benefits of gamma or electron beam radiation in the post harvest handling of fruits and vegetables lie in both insect and disease disinfestations (Morris, 1987).

II. CHEMICAL METHODS OF REDUCING DETERIORATION

Salting, smoking, sugar addition, artificial acidification, Ethyl-alcohol addition and antiseptic substances action are among chemical methods employed to reduce food deterioration (Colin, 1992). Chemical treatments are also used on lightly processed fresh produce mainly for controlling decay, reducing browning and retaining firmness (Brecht, 1995). Low-pH organic acid solutions are used as antimicrobials to control bacteria or as antioxidants to prevent browning; to reduce discoloration of pigments and to protect against loss of flavor, changes in texture, and loss of nutritional quality (Wiley, 1994). Chemical treatments with citric acid and or ascorbic acid solutions prevent browning in freshly prepared potatoes (Langdon, 1987) and lettuce (Castañer *et al.*, 1996)

In addition to such natural preservatives as salts, vinegar and spices, a number of chemicals when added to food prevent or retard deterioration. They are usually used in conjunction with other methods of preservation of fruits and vegetables (Holdsworth, 1983). For example sulphur dioxide is widely used in the drying of fruits and vegetables, chlorine compounds in hydro cooling and processing. Potassium sorbate and sodium benzoate are useful in preventing growth of yeasts and molds in fresh fruits (Janick, 1986).

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 (Appendix 1).

Laboratory and rooms at the Department of Horticulture were used for handling and keeping of produce at ambient temperatures while a refrigerator in the laboratory was used for the storage of produce. Hot water bath at the Pathology laboratory of Crop and Soil Sciences Department of the Faculty of Agriculture was used for the hot water treatment of fruits. Drying of fruits was done by the use of a solar cabinet dryer located at the food processing unit of the Biochemistry Department, Kwame Nkrumah University of Science and Technology. Proximate analyses of materials (samples) for nutrient content were carried-out in the Bio-chemistry laboratory of the Crops 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 4m x 4m and separated by paths of 0.5m from each other giving a total of 27 plots (9 per block)

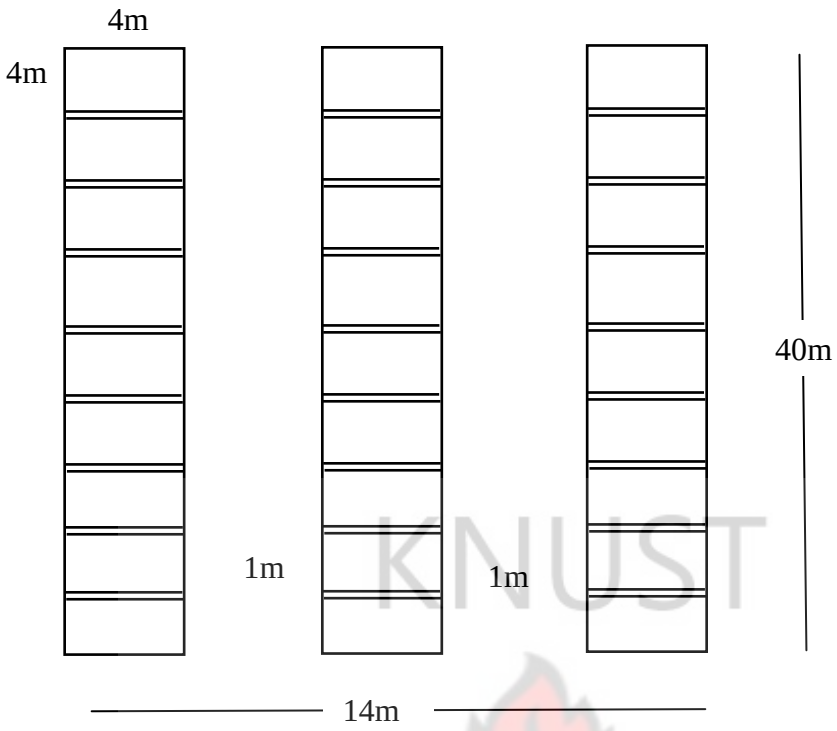

Fig.1; Layout of experimental plots (April to July 2003).

The same layout was used for three successive croppings, October 2003 to February 2004, April to July 2004 and October 2005 to February 2006 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, KNUST, was grown using seeds selected from a previous cultivation of the crop. The seeds were stored in the pods in the Departments' seed store for a year. Selected pods were cracked opened by the hand to remove seeds. The seeds were cleaned of debris by winnowing, and further cleaned of dead, broken and malformed seeds. More of the debris and seeds that floated were removed when the lot was soaked in water. Seeds that settled beneath the water were considered as good and were sown in the field at 50cm x 50cm intervals at 2 to 3 seeds per hill. Ten days after germination and emergence they were thinned to one plant per hill.

PARAMETERS FOR ASSESSMENT

1. DAYS TO 50% EMERGENCE

Counting of emerging 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.

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

PE = Percent emergence of plant.

THS = Total number of Hills sown

HE = Hills emerged before thinning

2. DAYS TO 50% FLOWERING

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

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

%F = Percent flowering.

Tp = Total number of plants

Fp = Flowered plants.

3. DAYS TO FRUIT SET, AFTER PLANTING

When flowers opened and closed, plants were observed for actual fruit set. Days to fruit set were estimated 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: 4 days 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 excess water from the surface. The fruits thus cleaned were spread on a flat bench in the store room at the Department of Horticulture, for cooling overnight at ambient temperature.

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 5 days of sowing. Seedling emergence continued vigorously such that after the sixth day of sowing 80% of the total seeds sown had 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 used took an average of 45 days for 50% of the total plant population to initiate flower buds.

(3) Days to 50% fruit set:

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

(4) Days to first and second harvests:

The first fruits were harvested at 56 days from the day of sowing; that is 4 days after fruit set. The second harvest was done on the 58th day after seed sowing, or 6 days after fruit set. Fruits were harvested at these two stages of maturity for the three experiments of fresh storage, hot water treatment and solar drying.

Plate 1: Fresh okra fruits harvested at 4 days after setting.

LABORATORY EXPERIMENT ONE

PACKAGING AND STORAGE OF FRESH OKRA FRUITS

After cooling overnight, two hundred fruits from each maturity stage 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 the selected 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 on 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 the 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 shrivelling.

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

1…….no shrivelling observed

2……1 – 10% shrivelling

3……10 – 25% shrivelling

4……25 – 50% shrivelling

5……50% and above shrivelling (after Hirata *et al.*, 1987).

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

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 on the day of assessment.

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

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

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 was recorded as saved materials from the total put into storage. These saved materials were then expressed as a percentage of the total put into storage over the period of observation.

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

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 the difference and expressed as a percentage.

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

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 millilitres of boiling 1.25%

sulphuric acid (H_2SO_4) 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 millilitres 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. Twenty-five millilitres (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 millilitres (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 (NH_3) 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.

$$\text{Percent Total Nitrogen} = \frac{(Va - Vb) \times Na \times 14.01}{\text{Weight of fresh sample}} \times 100$$

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 the 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 litre (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 the 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 a 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 and 0.5ml of 1,10-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 a refrigerator, making the volume up to 200ml.
2. Metaphosphoric acid (3%): Thirty grams (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 5ml of 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 grams (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 and blended. 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.

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 unperforation of packaging material.

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

DATA ANALYSIS

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

RESULTS
LABORATORY EXPERIMENT ONE

Fresh okra fruits packed in polypropylene and polyethylene bags were stored at 7 to 9ºC in a refrigerator for 24 days.

Table 1 below showed the extent of weight loss recorded during the storage period.

1. Weight loss.

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

Treatment	Initial Weight(g)	Weight loss after 8days(g)	Weight loss After 16days(g)	Weight loss after 24days(g)	Total weight Loss(g)	Mean weight Loss(g)
M_1P_1F	89.50	3.02	3.10	4.14	10.26	3.42
M_1P_1N	87.80	2.30	3.00	3.40	8.70	2.90
M_1P_2F	90.50	2.14	3.20	3.50	8.84	2.95
M_1P_2N	91.60	2.00	3.10	3.15	8.25	2.75
M_2P_1F	98.70	1.20	2.30	3.35	6.85	2.28
M_2P_1N	95.10	1.13	2.15	2.40	5.65	1.89
M_2P_2F	92.40	2.00	2.04	2.40	6.44	2.15
M_2P_2N	90.80	1.04	2.30	2.45	5.79	1.93
CM_1	87.40	20.15	30.10	35.04	85.29	28.43
CM_2	98.30	25.00	25.80	35.00	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 factors studied: M_1=3.00g, M_2= 2.06g, P_1= 2.78g, P_2= 2.44g, F =2.85g and N=2.38g.

