KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF AGRICULTURE

QUALITY OF KEITT MANGO CHIPS AS AFFECTED BY METHOD OF DRYING, PACKAGINGAND STORAGE PERIODS

BY

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DECLARATION

I hereby declare that except for references to other people's work which have been duly acknowledged, this work submitted to the Board of Postgraduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana is the result of my own research work and investigation and has not been presented for any other degree in this University or elsewhere except where due acknowledgement has been made in the text.

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DEDICATION

This work is dedicated to the Glory of God

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To my Maker, the most high God, I say glory and honour unto His name, for the knowledge, protection and blessings He has given me throughout my education up to this level. Also, to my parents and siblings, I gratefully acknowledge the kind support given me throughout the period of study. I am very grateful to my supervisor, Dr Francis Appiah and the co-supervisor Madam Hannah Adziraku for their tremendous contribution and patience throughout this work.

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ABSTRACT

Mango (*Mangifera indica*) fruits i.e. Keitt variety were harvested at the green mature stage from Peterbeck farms at Dodowa in the Greater Accra Region of Ghana and transported to the laboratory of the Department of Horticulture, Faculty of Agriculture, KNUST, Kumasi, Ghana for analysis. The research was carried out on mango slices to study the effects of two drying methods using the sun and oven drying. The study has shown that different drying and packaging methods have varying effect on proximate, mineral, microbial and sensory qualities on Keitt mango pulps. The oven drying was superior in preserving potassium (1.93mg/100g), calcium (0.27mg/100g), protein (3.94%), fibre (1.55%), and pH (5.48). Oven drying therefore showed superior capacity in preserving the nutritional composition of mango pulps and it should be the method of choice. It was observed that storage period and packaging methods influenced both nutritional and proximate composition of dried mango pulps. Aluminium packs were the best packaging material for maintaining ash content (2.25%). Zip lock bags were the ideal packaging material with respect to protein (4.82%), fibre (2.01%) and vitamin C (4.36mg/100g) content retention of the mango chips samples with storage period. The results showed that PET containers were better materials for storing dried mango pulps as compared to Zip lock bags, aluminium packs and Control (unpackaged) as these packaging materials formed good moisture barrier. Packaging materials also determined the presence of particular microbes and microbial counts during storage. *Mucor sp* were identified in PET containers and Aluminium packs. *Rhizopus sp* was found in Zip lock bags and Control (unpackaged). *Aspergillus niger* was identified in PET containers, aluminium and zip lock bags. *Penicillium sp* and *Aspergillus niger* were identified in all the packaged material except the Control (unpackaged).oven dried mango chips stored in zip lock bags and control. The sun dried PET containers gave better appearance (7.55) whereas the oven dried PET containers had the highest score of the other parameters.

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CHAPTERONE

1.0 INTRODUCTION

Fruits and vegetables represent an important area of world agriculture production and form an indispensable part of human diet in Ghana. Their nutritional value serves as a source of essential amounts of minerals, vitamins, dietary fibre, protein and calories (Salunke*et al*. 1991). However, in Ghana many fruits and vegetables are usually in short supply especially during the dry seasons and because the indigenous ones grow abundantly in the rainy season, they are mostly wasted, due to lack of effective processing and preservation methods.

Approximately, 30-50% of fruits and vegetables harvested in developing countries are never consumed due to spoilage during transportation, storage and processing (Alzamora*et al*.2000). This draws its importance not only from a moral obligation to avoid waste, but also because the cost of preventing food losses in general is less than producing a similar amount of food of the same quality. Considering the production of mango and major means of maintaining longevity of the commodity shelf life, both consumers and the producers have to take into account certain qualities in order to keep specific varieties in the market. Six commercial varieties of mangoes are currently produced in the country. They are Kent, Keitt, Haden, Tommy Atkins, Palmer and Zill.

In Ghana, the southern belt is the main mango production area, with about 457 farmers and a total of 5,600 acres under cultivation. Mango cultivation also takes place in the Northern Region and part of Brong Ahafo Region with various varieties of mangoes under cultivation. Mango cultivation represents one area within the horticultural sector which, if well developed and provided with the necessary logistics and support, can easily become a major foreign exchange earner. This is because the country has the natural conditions that can position the crop as a top export product.

According to the experts in the industry, Ghana is one of the few countries in the world with two mango seasons and with the right practices both seasons can yield fruits for the international market. Mangoes make up 50 percent of all the tropical fruits produced worldwide. Global production of mangoes was estimated to be 35.04 million tonnes in 2009. India was the leading producer with 13.65million tonnes in 2008. In 2005, the world's export of mango reached 912,853 metric tonnes and was worth US$543.19 million (FAOSTAT, 2010). In spite of these economic indicators mango is a delicate and highly perishable fruit and therefore has to be processed to ensure all year round availability in different form. Mango is utilized for the processing of juice, nectars, fruit leather and frozen pulp as well as a flavouring product for baked foods, ice cream and yoghurt(Temple, 1999).Dried pieces may be added to salads and fruit cocktail(Sauco, 2004).

Due to high post harvest losses of fruits and vegetables, there is the need to process and preserve perishable fruits during bumper harvest to make these fruits available throughout the year in a value added form. Dehydrated mango fruits slices could be processed from the glut by individuals or farmer-groups to address the vitamin A and C problems experienced especially in relevant areas in the north and the entire country as a whole. According to (Benamba, 2005) vitamin A deficiency is a major public health problem in Ghana. This is because consumption of vitamin A is low among the Ghanaian population and especially in the northern part of country in children under 5 years of age. Inadequate intake of vitamin A over a long period can result in vitamin A deficiency.