(a) Fruits harvested 4 days after fruit set.

The results (Table 1) indicated that okra fruits harvested at 4days after fruit setting and packed in perforated polypropylene bags lost 3.02g of weight from an initial weight of 89.50g after eight days of storage. Up to the 16th day they lost 3.10g of weight and further lost 4.14g by the 24th day of storage. Thus at the end of 24 days of storage the total weight lost recorded was 10.26g, giving a mean weight loss of 3.42g for each 8 day period.

Okra fruits from the same maturity stage packed in unperforated polypropylene bags lost 2.30, 3.00 and 3.40g of weight after the 8th, 16 and 24th day of storage respectively from an initial weight of 87.80g. The total weight lost in this case was 8.70g and a mean of 2.90g for each 8day period.

Okra fruits harvested at 4days after setting and packed in perforated polyethylene bags lost 2.14g weight after 8days of storage. They further lost 3.20 and 3.50g by the 16th and 24th days of storage respectively from an initial weight of 90.50g.The total weight lost was 8.84g giving a mean of 2.95g for each 8day period. Those packed in unperforated polyethylene bags lost 2.00, 3.10 and 3.15g after the 8th ,16th and 24th day of storage respectively. These gave a total weight lost of 8.25g from an initial weight of 91.60g.The mean weight lost was2.75g for each 8day period. The control (unpacked) samples lost 20.15g after 8days of storage and subsequently lost 30.10 and 35.04g after the 8th and 24th day of storage respectively. The total weight lost recorded was 85.29g from an initial weight of 87.40g giving a mean loss of 28.43g for each 8day period.

(b) Fruits harvested 6 days after fruit set.

Okra fruits harvested at 6days after setting and packed in perforated polypropylene bags lost 1.20g of their weight after 8daysof storage. Further losses of 2.30 and 3.35g were recorded for the 16th and 24th days respectively. Total weight lost was 6.85g from an initial weight of 89.7g, giving a mean of 2.28g. Those samples packed in unperforated polypropylene bags recorded weight losses of 1.13, 2.15 and 2.40g after 8, 16and 24days of storage respectively. The total weight lost was 5.68g from an initial weight of 95.1g giving a mean of 1.89g for each 8day period. Samples packed in perforated polyethylene bags lost 2.00g of their weight after 8days of storage and further lost 2.04 and 2.40g after the 16 and 24 days of storage respectively. Total weight lost recorded was 6.44g out of the initial weight of 92.4g and a mean of 2.15g for every 8days of storage. Those packed in unperforated polyethylene bags lost 1.04, 2.30 and 2.45g of their weight after 8, 16 and 24 days of storage respectively. The total weight lost by these samples was 5.79g from the initial weight of 90.8g giving a mean of 1.93g loss every eight days.

The control (unpacked) samples of fruits harvested 6 days after setting lost 25.00g of their weight after 8 days of storage. They further lost 25.80 and 35.00g after the 16th and 24th days of storage respectively. Total weight lost was 85.80g from an initial of 98.30g. On the average a loss of 28.60g was recorded for every eight days of storage.
The results indicated that fruits harvested 4 days after setting on the average lost more weight (3.00g) compared to those harvested 6 days after setting which lost 2.16g

2. Percentage salvage and shrivelling

Table 2. Per cent salvage and shrivelling of fresh okra fruits stored at 7-9°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

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.

Results after 24days of storage gave the following trend for salvage and shriveling of okra fruits (Table 2). 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 4 days 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 4 days after fruit set recorded 1% salvage while those harvested at 6 days after fruit set recorded 3%. Shrivelling was 10% for all the packed samples, while that for control samples harvested at 4 days after setting was 50% and above and 25-50% for samples harvested at 6 days after setting.

3. Colour score

Table 3: Colour score for okra fruits stored at 7-9^{o}C.

Treatment	Initial colour	Colour after 8days	Colour after 16dyas	Colour after 24 days
M_1P_IF	4	4	3	3
M_IP_IN	4	3	3	3
M_1P_2F	4	4	3	3
M_1P_2N	4	3	3	3
M_2P_1F	4	4	3	3
M_2P_1N	4	3	3	3
M_2P_2F	4	4	3	3
M_2P_2N	4	3	3	3
CM_1	4	2	1	1
CM_2	4	2	1	1

NB:

5……..deep green

4……..apple green.

3…… .....spinach green.

2…… .....yellowish green

1…….....bracken green

0……oak brown

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.

Observable colour changes were recorded for the stored samples up to 24 days using the colour chart. The initial colour for all fresh okra fruit samples was scored 4 (apple green). Table 3 showed the initial colour and the observed changes after 8, 16 and 24 days of storage. After 8 days of storage okra fruit samples packed in perforated

polypropylene and polyethylene bags showed no observable change in colour from the initial score of 4 (apple green).

However those samples packed in unperforated bags of both polypropylene and polyethylene showed a deviation from the initial score of 4 (apple green) to 3 (spinach green).The control samples from the two maturity stages showed a sharp deviation from 4 (apple green)to 2 (yellowish green). By the 16th day of storage all the samples in the perforated polypropylene and polyethylene bags deviated from 4 (apple green) to 3 (spinach green) whilst those samples in the unperforated bags of both polypropylene and polyethylene remained at score 3 (spinach green).

The two control samples further deviated from 2 (yellowish green) to a score of 1 (bracken green). Scores for samples in both perforated and unperforated bags of polypropylene and polyethylene remained unchanged, from the 16th to 24th day of storage. The control for samples harvested at 6days after setting also showed no change in their colour on the 24th day compared to the 16th day. However the control samples harvested at 4 days after setting showed a deviation from 1(bracken green) on the 16th day to 0 (oak brown) on the 24th day after storage.

VISCOSITY

Table 4. Viscosity (seconds $_{Redwood}$) of fresh okra fruits stored at 7-9^{o}C

Treatment	8days of storage	16 days of storage	24 days 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 seconds $_{Redwood}$, M2=8.52 seconds $_{Redwood}$

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

NB:

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.

Viscosity, an indicative measure of the sliminess of okra's 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.

The highest mean viscosity (3:81 seconds $_{Redwood}$) was recoded for okra fruit samples harvested at 4 days 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 (4days after fruit set) 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 4 days after setting gave mean viscosity of 3:81, 3:59, 3:44 and 3:31seconds $_{\text{Redwood,}}$ while those harvested at 6 days after setting gave mean values of 3:28, 3:23, 3:18, and 2:79 seconds $_{\text{Redwood.}}$ Okra fruits harvested at 4 days after fruit set gave comparatively higher viscosity values than those harvested at 6days after setting. Similarly the control (unpacked) samples from fruits harvested 4 days after setting recorded a mean of 2:82 seconds $_{\text{Redwood}}$ and those harvested at 6 days after setting recorded 1:82seconds $_{\text{Redwood}}$

NUTRIENT CONTENT

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 friut samples was checked before packaging and storage and then at the end of the storage period to ascertain any variations. At the end of the storage period of 24 days, results of the final produce salvaged were as shown in Table 5.

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

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.

(1) CALCIUM:

Mean calcium content of fresh okra fruits harvested at 4days after fruit set was 20.50g/100g and that for fruits harvested at 6 days after fruit set was 21.00g/100g before packaging and storage. After the storage period of 24 days the control sample (unpacked) of fruits harvested 4 days after setting had their mean calcium content reduced to 18.7g/100g and 19.3g/100g for those harvested 6 days after setting.

The mean calcium content of okra fruits from the two maturity stages packed in perforated and unperforated Polypropylene and Polyethylene bags ranged between 17.00 and 21.00g /100g after 24 days of storage.

(2) PHOSPHORUS.

The mean phosphorus content for fresh okra fruits harvested 4 days after fruit set was 0.87g/100g and 0.91g/100g for those fruits harvested 6 days after setting before packaging and storage. After the storage period of 24 days the mean Phosphorus content for the controls (unpacked samples) was 0.80g/100g for fruits harvested 4 days after setting and 0.83g/100g for those harvested 6 days after setting. For samples packed in perforated and unperforated polypropylene and polyethylene bags, the highest mean Phosphorus content after 24 days of storage was 0.81g/100g and the lowest 0.77g/100g.