In Ghana, mango grows very well in both transitional and the savannah belt due to the favourable climatic conditions. The mango industry in Ghana is growing at a fast pace especially in the Northern part of the country as a result of the excellent climatic conditions. It is expected that mango production will increase in the near future and this calls for drying

systems such as dehydration to extend the shelf life of these products and make them available all year round for local consumption and for export according to (MOFA, 1998). Dried fruits are susceptible to contamination and moisture reabsorption and must be properly packaged and stored immediately after drying, (Chasery and Gormley, 1994).The type of packaging material used has been reported to have effect on nutrient content during storage (Salunkhe*et al.*1991). Unfortunately, available packaging materials used for mango chip have not been assessed as to their suitability for mango. The absence of such information has resulted in processors using different packaging materials without recourse to their properties. It is therefore important to assess the packaging materials to ascertain their performance in ensuring product quality during storage.

Post harvest management is essential for extending the consumption period of fruits, for regulating their supply to the market and for transporting them over long distances. Mango fruits are able to respond metabolically to the environment under which they are stored. This reduces food availability and income as a result of loss in quality. Drying procedures such as sun drying, hot-air cabinet drying, vacuum drying, tunnel dehydration, and osmotic dehydration may be used. Dried mango products are intended either for direct consumption (dried slices, dices/cubes, mango chips) or for use in other food formulations (mango leather, powder).Drying extends the shelf life of biological materials through the reduction of water activity; reduce weight and bulk of the material and convenience for consumers. Textural changes, loss of vitamins and other essential nutrients through various reactions, colour changes associated with browning reactions, non uniformity in slice thickness and mould growth are some of the major problems associated with fruits and vegetables during and after drying (Salunkhe*et al*., 1991). To overcome some of these problems dried products should be packaged well in a good material to extend their consumption period, regulate their supply

to the market and also for transportation over long distances without altering the nutritional composition.

This project therefore seeks to evaluate the effect of different packaging materials on the storage of mango chips.

The specific objectives were:

- Determine the effect of sun and oven drying on the physico-chemical properties of Keitt mango chips.
- Determine the effect of packaging materials on physico-chemical properties of Keitt mango chips.
- Determine the interactive effect of different method of drying, packaging materials and storage period on the quality of Keitt mango chips.
- Determine the effect of storage on quality of Keitt mango chips.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

Mango belongs to the genus *Mangifera indica*, consisting of numerous species of tropical fruiting trees in the flowering plant family *Anacardiaceace*. The mango is indigenous to India, cultivated in many tropical and subtropical regions and distributed widely in the world. Mango is used as food in all stages of its development. Salunkhe and Desai (1984) observed that green or unripe mango contains a large portion of starch which gradually changes into glucose, sucrose and maltose as the fruit begins to ripe. It disappears completely when the fruit is fully ripe. Reeb*et al.*(1991) also noted that half ripened mango is a valuable source of vitamin C. It contains more vitamin C than half ripe or fully ripe mangoes and it is also a good source of vitamins B1 and B2 and contains sufficient quantity of niacin. These vitamins differ in concentration in various varieties during the stages of maturity and environmental conditions

Mango is well known for its medicinal properties both in ripe and unripe states. The unripe fruit is acidic, astringent and stimulant tonic. The bark is also astringent and has a marked action on mucous membranes. Mango pickles preserved in oil and salted solution is used throughout India as food. However, these pickles, if extremely sour, spicy and oily are not good for health and should be specially avoided by people suffering from arthritis, rheumatism, sinusitis, sore throat and hyperacidity. According to Cherry *et al*. (1990), the resinous gum from the trunk is applied on cracks on the feet and on scabies and is believed to be helpful in cases of syphilis.

Mango is one of the major tropical fruits from which a variety of processed and semi processed products are produced commercially. Minimally processed or fresh-cut mango products could be classified as "semi processed" because these do not undergo high-temperature treatments that are typically used in canning or dehydration. The commonly processed mango products are puree/pulp, nectar, juice, juice concentrate, and dried/dehydrated mangoes. Besides these common products, there are a number of traditional products that are processed commercially in major mango producing countries, which include pickles, sweet or sour chutney (a tomato ketchup type product), *amchoor*or dried powder, mango leather, and a variety of soft drinks and beverages.

2.2 DISTRIBUTION AND PRODUCTION

Mangoes (*Mangifera indica L.),* make up 50 percent of all the tropical fruits produced worldwide. Global production of mangoes was estimated to be 35.04 million tonnes in 2009. India was the leading producer with 13.65million tonnes in 2008. In 2005, the world's export of mango reached 912,853 metric tonnes and was worth US$543.19 million (FAOSTAT, 2010). Much of this new production has occurred outside the traditional centres of mango cultures, in South and Central America, Africa and Australia and a significant proportion of the new mango production is for export markets. The high esteem in which this fruit has always been held in Asia, where mango has been cultivated to be the king of fruits (Purseglove, 1969), is now apparently true for much of the world.

Mangoes are now widely available as fresh fruit and in the form of frozen and processed products, not only in the tropics and subtropics, but also year-round in North America, Japan and Europe.

According to Samson (1986), India has the largest mango cultivation area by far, about one million hectares. Cultivation is also widespread in Pakistan, Bangladesh and other countries of the South-East Asia. The southern Sahel is well suited to mango culture and commercial cultivation of the produce is found in Israel, Florida (USA), Mexico, Queensland and Egypt. In Africa, the mango has become naturalized due to germinating discarded seeds in the wild in most areas. Because many African mangoes are produced from seedlings fruits are strongly flavoured and fibrous. Fruits are seasonal and are consumed locally with a small quantity being exported. Studies have shown that where high-quality improved cultivars are grown some exportation, primarily to Europe, does occur. Africa exporters of mangoes include Kenya, Malagasy, Mali, Senegal, Congo, Burkina Faso, Cote D'Ivoire and Southern African countries (Rice *et al*. 1987). In Ghana the crop does well in savannah and transitional areas, high potential production areas include Central, Greater Accra, Eastern, Volta and Northern regions. The crop is cultivated by both small and large-scale holders with reasonable proportion of the crop growing in the wild.