(3) IRON

The mean iron content of fresh okra fruits from both stages of maturity was 0.07g/100g before packaging and storage. Fruits harvested at 4 days and 6 days 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.

(4) ASH

The mean ash content for the fresh okra fruits, from both stages of maturity was 1.38g/100g before packaging and storage. After 24 days of storage the controls (unpacked) sample recorded means of 1.23g/100g for fruits harvested at 4days after fruit set and 1.37g/100g for those fruits harvested at 6 days after setting.

The mean ash content of all the other treatments ranged between 1.19g/100g and 1.30g/100g which were statistically not different from each other as well as the controls

(5) FATS.

The mean fat content for fresh okra fruits ranged between a highest 0.17g/100g and a lowest of 0.13g/100g before and after the storage period of 24 days respectively. The controls from both stages of maturity recorded a mean value of 0.14g/100g which is not significantly different from values recorded for the other treatments packed in perforated and unperforated bags of Polypropylene and Polyethylene materials ranging between 0.13 and 0.17g/100g.

(6) FIBER

The mean fiber content recorded for the fresh okra fruits for both stages of maturity was 0.02g/100g before packaging and storage. After 24 days of storage the control (unpacked) for samples harvested at 4 days after fruit set and the same samples packed in perforated and unperforated Polypropylene bags recorded a mean fiber content of 0.02g/100g.The same mean(0.02g/100g) was recorded for materials harvested at 6 days after fruit set and packed in unperforated Polyethylene bags.

(7) PROTEIN

Mean protein content, before packaging and storage, for fresh okra fruits harvested 4 days after fruit set was 2.51% and 2.40% for fruits harvested at 6 days after fruit set. After 24 days of storage the control (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 4 days after setting and packed in perforated Polypropylene bags. Okra fruit samples from the two stages of maturity packed in unperforated Polypropylene bags gave the lowest mean protein content of 2.14%. The means for the rest of the treatments, packed in perforated and unperforated Polypropylene and polyethylene bags, in percentages, were 2.18, 2.21, 2.32, 2.37 and 2.44.

(8) CARBOHYDRATE

Carbohydrate content of fresh okra fruits harvested at 4 and 6 days after fruit set were 8.61 and 8.82% respectively, before packaging and storage. After 24 days of storage at 7-9^{o}C, samples harvested at 4 days 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 4 days after setting and packed in perforated Polypropylene bags. Another lower mean of 6.66% was

registered for samples harvested 4days after setting and packed in unperforated Polyethylene bags. The rest of the treatments, including the controls, registered percentage mean carbohydrate contents of 6.69, 6.76, 6.79, 6.99, 7.02, 7.11 and 7.34 which were not significantly different from each other.

(9) ASCORBIC ACID.

The mean Vitamin C (ascorbic acid) content for the fresh okra fruits harvested at 4 days after fruit set was 24.4g/100g and that of fruits harvested at 6 days after fruit set was 24.2g/100g before packaging and storage. After the storage period of 24 days fruits harvested at 4 days 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 6 days 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. The controls (unpacked) recorded 4.4 and 4.2g/100g respectively for samples harvested at 4 and 6 days after fruit set.

DISCUSSION

WEIGHT LOSS IN FRESH STORED OKRA

Packaging and its effect on weight of produce.

The two controls were significantly different from all the other treatments ($p<0.01$). However there was no significant difference between the controls. The highest mean weight loss of 3.42g (11.46%) in packed samples and the lowest was 28.43g (97.59%) in the controls(Table 1).Considering the losses in the storage environment, it was estimated that up to 86.13% of deterioration in respect of weight loss over the control was prevented with the packaging of the okra fruits. 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 *Colocasia* leaves restricted weight loss by 0.3-0.7% compared to 2.7-7.3% in unpacked leaves per day. They further reported that, after 24 days under refrigerated storage all packed samples recorded 1 to 10% weight loss whilst unpacked samples recorded 50 to nearly 100% weight loss.

Effect of packaging material on weight of produce.

There was no significant difference ($P<0.05$) between the percentage weight loss of okra fruits packed in polypropylene bags (8.48%), and that of those packed in polyethylene bags (8.03%) 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 within them. Di Pentima *et al.* (1996) observed a similar phenomenon in a study on the storage of broccoli, spinach leaves and asparagus packed in polyethylene and polypropylene, and reported that there was 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 ranged between 1.3 to 3.6% while the controls (unpacked) gave between 18.4 to 28.8% losses. Thus okra fruits can be held for up to 24 days if properly packed and held at 7-9°C with a minimal loss in weight.

Table2: Least Significance Different Test (Lsd) matrix

	M_1P_1 F	M_1P_1 N	M_1P2 F	M_1P_2 N	CM_1	M_2P_1 F	M_2P_1 N	M_2P_2 F	M_2P_2 N	C M_2
M_1P_1 F										-
M_1P_1 N	0.53NS									-
M_1P_2 F	0.47NS	0.04NS								-
$M1P_2$ N	0.67NS	0.15NS	0.19NS							-
CM_1	25.29**	25.53**	25.49**	25.68**						-
M_2P_1 F	1.13NS	0.62NS	0.68NS	0.46NS	26.14**					-
M_2P_1 N	1.52NS	1.01NS	1.05NS	0.86NS	26.54**	0.39NS				-
M_2P_2 F	1.27NS	0.76NS	0.80NS	0.61NS	26.29**	0.14NS	0.25NS			-
M_2P_2 N	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 not significantly different

Lsd (0.01): 2.75 x 2.49 = 6.89 **…….Means significantly different at 1%

NB:

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.

Perforated and Non- perforated packaging materials

Statistically there was no significant difference ($p<0.05$) between the mean weight loss of samples in perforated packages (2.85g) and the mean of those in unperforated

packages (2.73g), (Table1). It is probable that a modified atmosphere was created around the produce packed in the two types of packaging material resulted in nearly the same rate of reduction in water loss regardless of the type, perforation and unperforation. In an experiment on the packaging of fresh vegetables, Kader *et al.* (1989) reported that in modified atmosphere packaging (MAP), the gas atmosphere inside a package was typically low in oxygen and high in carbon dioxide with equilibrium values in ranges of 2-3% and 5% respectively. The authors stated that, lower oxygen content stabilizes the product by slowing down respiratory activity of the produce as well as metabolic activity and growth of spoilage micro organisms. Cooling, according to Daryl and Brain (1994), reduces the vapour pressure of liquid water in the 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) lost comparatively more weight (3.00g) than those from the second stage of maturity (M_2-6days after fruit set) which lost 2.60g (Table 1). Statistically there was significant difference ($P<0.05$) between fruit samples harvested at 4 and 6 days after setting. It is probable that the samples harvested at 4days after fruit set contained much more water and respirable substrates than those harvested 6 days after setting. It is also likely that the more mature samples might have converted their matter contents into soluble lignified materials, hence had less to loss through respiration. Iremiren *et al.*, (1991) reported from a study on the effect of age of harvesting, after pod set, in okra, that increasing age results in increase in crude fiber and reduction in moisture.

Losses due to respirable substrate and moisture tend to be more in the comparatively less mature okra samples resulting into greater weight loss. According to Douce and Day (1985) respiration is an excellent indicator of metabolic activity in plant tissue hence a useful guide to the potential storage life of produce.

Per cent Salvage of Fruits.

Table 3 shows per cent fruits salvaged and shrivelling. 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. This indicated that deterioration was faster in the younger fruits than the older ones. The younger fruits probably contained 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 thus a reduction in moisture content.

Succulence, according to Oyolu (1983), 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 have 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 as 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 the loose water hence the relatively lower salvage. Perforation on the other hand is an approach to condensation control that prevents the formation 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 (1962) observed that perforation established high CO_2 and low O_2 atmosphere in the packages. This retards respiratory 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.,* 1993).

VISCOSITY

(I) Stage of Maturity

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 $_{Redwood}$ at 30^0C before packaging and storage (Table 4). Eight days after storage viscosity of fruits harvested at 4 days 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 24 days viscosity dropped to 2:57seconds $_{Redwood}$ indicating a loss of 69.1% of the initial viscosity.

The viscosity of fruits harvested at 6 days 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. . 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, 4 days 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 stages of maturity lost nearly half of their initial viscosity within 8days of storage. The results indicated that viscosity of the okra mucilage decreases with increasing storage time.

Fresh produce continue to respire during storage, this biological process resulted in the production of carbon dioxide and water (Roy *et al*., 1972). Okra fruit mucilage, according to Zook (2004), is highly soluble in water.