2.3 CULTIVARS OF MANGO

One of the keys to improving mango production in Africa is the identification of cultivars which have good flavour and low fibre content and can grow under local conditions. Many cultivars have been imported from India, Australia, the West Indies, Brazil, and the United States and these should be tried in different environment to select the best ones for widespread planting (Campbell, 1992).

Some list of mango cultivars that are of interest in areas other than their places of origin, with descriptions intended to help differentiate them are as follows;

2.3.1 Alphonso (India)

The tree is moderately large, with broadly rounded, dense canopy; the fruit is yellow, ovate - oblique, averaging 6 cm long by 5 cm broad, weighing 225-325 g (mean 266 g), the skin is thin, the flesh is firm to soft and has a very pleasant taste (Litz, 1997).

2.3.2 Amelie (West Africa)

They also known as "Governeur''in the Caribbean. They are tall with rounded, dense canopy; the fruit is green to orange-yellow with the advance of the season, round, 10-15cm long by approximately 10cm broad by approximately 7-8 cm thick and weighing 300- 600g (mean 366 g). The skin is thin and separated with difficulty. The flesh is soft, juicy, melting without fibre and has a deep orange colour (Litz, 1997).

2.3.3 Haden (Florida)

The tree is vigorous, with large, spreading canopy. The fruit is bright yellow with deep crimson or red blush and numerous large yellow dots, oval with rounded base, 10.5-14cm long by 9-10.5 cm broad by 8.5- 9.5cm, weighing 510- 680g (Litz, 1997). The skin is thick, tough, and adherent. The flesh is firm and juicy with abundant fibre, deep yellow, rich and sweet with pleasant aroma of good to excellent quality.

2.3.4 Irwin (Florida)

The tree is small to medium, moderately, with open canopy. The fruit is bright yellow with crimson or dark red blush, numerous large white dots, ovate with rounded base, 11.5-13cm long by 8-9cm by 6.5-7.5cm thick, weighing 340-450g. The flesh is soft, tender, and juicy without fibre (Litz, 1997).

2.3.5 Julie (West Indies)

The tree is compact (quite dwarf in Florida), with a dense canopy; the fruit is green-yellow with light pink to maroon blush and numerous small white dots, rounded with flattened apex, pronouncedly compressed laterally, 7-9.5cm long by 4-7.5cm broad by 2.5cm thick, weighing

200-325g with a thin, tender skin and soft, melty, juicy orange flesh with scanty fibre, of rich, spicy flavour with a strong, pleasant aroma (Litz, 1997).

2.3.6 Keitt (Florida)

The tree is medium-sized, moderately vigorous, upright with open canopy; the fruit is greenish yellow, with pink or red blush, numerous small white or yellow dots, oval, with rounded base, 13-15cm long by 9-11cm broad by 8.5-10cm thick weighing 510-2000g (Litz, 1997). The skin is thick, tough and adherent; the flesh is firm and juicy, with little fibre, lemon yellow, sweet and wild with a pleasant aroma. There are late season varieties. After "Tommy Atkins" it is the most important commercial cultivar in Florida and resistant to anthracnose disease, packaging and shipping stress (Campbell, 1992).

2.3.7 Kent (Florida)

The tree is large and vigorous, with dense, upright canopy. The fruit is greenish-yellow with red or crimson blush, numerous small yellow dots, and oval, with rounded base, 11-13cm long by 9.5-11cm broad by 9-9.5cm thick, weighing 600-750g. The skin is thick, tough and adherent, with flesh being firm, tender and melting and juicy with little fibre. The flesh has a deep orange yellow colour, sweet with a rich flavour and pleasant aroma, of excellent quality. It is a late midseason to late season variety and may alternate in their bearing behaviour. Kent is not commonly commercial in Florida because it is prone to storage disease, but is a successful commercial cultivar in drier parts of Morocco, Central America and West Africa (Campbell, 1992).

2.3.8 Sensation (Florida)

The tree is vigorous, with moderately open, symmetrical canopy. The fruit is dark yellow with prominent dark red to purple blush that covers most of its surface. It is oval with rounded base and rounded apex, 9-11.5cm long by 7-8cm broad by 6.5-7cm thick, weighing 280-340g (Litz, 1997). The skin is medium thick, juicy, fibreless, deep yellow, mild and sweet with a weak pleasant aroma.

2.3.9 Tommy Atkins (Florida)

The tree is vigorous, with dense, rounded yellow canopy. The fruit is orange to yellow, with crimson or dark red blush and numerous small white dots. It is oval to oblong, with broadly rounded base, 12-14.5cm long by 10-13cm broad by 8.5-10cm thick weighing 450-700g (Litz, 1997). The skin is thick, tough and adherent with firm flesh and medium juicy, with some amount of fibre. It is lemon to deep yellow, mild and sweet with strong pleasant aroma.

2.3.10. Turpentine (West Indies)

The tree is vigorous, with large spreading rounded canopy. The fruit is bright yellow with a few large white dots, occasionally with a pink blush oval shape with a flattened base, 7.5-8cm long by 6.5-7.5cm broad by 6-6.5cm thick and weighing 140-200g (Litz, 1997).The skin is thick, tough and easily separating with firm flesh and juicy with abundant course fibre that is lemon yellow with pleasant aroma.

2.3.11. Zill (Florida)

The tree is vigorous and tall with an open, spreading canopy. The fruit is greenish yellow to yellow with intense red or crimson blush, oval to ovate with base slightly flattened, apex rounded to bluntly flatten with a small beak. It is 8.5-10cm long by 7.5-8.5cm broad by 6-7cm thick, weighing 230-370g (Litz, 1997). The skin is thin, tender and adherent. The flesh is pale yellow, soft and juicy without fibre, mild and sweet with a strong pleasant aroma, of good to excellent quality. Zill does not withstand storage and shipping stresses well, and thus is not favoured for commerce (Campbell, 1992).