During the storage period of the fresh okra fruits, respiration definately occured which resulted in the production of water that hydrolysed the mucilage which is soluble thereby decreasing its viscosity. Therefore as the prouduct continued to stay longer in storage, respiration would also continued with the resultant production of water leading to the hydrolyses of the mucilage resulting in decreased viscosity.

Figure 2: Relationship between storage time and viscosity

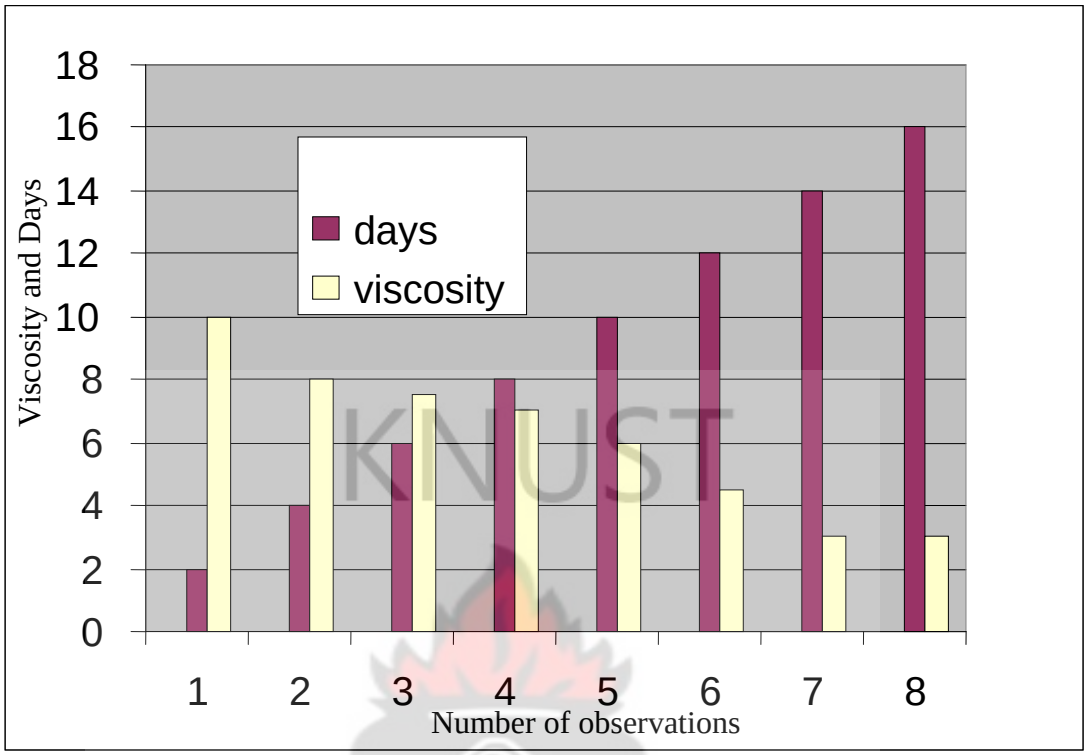

Figure 2 above shows the relationship between storage time and viscosity of the fresh okra fruits observed for 16 days of storage. For the first two days of storage viscosity of the fruits was 10 seconds $_{Redwood.}$ There was a steady decrease in viscosity as storage period increased such that by the 14th and 16th day of storage the value had fallen from 10 to 3.1 seconds $_{Redwood.}$

(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 4 days 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 6 days 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 8 days 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 lost 49.9% whilst the control lost 66.2% after 8 days of storage.

After 16 days of storage, fruits harvested 4 days after setting (M_1) and packed in Polypropylene (P_1) had their viscosity reduced to 3:24seconds $_{Redwood,}$ indicating a loss of 65% of the initial viscosity. Those packed in Polyethylene (P_2) also had 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 loss 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) had 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 24 days of storage okra fruits harvested 4 days 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 0.37 seconds $_{Redwood}$ 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 4:22 and 4:25 seconds $_{Redwood}$ respectively.

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

After 16 days of storage viscosity for fruits packed in the various materials had 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 day 16 storage periods. Fruits packed in perforated Polyethylene bags had 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 to 2:53 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 as storage time increases.

Considering results from the three parameters, stage of maturity, packaging, perforation and unperforation of packaging material, reduction in viscosity was found to be directly related to moisture loss. The unpacked samples recorded 87.3 to 97.6% loss in weight (results Table 1.) and a corresponding reduction of 95.7% in viscosity. It is probable the viscosity of the okra fruits were lost through a reduction of the mucilage as a result of moisture loss. According to Siemonsma and Hamon (2002) carbohydrates in the okra fruits are present in the form of mucilage consisting of long-chain molecules. The mucilage is highly soluble in water and has an intrinsic viscosity value of about 30. The authors further stated that physiological processes that caused water loss in the harvested fruits also resulted in the hydrolysis of the carbohydrates causing a breakdown of the mucilage hence the reduction in viscosity.

NUTRIENT CONTENT

(1) CALCIUM:

Mean calcium content of fresh okra fruits harvested at 4 days after fruit set was 20.50g/100g and that for fruits harvested at 6days after fruit set was 21.00g/100g before packaging and storage. After the storage period of 24days the control sample (unpacked) of fruits harvested 4 days after setting had the 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 affected by storage time.

(2) PHOSPHORUS.

The mean phosphorus content for fresh okra fruits harvested at 4days after fruit set was 0.87g/100g and 0.91g/100g for those fruits harvested at 6 days after setting before they were packaged for storage. After the storage period of 24 days the mean Phosphorus content for the controls (unpacked samples) was 0.80g/100g for fruits harvested 4 days after setting and 0.83g/100g for those harvested 6 days after setting. For the packed samples, the highest mean Phosphorus content, after 24 days 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 had no significant effect on the Phosphorus content of okra fruits.

(3) IRON

The mean iron content of fresh okra fruits from both stages of maturity was 0.07g/100g before packaging and storage. Fruits harvested at 4 days and 6 days 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 had no significant effect on the iron content of okra fruits.

(4) ASH

The mean Ash content for the fresh okra fruits, from both stages of maturity was1.38g/100g before packaging and storage. After 24 days of storage the controls (unpacked) sample recorded means of 1.23g/100g for fruits harvested at 4 days after fruit set and 1.37g/100g for those fruits harvested at 6days after setting. Both mean were statistically not different ($P<0.05$). The mean ash content of all the other treatments ranges between a lowest value of 1.19g/100g and a highest of 1.30g/100g which were statistically not different from each other as well as the controls. Ash content therefore did not change significantly during the storage period.

The results indicated that Calcium, Phosphorus, Iron, Ash and its other components in Okra fruits did not change significantly during storage.

It is probable that biological activities of metabolism do no affect, to a significant level, the mineral constituent of the okra fruit during storage. In a related experiment on the storage of green beans, Sanchez-Mata *et al.* (2003), observed and thereby concluded that Calcium, Iron, Phosphorus and other minerals constituting the ash were the most stable elements during all the storage periods considered with no significant variation due to storage time. Their assertion confirmed and agreed with earlier authors (Perring and Pearson, 1987, Zagory and Kader, 1989, Fernandez, 1998, and Bognar *et al*., 1990) who stated variously that since minerals are not metabolized their content should not change. However any variations of mineral content during storage have been attributed to redistribution and possible microbial action at later stages of storage.

(5) FATS

The mean Fat content for fresh okra fruits ranged between a highest 0.17g/100g and a lowest of 0.13g/100g before and after storing for 24 days respectively. The controls from both stages of maturity recorded a mean value of 0.14g/100g which was not significantly different from values recorded for the other treatments packed in perforated and unperforated bags of Polypropylene and Polyethylene material with a range of 0.13 and 0.17g/100g. These results indicated that; stage of maturity, packaging material

(perforated and unperforated) and storage time had no significant effect on the fat content of the okra fruits.

Fat is one of the organic materials that are broken down into simple end products through respiration. The rate of deterioration and breakdown of harvested produce is generally proportional to the respiration rate (Fallik and Aharoni, 2004). Under refrigerated storage respiration rate is reduced with a subsequent reduction in metabolic activity. This probably might have resulted in the less reduction or comparatively no reduction in the fat content of okra fruits stored at 7-9^{o}C for 24 days.