2.4 DRYING

The technique of drying is probably the oldest method of food preservation ever practiced by mankind. Drying is a method of food preservation that works by removing water from the

food. The removal of moisture prevents the growth and reproduction of microorganisms responsible for decay and reduces the moisture mediated deterioration reactions. Drying brings about

substantial reduction in weight and volume of products minimizing packaging, storage and transportation costs. (Troftgruben*et al*, 2012). Research by (FAO, 1995), revealed that drying enables storability of products under ambient temperatures. The merit of this procedure is that the dried product weighs very little and the size is reduced considerably for easy storage. Also, a plus is that the food retains almost all of its nutrients. There are several ways to dry food which includes sun drying, oven drying and drying in a dehydrator. The first two methods are difficult. Sun drying can be done with window screens that are washed thoroughly. Oven drying is done in a shallow baking pan at a very low temperature for several hours.

Drying food using sun and wind to prevent spoilage has been practiced since ancient times, and was the earliest form of food curing (Nummer, 2012) Water is usually removed by evaporation (air drying, sun drying, smoking or wind drying) but, in the case of freeze-drying, food is first frozen and then the water is removed by sublimation. Drying effectively prevents the survival of bacteria, yeasts and molds in food because there is little water to support their growth. Dried foods keep well because the moisture content is so low that spoilage organisms cannot grow. Food dehydrators are less expensive to operate but are only useful for a few months of the year. A convection oven can be the most economical investment if the proper model is chosen. A convection oven that has a controllable temperature starting at 120 degrees F. and a continuous operation feature rather than a timer-controlled one will function quite well as a dehydrator during the gardening months. For the rest of the year, it can be used as a table-top oven. People in warm, dry climates have found it

easy to preserve their foods simply by properly spacing their produce out and letting the air take the moisture out of the food. Properly dried fruits and vegetables will have 80-90 percent of their water removed. Because drying does not violently heat food, it does not destroy as many of the nutrients as canning or cooking. Dried foods can be reconstituted by adding water or often simply consumed dry. Although there are different drying methods, the guidelines remain the same.

2.4.1 Principle of Drying

From investigation conducted by (FAO, 1995) dried, desiccated, or low moisture foods are those that generally do not contain more than 25% moisture. Drying involves the application of heat to vaporize water and a means of removing water vapour after its separation from food tissues. Hence, it is a combined/simultaneous heat and mass transfer operation for which energy must be supplied. A current of air is the most common medium for transferring heat to a drying tissue. The two important aspects of mass transfer are:

1) Transfer of water to the surface of material being dried.

2) The removal of water vapour from the surface.

As reported by (Alzamora*et al*. 2002), dehydration prevents problems due to sugar accumulation during storage and eventual browning on drying. One of the most important considerations in preventing fungal spoilage during storage of dried foods is the relative humidity of the storage environment. Properly packed dried foods should be stored under conditions of low humidity to prevent moisture re-absorption. The following are the factors influencing drying process:

a) Surface area: Generally, the fruits and vegetables to be dehydrated are cut into pieces or thin layers to speed heat and mass transfer. This subdivision speed up drying for two reasons:

i) Large surface area provided more surface in contact with the heating medium (air) and more surface from which moisture can escape;

ii) Smaller particles or thinner layers reduce the distance through which moisture in the centre of the food must travel to reach the surface and escape.

b) Temperature: The greater the temperature differences between the heating medium and the food, the greater will be the rate of heat transfer into the food which provides the driving force for moisture removal.

c) Atmospheric pressure and vacuum: Research by FAO (1995) research shows that if food is placed in a heated vacuum chamber the moisture can be removed from the food at a lower temperature than without a vacuum. Alternatively, for a given temperature, with or without vacuum, the rate of water removal from the food will be greater in the vacuum. Lower drying temperature and shorter drying times are especially important in the case of heat sensitive foods.

2.4.2. Types of Drying

There are several types of drying methods including;

- Sun drying
- Freeze drying
- Oven drying
- Solar drying
- Microwave drying and
- Osmotic drying

2.4.2.1. Sun drying

During sun drying heat is transferred by convection from the surrounding air and by absorption of direct and diffuse radiation on the surface of the crop. The convected heat is partly conducted to the interior increasing the temperature of the crop and partly used for effecting migration of water and vapour from the interior to the surface. The remaining amount of energy is used for evaporation of the water at the surface or lost to ambient via convection and radiation. The evaporated water has to be removed from the surroundings of the crop by natural convection supported by wind forces.

Under ambient conditions, the processes continue until the vapour pressure of the moisture held in the product equals that held in the atmosphere. Thus, the rates of moisture desorption from the product to the environment and absorption from the environment is in equilibrium and the crop moisture content. Under ambient conditions, the drying process is slow and in environments of high relative humidity, the equilibrium moisture content is insufficiently low for safe storage.

Due to the hygroscopic properties of all agricultural products, during sun drying the crop can either be dried or rewetted. Especially during night time when ambient temperature in general is decreasing, causing a simultaneous increase of the humidity, remoistening effects can occur either by condensation of dew or by vapour diffusion caused by osmotic or capillary forces.

Sun drying of crops is the most widespread method of food preservation in a lot of African countries due to solar irradiance being very high for most of the year. There are some drawbacks relating to the traditional method of drying i.e. spreading the crop in thin layers on the mats, trays or paved grounds and exposing the product to the sun and wind.

These include poorer quality of food caused by contamination by dust, insect attack, enzymatic reactions and infection by micro-organisms. Also this system is labour and time intensive as crops have to be covered at night and during times of bad weather and the crop continually has to be protected from attack by domestic animals. On uniform and insufficient drying also leads to deterioration of the crop during storage. Serious drying problems occur especially in humid tropical regions where some crops have to be dried during the rainy season.