(6) FIBER

The mean Fiber content recorded for the fresh okra fruits from both stages of maturity was 0.02g/100g before packaging and storage. After 24 days of storage the control (unpacked) for samples harvested at 4 days after fruit set and the same samples packed in perforated and unperforated Polypropylene bags recorded a mean Fiber content of 0.02g/100g. The same mean (0.02g/100g) was recorded for materials harvested at 6days after fruit set and packed in unperforated Polyethylene bags. These were significantly different ($P< 0.05$) from the rest of the treatments which had mean values of 0.01g/100g. The result indicated decreases in fiber content for the control (unpacked) samples harvested at 6 days after fruit set and samples from the two stages of maturity packed in both perforated and unperforated Polypropylene and Polyethylene bags. The control (unpacked) for samples harvested at 4 days after fruit set and those packed in perforated and unperforated Polypropylene bags together with a sample from fruits harvested at 6days after fruit set packed in unperforated Polyethylene bags showed no decrease in fiber after storage.

Thus observable differences in fiber content were not due to treatment effects but probably unexplained inherent factors. Therefore stage of maturity, type of packaging material perforation and unperforation had no effect on the fiber content of okra fruits stored for 24 days at 7-9^{o}C.

(7) PROTEIN

Mean Protein content, before packaging and storage, for fresh okra fruits harvested 4 days after fruit set was 2.51% and 2.40% for fruits harvested at 6days after fruit set. After 24 days of storage the controls (unpacked) samples of okra fruits harvested at 4 and 6 days 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 fruit samples harvested at 4days after setting and packed in perforated Polypropylene

bags. Okra fruit 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 24 days.

(9) CARBOHYDRATE

Carbohydrate content of fresh Okra fruits harvested at 4 and 6 days after fruit set were 8.61 and 8.82% respectively, before packaging and storage. After 24 days of storage at 7-9o C, samples harvested at 4 days 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 4 days 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.

(10) ASCORBIC ACID.

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 6 days after fruit set was

24.2g/100g before packaging and storage. After the storage period of 24 days, fruits harvested at 4 days 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 and 15.9g/100g of Vitamin C respectively. After the same period of storage okra fruits harvested at 6 days 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 not statistically 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 (Table 5) respectively for samples harvested at 4 and 6 days 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) lost 82-83% of their Vitamin C after 24 days of storage whilst the packed samples lost 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. 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. Zepplin and Elvehjein (1949) reported that vegetables stored at low temperatures lose 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 6 days while those held at room temperature lost 20% in only 2 days. 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 Strawbery, 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 also no significant differences in whether the packages were perforated or unperforated.

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 4 days after setting, retained more of their Vitamin C (15.9-17.0g/100g) than those harvested at 6 days after setting which had means of 14.8-15.7g/100g. Vitamin C retention was 65.2-69.7% for fruits harvested at 4 days 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 about 30% higher than that of green pepper.

In various earlier reports on Tomato, Kader *et al*. (1977) and Bentacourt *et al*. (1977) stated that fruits at breaker stage contained less Vitamin C than those at table ripe stages. They concluded that fruits analyzed at the breaker stage contained 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 contained the highest concentration of Vitamin C whereas the matured fruits contained 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 4 days after setting as against those harvested at 6 days.

Plate 2: Fresh okra fruits stored for 24 days

Fruits harvested 4 days after setting

Fruits harvested 6 days after setting

LABORATORY EXPERIMENT TWO

HOT – WATER TREATMENT OF FRUITS AND STORAGE.

MATERIALS AND METHODS

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 being put into a refrigerator. Packaging increased 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 difference between the initial weight and the final weight, and worked as percentage of the former.
2. **Shrivelling:** Changes in size and shape were scored for as shriveling as follows

   1……no shrivelling observed

   2……1 – 10% shrivelling

   3……10 – 25% shriveling

   4……25 – 50% shrivelling

   5……50 – 100% and above shrivelling (after Hirata *et al.,* 1987).

   3. Fruit colour: Observable change in colour during storage was scored 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 was 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.

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

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.

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

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 (H_2SO4) 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 a 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 (NH_3) 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.

$$\text{Percent Total Nitrogen} = \frac{(Va - Vb) \times Na \times 14.01}{\text{Weight of fresh sample}} \times 100$$

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 the 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 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 and 0.5ml of 1,10-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 a refrigerator, making the 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 5ml of 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 the 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:

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

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 was 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 slimy mucilage was collected. Viscosity was 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 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 wasnoted using an electronic stop-watch.

Viscosity was quoted as: Nseconds $_{\text{Redwood}}$ @T°C

V = Nseconds $_{\text{Redwood}}$ @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.

RESULTS

LABORATORY EXPERIMENT TWO

Weight loss:

Observations on weight changes of okra fruits during the storage period, after dipping them in hot water at 50 and 75^{o}C, indicated a more stable weight for all the samples except the controls. The results were shown in Table 2.1 below:

Table 2.1: Mean weight of okra fruits immersed in hot water at 50 and 75^{o}C

Treatments	Initial mean weight(g)	Mean weight after 8 days(g)	Mean weight after 16 days (g)	Mean weight after 24 days (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

Table 2.1 showed the mean weights of fruit samples harvested at 4 and 6 days after setting, dipped in the hot water for 3 minutes at 50 and 75^{o}C packed in polypropylene and polyethylene bags for storage. Samples treated in hot water at 50^{o}C and packed in polypropylene bags gave an initial mean weight of 44.15g. This reduced to 44.05g after eight days of storage and further reduced to 43.55 and 43.15g on the 16th and the 24th days of storage respectively. Those packed in polyethylene bags showed no reduction in the initial weight (43.50g) up to the 16th day. However, on the 24th day they recorded a mean of 43.30g.

Fruit samples harvested 4 days after setting and dipped in hot water at 75^{o}C recorded an initial mean weight of 50.70g for those packed in polypropylene bags. There was no observable weight change after eight days of storage. However mean weights of 50.50and 50.40g were recorded on the 16th and 24th days respectively. The initial mean weight of samples packed in polyethylene bags, dipped in hot water at 75^{o}C was 52.60g.

This reduced to 52.40g after 8days of storage and then to 52.10g on the 16th and the 24th days.

The control of these samples had an initial mean weight of 57.4g.this reduced to 38.10, 22.00and 11.40g on the 8th, 16th and 24th days of storage. The second group of samples, harvested at 6days after fruit set, gave a very minimal change in weight during storage. The mean weight for fruits dipped in hot water at 50°C and packed in polypropylene bags was 64.80g before storage. There was no observable change after the eighth day of storage, but it reduced to 64.70g on the 16th day and did not change no the 24th day. Samples packed in polyethylene had initial weight of 66.20g. This reduced to 66.10g on the 8th day after storage. The weight further reduced to 66.00g and 65.90g on the 16th and 24th days respectively after storage.

Samples packed in polypropylene bags, after dipping in hot water at75°C, gave an initial mean weight of 78.90g.thi reduced to 78.70g after 8days of storage and 78.10g after the 16th day and did not changed on the 24th day. For those packed polyethylene bags, the mean weight was 68.90g which reduced to 68.70g after the eighth day of storage. This further reduced to 68.70and then 68.50g on the 16th and the 24th days respectively after storage. The initial mean weight for the control was 60.70g, this reduced to 41.30g on the eighth day after storage. It again reduced to 26.10and 12.70g after the 16th and the 24th day of storage respectively.

Shrivelling

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

Colour change.

The colour of the fresh fruit samples was scored 4 (apple green) before dipping into hot water at 50 and 75^{O}C. After the 8th day of storage materials dipped in water at 75^{o}C turned to 3(spinach green) whilst those dipped 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 temperatures treatments 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 2.2 Viscosity (seconds $_{Redwood}$) 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 16 days of storage	Viscosity after 24 days 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 seconds $_{Redwood}$, M_2=8:52 seconds $_{Redwood.}$

Table 2.2 above shows 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 4 and 6 days after setting lost 66 and 65% of their viscosity respectively after the 8days of storage.

At the end of 16 days of storage loss 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 6 days after setting lost 77 and 75.3% of their respective viscosities. Samples deteriorated completely by the 24th day of storage hence were not further tested for viscosity.

NUTRIENT CONTENT

At the end of the stipulated storage period of 24 days, 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.

DISCUSSIONS

WEIGHT LOSS

Effects of packaging on weight loss.

The highest mean weight loss of 1.0g among the packed samples was recorded for fruits harvested at 4 days after 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}C and 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 4 and 6 days after setting respectively. The percentage lost was 79 for samples harvested at 4days after setting and 81 for those harvested at 6 days 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 packaging materials however did not indicate any different influence on weight loss.

Packaging in this regard helped to restrict weight loss 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.

Effects of water temperature on weight loss.

Samples dipped in water at 75^{o}C showed marginally higher mean weight loss of 2.20g compared to 0.74g for those dipped at 50^{o}C. It is likely that samples dipped into higher water temperature might have lost much more moisture than those in the lower temperature. Colin (1992) stated that the greater the temperature difference between the heating medium and the produce the greater will be the heat transfer into the produce, which provides the driving force for moisture removal leading to a reduction in weight.

The temperature difference factor might have caused an initial reduction in weight as a result of heating. However the relatively stable weight of heated fruit samples during storage may be due to the heating effect which might have killed plant tissues and thereby stopped transpiration activities in the fruits. Transpiration according to

Hurschka (1977), Hultin and Milner (1978), FAO (1989) and Wills *et al*. (1998) is the singular factor that causes water loss in fresh produce resulting in rapid loss in quality including weight. Hot water dipping of produce is one of the methods used in controlling transpiration in certain fruits and vegetables. Barkai-Goland and Philip (1991) reported that weight loss and wastage in papaya, mango, cantaloupe and green beans were prevented through hot water dipping at 50-55^{o}C for 4 minutes.

VISCOSITY

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

At the end of 16 days of storage loss 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 6 days 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 loss in viscosity which was not different from the packed samples. The mucilage of okra is known to be composed of long -chain carbohydrate molecules which are very highly soluble in water (Tomoda *et al*., 1980). It is likely that the heating process might have destroyed the structure of the carbohydrate molecules leading to its breakdown. Heating might have also increased the solubility of the mucilage and coupled with hydrolysis would have led to reduction in viscosity of the fruits during storage.

Plate 3: Fruits immersed in hot water

Fruits immersed in water at 50^0C

Fruits immersed in water at 75^0C

Fruits immersed in water at 50^0C stored 16 days

Fruits immersed in water at 75^0C stored 16 days

LABORATORY EXPERIMENT THREE

SOLAR DRYING OF OKRA FRUITS

METHODOLOGY:

Fresh fruits selected and harvested at 2 stages of maturity (4 and 6 days 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 4 days after setting, sliced 0.5cm thick, dried for 24 hours

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

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

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

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

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

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

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

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

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

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

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

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.

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

%WL = Percent weight loss

IW = Initial weight

WAD = Weight after drying

2. **Colour:** Changes in colour were 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 done to check for nutrient contents.

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.

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

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 (H_2SO_4) 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 a 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_2SO4 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 (NH_3) 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.

$$\text{Percent Total Nitrogen} = \frac{(Va - Vb) \times Na \times 14.01}{\text{Weight of fresh sample}} \times 100$$

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:

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

Test for viscosity

Twenty grammes (20gm) of sample were weighed by a triple beam balance (Ohaus, U.S.A) into an electronic blender (Moulinex 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: Nseconds $_{\text{Redwood}}$@T°C

V = Nseconds $_{\text{Redwood}}$ @T°C.

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

RESULTS

LABORATORY EXPERIMENT THREE

WEIGHT LOSS

Table 3.1 WEIGHT LOSS IN SLICED OKRA FRUITS AFTER DRYING.

Treatment	Initial weight (g).	Weight after drying (g).	Weight loss (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

Table 3.1 shows the loss in weight for the various sliced okra fruits after drying for 24 and 48 hours respectively. 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 86.1 was 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 lost more weight compared to those dried for 24 hours irrespective of slice thickness. The percent mean weight loss for all the samples dried for 24 hours ranged between 86.1 and 87.6 while that of samples dried for 48 hours ranged between 89.5 and 90.7%.

Differences in slice thickness among samples from the same stage of maturity dried for the same time period had very little influence on the rate 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 was due to the drying period rather than slice thickness. The loss in weight was the direct effect of moisture loss during drying

indicating that longer drying time resulted in greater moisture loss and a subsequent loss in weight.

NUTRIENT CONTENT OF DRY OKRA FRUITS

Table 3.2 Mean nutrient content of dried sliced okra fruits

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

Table 3.2 above showed the nutrient content of okra fruits after drying:

Protein content:

The highest mean protein content of 2.70% was recorded for samples harvested at 4 days after fruit set, sliced 1.5cm thick and dried for 24 hours. The next higher value of 2.68% was recorded for samples harvested at 4days after setting, sliced 0.5cm thick and dried for 24 hours. The lowest mean protein content of 1.93% was recorded for samples harvested at 6 days after fruit setting, sliced 0.5cm thick and dried for 24 hours.

The mean protein content of the control samples (fresh fruits) were 2.57 and 2.09% for samples harvested at 4 and 6 days after setting respectively.

Fat content:

The highest mean fat content of 0.39g/100g was recorded for dried samples of materials harvested at 6days after setting which were sliced 1.5cm thick and dried for 24 hours.

The rest of the dried samples have mean values between 0.09 and 0.11g/100g.the mean values for control samples harvested at 4 and 6days after setting were 0.11and 0.15g/100g respectively. These showed a reduction of 18 and 40% of the fat content of dried okra fruit samples harvested at 4 and 6 days after setting respectively compared to the control (fresh fruit) samples.

Ash content

The ash content of all the dried samples indicated marked reductions compared to the fresh samples regardless of stage of maturity, slice thickness and drying time. The highest mean value recorded among the dried samples was 1.27g/100g for samples harvested at 4 days after fruit set, sliced 1.5cm thick and dried for 48 hours. The lowest ash content was recorded for two samples, one from materials harvested at 4 days after setting, sliced 1.5cm thick and dried for 48 hours whilst the other was from samples harvested at 6 days after setting, sliced 0.5cm thick and dried for 24 hours.

The mean ash content of the control for samples harvested at 4days after setting was 1.45g/100g. The dried samples from this maturity stage had mean values between 0.91and 1.27g/100g indicating losses of 12.41-32.00% after drying. For samples harvested at 6 days after setting, the mean for the control was 1.33g/100g while the dried materials had means between 0.91and 1.11g/100g indicating losses between 18. 8 and 30.8% after drying.

Fiber content

Fiber content of okra samples had increased considerably after drying.

The highest fiber content of 1.3g/100g was recoded for samples harvested at 4 days after setting, sliced 1.5cm thick and dried for 24 hours. The rest of the samples had values ranging between 0.91and 1.22g/100g compared to the control samples with fiber content of 0.02 and 0.01g/100g for samples harvested at 4 and 6 days after fruit set respectively. These values indicated higher fiber contents for the dried samples compared to the fresh ones. Fruit samples harvested at 4 days after setting showed an increase of 89.5% in fiber after drying while those harvested at 6 days after setting showed an increase of 99.1%. This indicated that the older materials had higher fibre content than the younger ones

Carbohydrate content

There were generally, marginal reductions in carbohydrates in the dried samples compared to the fresh samples. The highest mean value of carbohydrate recorded after drying was 7.01% for samples harvested at 4days after setting, sliced 0.5cm thick and dried for 24hours. The lowest mean value of 5.64% was recorded for samples harvested at 4days after setting, sliced 1.5cm thick and dried for 24hours. All the other dried samples had mean values ranging from 6.20 to 6.95% while the control samples recorded 7.10 and 7.00% for materials harvested at 4 and 6 days after setting respectively.

Losses in carbohydrate content recorded were 1.30 to 20% for samples harvested at 4 days after fruit set and 2.1 to 15.14% for those harvested at 6 days after setting. Thus the less mature fruit samples lost comparatively more of their carbohydrates than the mature ones during drying.

Vitamin C (ascorbic acid) content

Fresh okra fruits harvested at 4days after fruit set had Vitamin C content of 24.4mg/100g whilst that for those harvested at 6 days after setting was 24.2mg/100g. After drying for 24 and 48 hours there was a remarkable drop in the Vitamin C content of all the samples from both stages of maturity. Samples from fruits harvested at the maturity stages of 4 days after setting, sliced to 0.5, 1.0 and 1.5 cm thickness and dried for 24 hours recorded Vitamin C contents of 11.4, 11.6 and 11.3mg/100g respectively. Those harvested at the maturity stages of 6 days after setting, sliced to 0.5, 1.0 and 1.5 cm thickness and dried for 24 hours recorded Vitamin C contents of 11.2, 10.9 and 10.7mg/100g respectively. Similarly samples from the two maturity stages, with the same three slice thicknesses and dried for 48 hours gave values of 9.6, 9.9, 9.7, 9.8, 9.5 and 9.3mg/100g. Indicating that, irrespective of slice thickness, samples dried for 48 hours lost more of their Vitamin C than those dried for 24 hours.