2.4.2.2 Oven Drying

Reeb *et al.* (1999) reported that oven drying is the simplest way to dry food because there is no need for special equipment. It is also faster than sun drying or using a food dryer. But oven drying can be used only on a small scale. An ordinary kitchen oven can hold only 4 to 6 pounds of food at one time. The oven is set to the lowest possible setting and preheated to 60^{o}C. Some gas ovens have a pilot right, which may keep the oven warm enough to dry the food. It is important to keep the oven temperature at 60˚C to 70˚C. An oven thermometer can be put on the top tray about half way back where it can be easily seen and the temperature checked half hourly. Troftgruben *et al.* (1984) also reported that drying food in the oven of a kitchen range, on the other hand, can be very expensive. In an electric oven, drying food has been found to be nine to twelve times as costly as canning it. A commercial or homemade food dryer or convection oven provides automatically controlled heat and ventilation. Most households will not need a dryer unless they dry large quantities of food. A food dryer takes less electricity than drying the same amount of food in an electric oven. However, the temperature is usually lower (50^{0} C.), so drying takes a little longer than in an oven.

2.5 PACKAGING

Packaging is the art, science and technology of enclosing or protecting products for distribution, storage, sale and use. It is thus the act of making products handy by putting in containers with purpose of enhancing mobility, excluding contaminants such as pathogens, dirt and undesirable reactions with the environment in order to improve their shelf-life and make them presentable to the consumer. Packaging materials provide a means to preserve, protect, merchandise, market and distribute foods. They play a significant role in how these products reach the consumers in a safe and wholesome form without compromising quality. The relationship between the food and contact with the packaging material continuously interact and contribute to changes that can occur over time in these products. It is therefore important that several factors are considered when choosing the right package for a particular food product. Generally, the packaging material may either be rigid or flexible. Rigid containers include glass and plastic bottles and jars, cans, pottery, wood boxes, drums, tins, plastic pots and tubes. They give physical protection to the food inside that is not provided by flexible packaging. Flexible packaging is a major group of materials that includes plastic films, papers, foil, some types of vegetable fibres and cloths that can be used to make wrappings, sacks and sealed or unsealed bags.

Both flexible and rigid packaging materials, alone or in combination with other preservation methods, have been developed to offer the necessary barrier, inactivation, and containment properties required for successful food packaging. Cutter (2002) reported that the combination of rigid packaging materials made from metal, glass, or plastic with heat was shown to provide the most effective and widely used method for inactivating microorganisms. Packaging of processed products is to assemble the produce in convenient units to protect them from deterioration during their handling from the point of processing to

the point of consumption. Adequate and proper packaging protects the processed products from physical (firmness), physiological and pathological deterioration. A functional package for mango products has to protect the contents against rancidity, increase of moisture, loss of odour, pick up of foreign flavour and should offer physical protection from breaking, crushing etc. Besides these, it has to perform the job of attracting the customers by its attractive design and printing.

2.5.1 Commonly Available Food Packaging Materials

The most common food packaging materials are glass, wood, metal, plastics, paper and other flexible packages such as coatings and adhesives. Each of these packages offers unique advantages and disadvantages that have to be critically considered by the food processor in choosing the packaging material.

2.5.1.1 Plastic

According to (Marsh and Bugusu, 2007), plastic materials are made up of large, organic (carbon-containing) molecules that can be formed into a variety of useful products, they are fluid, moldable, heat sealable, easy to print, and can be integrated into production processes where the package is formed, filled, and sealed in the same production line. The major disadvantage of plastics is their variable permeability to light, gases, vapours, and low molecular weight molecules. Structural polymers such as polyethylene and polypropylene provide mechanical properties at low cost, while barrier polymers such as polyvinyldene chloride and ethylene vinyl alcohol provide protection against transfer of gases, flavours and odours through the package. Tie resins, co-extrudable adhesive resins, bond the structural and barrier resins together. The use of plastics in packaging has increased worldwide with an estimate at 280 metric tonnes as reported by (Paine and Paine, 2012). The packaging industry

is the largest user of plastics; more than 90% of flexible packaging is made of plastics, compared to only 17% of rigid packaging. Barrier resins are generally employed for plastic containers by modifications to improve product protection and make them more cost effective. Common plastic polymers used in packaging are as follows:

2.5.1.1.1 Polyethylene (PE)

There are different types of PEs

I. Low Density (LDPE): is used for flexible tubes, film and some bottles. It has a low melting point and, as a film, it is a relatively poor oxygen and moisture barrier.

II. High Density (HDPE): widely used for bottles and tubs. It has a higher melting point but not ovenable. It has a reasonably wide resistance which can be enhanced by fluorination. However, it is not a sufficient gas barrier for carbonated drinks.

III. Linear Low Density (LLDPE): is predominantly used as a film or as a sealing layer on multi-laminate materials for bottle seals, sachets, pouches and bags. It is available in expanded form for wads.

2.5.1.1.2 Polypropylene (PP)

It is widely used for closures due to ability to form a hinge which resists cracking and splitting. It is also used for dispensers, actuators, bottles, jars, cartons, trays and as film on its own or within laminations e.g. crisp bags or pouches. It is available in expanded form for tubs and trays. Typically it has a higher melting point than PE so although still

not “ovenable” it is better suited to hot fill products and it is resistant to a relatively wide range of chemicals.

2.5.1.1.3 Polyethylene **terephthalate (PET)**

This is widely used for stretch blown bottles containing drinks, toiletries and food. It has excellent clarity. Itis also used for jars, tubes and trays. It is by far the best gas and moisture barrier of any packaging plastic used for containers it is ideal for carbonated beverages. Its heat resistance quality makes it suitable for ovenable trays for ready meals.

2.5.1.1.4 Polyvinyl chloride (**PVC)**

This is not widely used even though only a third of its content is derived from oil. It still has a strong presence in vacuum forming used for inserts, clam packs and blister packs, due to its good production line performance. PVC films have excellent stretch and cling properties for hand wrapping fresh produce (Paine and Paine, 2012).

2.5.1.1.5 Polyvinylidene chloride (PVDC)

It is normally only used in multi-layer films, PVDC has exceptional moisture and gas barrier properties. Many pharmaceutical products could not be packed in blister strips without using PVDC as a layer in the blister film (Paine and Paine, 2012).