For samples harvested at 4 days after setting, the highest mean Vitamin C recorded after drying was 11.6mg/100g and the lowest being 9.6mg/100g. These gave a reduction of 52.5 to 60.7% in their vitamin content compared to the fresh samples.

The highest mean recorded for samples harvested at 6 days after setting was 11.2mg/100g with 9.3mg/100g as the lowest. These gave 53.7 to 61.6% reduction in Vitamin C compared to the initial values of the fresh samples. Thus samples harvested at 6 days after setting lost comparatively more of their Vitamin C than those harvested at 4 days after setting.

VISCOSITY OF SLICED OKRA FRUITS AFTER DRYING AND STORAGE

Table 3.3: Viscosity (seconds $_{Redwood}$) 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 seconds $_{Redwood}$.

Table 3.3 shows the viscosity of okra fruits harvested at 4 days (M_1) and 6 days (M_2) after setting, sliced 0.5, 1.0 and 1.5cm thick and dried for 24 (D_1) and 48 (D_2) hours. Viscosity of fresh okra fruits harvested at 4 and 6 days after setting was 9:33 and 8:57 seconds $_{Redwood}$ respectively. After slicing and drying for 24 hours samples from materials harvested at 4 days after setting gave a lower viscosity of 8:01seconds $_{Redwood}$ for fruits sliced 0.5cm thick. The highest viscosity of 8:20seconds $_{Redwood}$ was recorded for samples sliced 1.0cm 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 lowest loss in viscosity was 31.20% and the highest 30.87% compared to the initial viscosity of the fresh fruits

Samples from materials harvested at 4 days after setting and dried for 48 hours gave a low viscosity of 8:11seconds $_{Redwood}$ while 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 losses in viscosity after 90 days of storage were 24.12 and 23.00% for the less and more viscous samples respectively. For okra fruit samples that were harvested at 4 days after setting, slice thickness had 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 the drying period the more viscous the product. Okra fruit samples harvested at 6 days 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 15.00 and 26.50% from the initial fresh state values. 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 were 25.20 and 29.05 for the highest and the lowest values respectively.

COLOUR AFTER DRYING

Fresh okra fruits from both stages of maturity scored 4(apple green) before they were sliced and put into the solar dryer for 24 and 48 hours of drying. After the drying period of 24 and 48 hours the colour for samples from the two maturity stages looked deeper than the fresh stage before drying. After storing the dried samples for 30 days the samples harvested at 4 days after fruit set scored 3(spinach green) while those harvested at 6days after setting remained at a score of 4(apple green).Up to the 60th day of storage samples from both stages of maturity scored 3(spinach green) for colour and remained unchanged on the 90th day.

DISCUSSIONS

Weight loss

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

Lowest weight loss of 86.1 % was 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 lost much weight compared to those dried for 24 hours irrespective of slice thickness. The percent mean weight loss for all the samples dried for 24 hours ranged between 86.1and 87.6 while those of samples dried for 48 hours ranged between 89.5 and 90.7%.

Differences in slice thickness among samples from the same stage of maturity dried for the same time period had very little influence on the degree of weight loss. Thus slice thicknesses of 0.5, 1.0 and 1.5cm did not show marked differences in 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 was due to the drying period rather than slice thickness. Thus loss in weight was the direct effect of moisture loss during drying indicating that longer drying time resulted in 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 decreased significantly and this was influenced by slice thickness and drying time.

NUTRIENT CONTENT

1. Protein content

The highest mean protein content of 2.70% was recorded for materials harvested at 4 days after fruit set sliced 0.5cm thick and dried for 24 hours. Also material harvested 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 ($P<0.05$). The control (fresh material) harvested at 6days after fruit set was not significantly different from samples harvested at 4 days after fruit set sliced 1.5cm thick dried for 48 hours and those harvested at 6days after fruit set, sliced 1.0cm thick and dried for 24 and 48 hours respectively.

Observed differences between treatments indicated that slice thickness, drying time and stage of maturity did not significantly affect the protein content of okra fruit.

Also drying in general did not alter the protein content to a significant level. Schippers (2000) reported from an experiment on drying *Solanum scarbum* that the level of crude protein and mineral nutrients were not affected by drying.

Drying of okra fruits also did not affect the crude protein content just as observed in experiments on drying of other fresh produce.

2. Fat content

Material harvested at 6 days after maturity, sliced 1.5cm thick and dried for 24 hours gave the highest fat content of 0.39 g/100g. This value was significantly different ($P< 0.05$) from all the other treatments, which had values ranging from 0.09 to 0.11(were not different from each other). The value of 0.39 g100/g for this treatment might be due to unexplained circumstances. Generally it was observed that stage of maturity, slice thickness and drying time did not significantly affects the fat content of okra. However drying resulted in the reduction of the fat content of samples between 18 and 40% compared to the fresh stage.

3. Ash content

The two controls had 1.45 and 1.33 mg/g ash content respectively, which were not different significantly from each other. This was an indication that the two stages of maturity, 4 and 6 days, had little influence on ash content. A similar trend was observed over all the treatments. Treatments 8 and 12, were sliced 1.5cm thick from samples harvested 4 and 6 days after fruit set and dried 24 and 48 hours respectively and gave value of 1.02 and 1.05 mg/g, which were not significantly different from each other. Thus drying time and maturity though varied for the two treatments did not have any effect on the ash content. Treatments 6 and 7 sliced 1.5 and 0.5cm thick for material harvested 6 and 4 days after fruit set dried 48 and 24 hours respectively, had the same value (0.91g/100g) for ash content. This also indicated that slice thickness had no significant effect on ash content.

Treatments 2, 8, 9 and 12 also gave values of 1.07, 1.08, 1.02 and 10.5mg/100g which statistically had no significant differences. These results suggested that stage of maturity, slice thickness and drying time did not affect the ash content.

Comparing the other values with the control, there was a reduction in ash content when the materials were dried indicating drying had a significant effect on the ash content of

okra fruit. Materials harvested at 4 days after fruit set dried for 24 hours had their ash content reduced to between 29.7 and 37% ash, the same materials dried for 48 hours had their ash content reduced to between 27.36 and 36.5% ash of the initial content. Thus drying period of 48 hours resulted in much loss of ash content of fruit harvested at 4 days after fruit set. Fruits harvested 6 days after setting and dried for 24 hours retained between 23.3 and 31.6 % of the initial ash content after drying. The same samples dried for 48 hours retained 21 to 27.1% of their initial ash content. Longer drying period therefore resulted in more losses in the ash content of the okra fruits. From the above results, it was further observed that fruits harvested 4 days after setting retained much of their ash content compared to those harvested 6days after setting and dried for 24 and 48 hours respectively. It was probable the ash, which constituted the bulk of minerals, in the older pods was utilized in seed development resulting in its low content. Iremiren *et al*. (1991) studied the effect of age of harvesting after pod set on okra and showed that reduction in pod quality arose mainly from increase in crude fibre and a reduction in moisture, crude protein and ash content of older pods.

4. Fiber content

The initial fiber content was not significantly different for the two controls 0.02mg/100g and 0.01mg/100g respectively. All the treatments after drying had comparatively higher fiber content which was all significantly different ($P< 0.05$) from the 2 controls (fresh materials).

Okra fruits harvested at 4 days after fruit set, sliced 1.5cm thick and dried for 24 hours gave the highest fiber content of 1.31mg/100g which is significantly different from all the other treatments ($P< 0.05$). Also there were significant differences among samples dried for 24 and 48 hours, however stage of maturity and slice thickness did not show any effect on the differences. The dried materials generally had more fiber content than the fresh ones. This might probably be due to the loss of water during drying which resulted in the concentration of fiber in the dried materials. In a related experiment on drying of fresh Baobab leaves, Modibo (2000) reported that fibre and other minerals were not affected by drying. He concluded that water soluble fiber became concentrated in the dried produce as water was removed during the drying process.

5. Carbohydrate content

Carbohydrate content for fresh fruits (controls) harvested 4 days after setting was 7.10%. That for fruits harvested 6 days after setting was 7.00%. These were significantly different ($P< 0.05$) from all the dried samples.

Samples harvest 4 days after fruit set sliced 0.5cm thick and dried for 24 hours had 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 4 days after setting, sliced 1.5cm thick and dried for 48 hours.

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

Despite the variations observed in carbohydrate content, drying had 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 became concentrated with less marginal decreases. Drying, according to Jules (1986), removes water form tissues and the resultant produce is a highly concentrated material of enduring quality as natural deterioration of produce by respiration was stopped because of enzyme inactivation and lack of free water protects the dried products from decay by micro- organisms.

6. Vitamin C content

The two controls (fresh fruits from both stages of maturity) had Vitamin C content of 24.4 and 24.2mg/100g respectively. These were significantly different from the result obtained for all the other samples after drying for 24 and 48 hours. Samples from fruits harvested 4 and 6 days after setting, sliced to 0.5, 1.0 and 1.5 cm thickness and dried for 24 hours showed no significant differences in their Vitamin C contents of 11.4, 11.6, 11.3, 11.2, 10.9 and 10.7mg/100g. Similarly samples from the two maturity stages, with

the same three slice thicknesses and dried for 48 hours gave values of 9.6, 9.9, 9.7, 9.8, 9.5 and 9.3mg/100g which were not significantly different (P< 0.05) from each other. The results however showed a significant difference between the Vitamin C contents of samples dried for 24 and 48 hours. It was observed that samples dried for a longer period of 48 hours retained less vitamin C than those dried for 24 hours. This indicated the significant effect of drying time on Vitamin C content of okra during drying. Vitamin C, a common component of most fruits and vegetables, is not very stable and is usually destroyed during processing through the combined action of heat, oxygen and light (Bender, 1966, Eheart and Oldland, 1972).

However, no significant differences were observed between samples from the two stages of maturity and the three slice thicknesses. This suggests that, the rate and possibly the extent of Vitamin C destruction during solar drying of okra was not significantly influenced by the maturity and slice thickness of the samples. Vitamin C content was fairly stable in the dried okra samples. This was probably due to a reduction in Vitamin C destruction as a result of reduced water and physiological activity in the dried samples. In an experiment on the relation between water loss and Vitamin C content of fresh vegetables, Laio and Seib (1988), stated that any attempt to reduce water loss also restricted loss of Vitamin C.

VISCOSITY

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 4 days 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 sliced 1.0cm 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 4 days after setting and dried for 48 hours gave a low viscosity of 8:11seconds $_{\text{Redwood}}$ while the highest was 8:21seconds $_{\text{Redwood.}}$ 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 90 days of storage were 24.12 and 23.00% for the less and more viscous samples respectively. For okra fruit samples that were harvested at 4 days after setting, slice

thickness had 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 the drying period the more viscous the product. Okra fruit samples harvested at 6 days 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 13.04 and 14.24% respectively from the initial viscosity of 8:57seconds $_{Redwood}$. After 90 days of storage the highest and the lowest viscosities were 7:29 and 6:30seconds $_{Redwood}$ respectively, registering reductions of 15.00 and 26.50% from the initial fresh state values. Samples dried for 48 hours gave the highest viscosity of 7:55 and 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 were 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. While those dried for a longer period might have lost 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 lost through evaporation during the process of drying resulting in more concentrated mucilage as moisture was removed. Viscosity is therefore caused by mucilage which becomes concentrated in the product as moisture was 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*., 1995). Though viscosity was found to have decreased initially in the dried products compared to their fresh stages, it became more stable even over long period of storage. This may be the consequence of increased 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 4 days after fruit set and dried for 48 hours.

Plate 4: Sliced okra fruits

Freshly sliced okra fruits -1.0cm thick

Okra fruits harvested 4 days after fruit set, sliced 1.0cm thick and dried for 24 hours

Okra fruits harvested 4 days after fruit set, sliced 1.0cm thick and dried for 48 hours

Okra fruits harvested 6 days after fruit set, sliced 1.0cm thick and dried for 24 hours

Okra fruits harvested 6 days after fruit set, sliced 1.0cm thick and dried for 48 hours

SUMMARY AND CONCLUSION

The three experiments were carried out with the view of finding out a suitable post harvest processing method that could 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 stored at 7- 9^{o} C could stay up to 24 days with no significant ($p \leq 0.05$) weight loss.

Perforation and unperforation 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 packaged samples compared 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 unperforated bags of the two packaging materials. Viscosity of all stored samples decreased with increasing storage period. By the end of 24 days of storage fruits harvested at 4 days after fruit set lost 69.1% of their viscosity and those harvested at 6days lost 68.8% of their viscosity. Perforation or unperforation of packaging material had no effect on the viscosity loss 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 vitamin C which recorded a significant reduction all the other nutrient elements tested did not reduce in the fruit samples significantly over the storage period.

The second experiment involved hot water treatment of okra fruits before packaging for storage. Result of this experiment showed a very fast rate of deterioration of fruits after treatment. Though the weight of stored produce was quite stable, no fruit was salvaged at the end of the storage period.

Experiment three involved 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 24 hours lost comparatively less weight than those dried for 48 hours indicating that, the longer the drying period, the more the loss in weight. Generally weight loss after drying

ranged between 86.1 and 90.7% making the dried material lighter and convenient to carry.

Plant nutrient contents of the okra fruit were not significantly affected by the drying process except vitamin C which recorded 52.5-60.7% loss from the produce after drying. Drying resulted in a stable colour of samples which remained unchanged up to 90 days of storage.

Judging from the results of these three experiments it is concluded that: packaging and storage of fresh okra fruit enables the fruit to keep longer and remain in the useable state than unpacked storage.

Harvesting fruit at 4 and 6 days, after setting for storage is appropriate, however those harvested at 6 days 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 better results. Also perforation of the chosen material had advantages over the unperforated 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. Drying 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 convenience of a lighter load, easy handling and cheaper haulage.

RECOMMENDATIONS

It is recommended that further study be carried out on the hot water treatment of okra fruit considering different heating and storage temperature levels. It is further recommend that solar cabinet dryers that would be used in future drying experiments be provided with temperature recording and control gadgets 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 materials and different temperature levels.

Finally, a workable collaboration to carry out these experiments in some selected okra growing communities with farmer's participation is recommended.

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Appendix 1: Mean maximum and minimum temperatures, humidity and rain fall: 2003 to 2006.

2003				2004				
Month	Temperature ^{O}C Max.	min.	Humidity %	Rainfall mm	Temperature ^{O}C Max.	Min.	Humidity %	Rainfall mm
January	33.1	20.7	85	7.7	32.6	20.5	84	10.9
February	34.5	22.1	83	25.0	34.2	20.6	75	6.4
March	35.0	22.1	81	8.7	33.8	22.6	82	17.3
April	33.4	22.1	87	20.0	32.6	22.5	84	10.9
May	33.4	22.3	82	20.3	32.4	22.5	83	7.4
June	30.8	21.5	89	10.1	30.7	21.2	83	12.1
July	29.9	20.7	87	22.5	29.1	20.5	88	15.7
August	28.9	20.5	85	8.9	29.6	20.5	89	5.7
September	30.2	20.8	88	11.2	30.6	20.8	87	21.4
October	31.6	21.7	85	17.2	31.0	21.8	85	11.4
November	31.9	21.7	86	17.4	31.9	21.9	83	5.4
December	31.5	20.2	83	7.3	31.7	22.1	87	22.1

2005				2006				
Month	Temperature ^{O}C Max.	min.	Humidity %	Rainfall mm	Temperature ^{O}C Max.	min	Humidity %	Rainfall mm
January	32.4	16.3	69	8.1	32.6	21.2	87	21.9
February	35.1	22.6	82	12.1	33.1	22.0	86	22.8
March	34.1	22.0	82	10.6	32.9	21.8	82	9.1
April	34.2	22.9	83	14.0	34.3	22.5	82	0
May	32.5	22.5	84	24.6	32.3	22.0	84	9.6
June	30.6	21.7	87	9.3	31.5	21.6	82	10.3
July	29.3	20.6	89	3.8	30.3	20.8	86	11.3
August	28.4	20.3	89	5.9	29.2	20.5	86	12.5
September	30.7	21.1	87	19.6	30.1	21.1	88	8.7
October	31.8	21.6	83	16.4	31.5	21.7	85	11.2
November	32.0	22.0	85	6.1	32.5	21.8	82	20.1
December	32.1	21.5	86	Tr.	32.7	21.4	82	2.7

Tr. = trace

Source: Ghana Meteorological Agency, Agro meteorology Division, Station Number 0601-050-17. Kwame Nkrumah University of Science and Technology, Kumasi.

Appendix 2: Colour chart:

Hues of green used in scoring the colour of vegetables

Source: Kornerup and Wanscher, 1981