2.5.1.1.6 Polystyrene (PS)

Polystyrene is mainly seen in its expanded form as protective mouldings for fragile products. It is also available as moulded toiletries/cosmetics containers (compacts), some bottles, jars

and cups. It has good chemical resistance and excellent clarity although it can be coloured (Paine and Paine, 2012).

2.5.1.2 Paper and paperboards

Paper and paperboards are sheet materials made from an interlaced network of cellulose fibers derived from wood by using sulfate and sulfite. The fibers are then pulped and/or bleached and treated with chemicals such as slimicides and strengthening agents to produce the paper product. Paper and paperboards are commonly used in corrugated boxes, milk cartons, folding cartons, bags and sacks, and wrapping paper. Paper and paperboards provides mechanical strength, they are biodegradable and have good printability. Coatings such as waxes or polymeric materials can be used to improve their poor barrier properties. Apart from their poor barrier properties to oxygen, carbon dioxide and water vapour other drawbacks include their being opaque, porous and not heat sealable (Paine and Paine, 2012).

2.5.1.3Glass

Glass can be moulded into a variety of shapes. It can also be manufactured in a variety of colours. One of the reasons for using glass is that the product (normally a liquid) can be seen inside it. Some drinks have gases added and so glass bottles must be able to withstand internal pressure. Although glass is rigid (it is not flexible) it can be recycled. All these factors make glass a desirable packaging material.

Glass containers have the following advantages:

(a) they are impervious to moisture, gases, odours and micro-organisms

(b) they are inert and do not react with or migrate into food products

(c) they are suitable for heat processing when hermetically sealed

(d) they are re-useable and recyclable

(e) they are resealable

(f) they are transparent so theirthe contents can be seen

(g) they are rigid, to allow stacking without container damage.

The disadvantages of glass include:

(a) higher weight which incurs higher transport costs than other types of packaging

(b) lower resistance than other materials to fractures, scratches and thermal shock

(c) more variable dimensions than metal or plastic containers

(d) potentially serious hazards from glass splinters or fragments in foods

2.5.1.4 Metals

The metals used in packaging are predominantly tin-plate or aluminium and are used to make food and drink cans, aerosol cans, tubes, drums and slip or hinged lid boxes for gift sets and selections of confectionery or biscuits. All packs are recyclable. Tin-plate is tin-plated steel and the most common material used in food cans. Steel can also be used un-plated or with coatings. Tin- plate cans are normally used for packaging foods such as processed vegetables and products such as tuna and many more. Aluminium is used for drinks cans, closures, trays, tubs and tubes. As foil it can be used in multi-laminate constructions or as a blister pack or container seal. It is strong and withstands heat and processing. It can also withstand the internal pressure of gases that have been added to the product inside the can. Aluminium cans are also lightweight.

Metal can be exploited to produce the following packaging characteristics:

- Strength and rigidity
- Barrier to gas and moisture
- Pressure resistance

- Temperature and pressure resistance / tolerance
- Corrosion resistance via coatings
- Sterilisability
- Directly decorated or labelled

The limitations of metal packaging are in weight and shapes achievable, especially when compared to plastics.

2.6 PACKAGING AND STORAGE OF DRIED FRUITS

Dehydrated fruits and vegetables are used either as food products or as industrial ingredients in the processing of various foods, such as bakery products, soups, instant fruit powders, etc. The success of most preservation methods depends on how well the processed food is protected from adverse environmental conditions, which is mostly accomplished by packaging. There is a growing pressure in the fruits and vegetables packaging sector to use effective packaging materials with the aim of enhancing the shelf-life. Packaging plays an important role in determining the stability of foods by influencing those factors which cause or contribute to food deterioration during storage. The nature of a package determines the composition of air inside the package, which in turn is known to affect the rate and extent of nutrient loss and microbial activity among other things. According to Jaya and Das (2005), powdered dehydrated products require protection against ingress of moisture, oxygen and the loss of volatile flavorings and colour, during storage and distribution. As a consequence, foods may be altered to such an extent that they are either rejected by the consumer or they may become harmful to the person consuming them. According to Brown and Williams (2003), shelf life testing is carried out by holding representative samples of the final product under conditions likely to mimic those that the product will encounter from manufacturer to

consumption. It is a complex concept that is dependent on the nature of food product under consideration, the preservation technologies

applied, and the environmental conditions to which the food product is exposed. (Potter ,1978) reported that accelerated storage involving high humidity and temperature such as 90% relative humidity (RH) and 38 ± 2°C can be used for developing moisture ingress and storage time relationships quickly. Storage studies on mango powder have been reported extensively by some researchers.

Kumar and Mishra (2004) investigated the stability of mango soy fortified yoghurt powder in aluminum laminated polyethylene (ALP) and high-density polypropylene (HDPP) pouches under accelerated storage conditions (38 ± 1°C, 90% RH). Jaya and Das (2004) predicted the shelf life of mango powder packaged in aluminum foil laminated pouches stored under an accelerated storage environment (38 ± 2°C and 90% RH). Packaging is therefore supposed to provide the correct environmental conditions for shelf-life extension of foods, and as such, needs far greater thought and care than is customarily realized. Characteristics of the packaging materials such as mechanical and barrier properties are very important to decide on what type of material will be used in the packaging of different types of foods

Dried fruits are susceptible to contamination and moisture reabsorption and must be properly packaged and stored immediately. First, cool the dried fruits completely. (Chasery and Gormley, 1994) reported that packaging warm fruit causes sweating which could provide enough moisture for mould to grow. According to research (Kibir, 1994) dried fruit should be stored in cool, dry, dark areas. Recommended storage time for dried fruits ranges from four months to one year. Because food quality is affected by heat, the storage temperature helps to determine the length of storage. The higher the temperature, the shorter the storage time and vice versa. Most dried fruits can be stored for one year at 10°C and six months at 15°C. Fruits

that are packaged seemingly bone-dry can spoil if moisture is reabsorbed during storage. Glass containers are excellent for storage because any moisture that collects on the inside can be seen easily. (Heimdal*et al.* 1995) argued that fruits affected by moisture, but not spoiled, should be used immediately or redried or repackaged. Mouldy foods should be discarded.

2.7 FACTORS AFFECTING THE STORAGE STABILITIES OF DRIED FRUITS

2.7.1. Temperature

The effect of temperature changes on chemical and biochemical reactions in dried product during storage makes temperature an important factor with respect to quality maintenance. Low temperatures are necessary to maximize storage life. Studies have shown that, deteriorative effects of temperature on rate of chemical changes could be unexpectedly high. For example, rate of non-enzymatic browning reaction may increase two folds for a 4°C rise in temperature (Ahvenainen, 1998).

2.7.2. Moisture

The influence of moisture content and water activity are of profound importance in determining the shelf-life of most foods. This is because they affect physical (hardening, drying out), and physico-chemical properties, chemical changes, microbial spoilage and enzymatic changes, particularly with unprocessed foods (Ihekoronye and Ngoddy, 1985). For dried foods, it is better to keep the moisture content as low as possible.

2.7.3 Package

Nutrient losses during storage are largely dependent on packaging medium (Salunkhe*et al*. 1991). The package functions to prevent entry and exit of matter to and from the dried products. If the

package is defective, volatile compounds can be lost. The composition of air inside a package has been reported to affect the rate and extent of nutrient loss from foods.

2.7.4. Light

Light may have an effect on the rate of darkening in some products, and it has been known to cause a reduction in carotene according to (Bolin *et al.*1977).

2.7.5 Trace elements

Some salts and metals are detrimental to the nutritional value, flavour, and storage quality of dried fruits and vegetables. These may be picked up during washing or pre-treatment stages. Calcium has a firming effect on texture while sulphur may prevent browning in dried foods. Iron and copper combine with tannins to cause blackening and may accelerate ascorbic acid degradation (Baldwin *et al.*1995; Bolin *et al.*1977). Magnesium, sodium and calcium sulphates impart bitter flavour. Zinc, cadmium and chromium have toxic effect (Salunkhe*et al.*1991). Some of these elements can also be picked up from the packaged material.

2.8 The Dry Mango Fruits Processing Industry in Ghana

Dried fruits and other foods are tasty, nutritious, lightweight, easy-to-prepare, and easy-to-store and use. The energy input is less than what is needed to freeze or can, and the storage space is minimal compared with that needed for canning jars and freezer containers. The nutritional value of food is only minimally affected by drying. Vitamin A is retained during drying; however, because vitamin A is light sensitive, food containing it should be stored in dark places. Yellow and dark green vegetables, such as peppers, carrots, winter squash, and sweet potatoes, have high vitamin A content. Vitamin C is destroyed by exposure to heat, although pre-treating foods with lemon, orange, or pineapple juice increases vitamin C content. Dried foods are high in fibre and carbohydrate and low in fat, making them healthy

food choices. Dried foods that are not well dried (below 10-12 percent moisture) are susceptible to mould (Fennema,1996).

In Ghana, mango fruits are primarily consumed in the fresh state usually as dessert and sometimes as a fruit drink or juices. Dried mango snacks are not popular desserts among many Ghanaians; however, in recent times it is gradually gaining some preferences among some section of the public. Some African countries noted for the export trade in the dried mango fruit are Burkina Faso, Uganda, Niger and South Africa. In Ghana, Ebenut Ghana limited is one of the companies involved in the production of dry fruits which are mainly exported to South Africa and some sold in some leading supermarkets in the country. The mango industry in Ghana is growing at a fast pace especially in the northern part of the country as a result of the excellent climatic conditions. It is expected that mango production will increase in the near future and this calls for efficient and effective packaging to extend the shelf life of these products and make them available all year round for local consumption and export. Two drying methods were employed in the studies to access their effect on the nutritional composition and the sensory qualities of some mango cultivar fruits slices (MOFA, 1998).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL LOCATION

Mango chips were produced at the Laboratory of Department of Horticulture, Proximate and Mineral analysis were all also carried out at the Crops and Soil Science Department, KNUST, Kumasi Ghana.

3.2 SAMPLE COLLECTION

Keitt mango fruits were harvested at the mature green stage from Peterbeck farms at Dodowa in the Greater Accra Region of Ghana and transported to the Laboratory of the Department of Horticulture, Faculty of Agriculture, KNUST, Kumasi, Ghana for chip production and chemical analysis. Eighty fruits which were uniform and undamaged with no visible symptoms of infection were selected. They were allowed to ripen under ambient temperature (30-33^{o}C).

3.3 CHIPS PRODUCTION

Each variety of mango fruits were weighed and washed thoroughly with running water after which they were reweighed. The mango fruits were then peeled using knife and cut into two equal halves and the seeds removed. The pulps were then cut into slices (2cmx4cmx0.5cm) thoroughly mixed and divided into two. One half was sun dried for five days (44^{o}Cdaily temperature range) while the other half was dried in an oven at 60^{o}C for 12 hours,

3.4 SAMPLE SELECTION AND PACKAGING

The best products from each of the two drying methods were selected during the sensory evaluation and used for the packaging and the shelf-life studies. The selected products were gradually cooled and packaged for storage. They were stored at room temperature in a cool and dry environment. Samples of the chips were analyzed in the laboratory before packaging to assess certain parameters to serve as reference for the data analysis during storage. The dried chips were packaged in the different packaging materials (Aluminium packs, PET containers and zip lock bags) and were stored for two months at the laboratory of the Department of Horticulture, KNUST

Table 3.1: Treatment combination

Treatment code	Treatment
T1	Keitt chips sun dried and kept in opened containers (control)
T2	Keitt chips sun dried and packaged in PET containers
T3	Keitt chips sun dried, packaged in zip lock bags and sealed under vacuum
T4	Keitt chips sun dried and packaged in aluminium packs
T5	Keitt chips oven dried and kept in opened containers (control)
T6	Keitt chips oven dried and packaged in PET Containers
T7	Keitt chips oven dried, packaged in zip lock bags and sealed under vacuum
T8	Keitt chips oven dried and packaged in aluminium packs

3.5 EXPERIMENTAL DESIGN

The experiment was laid in a 2x4 factorial complete randomized designed (CRD) with three replications.

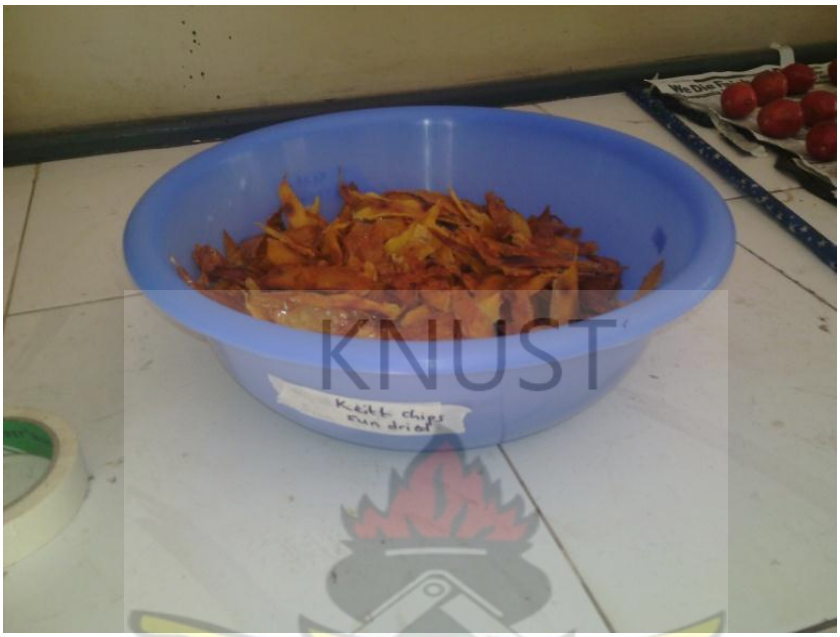

Plate I: A picture of sun dried Keitt mango chips

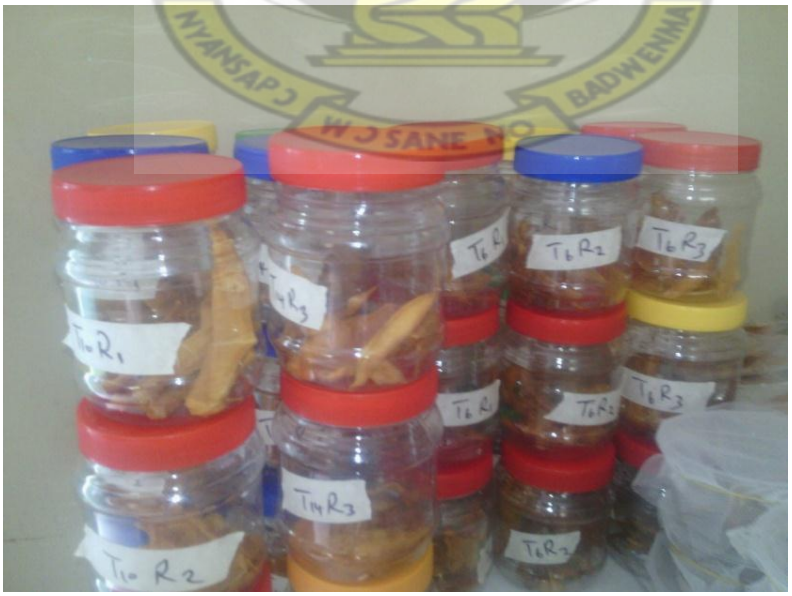

Plate II: A picture of Keitt mango chips stored in PET containers

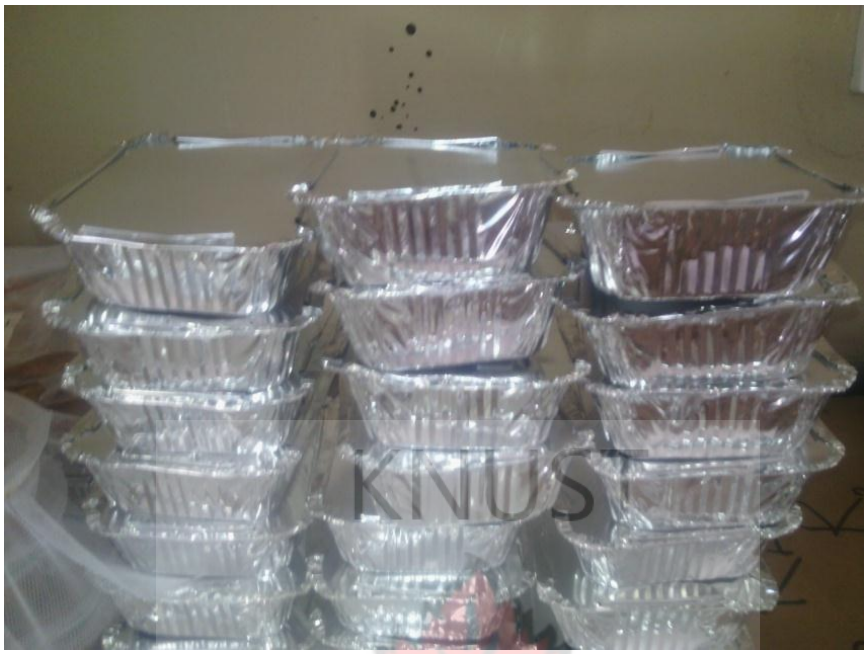

Plate III: A picture of Keitt mango chips stored in Aluminium packs

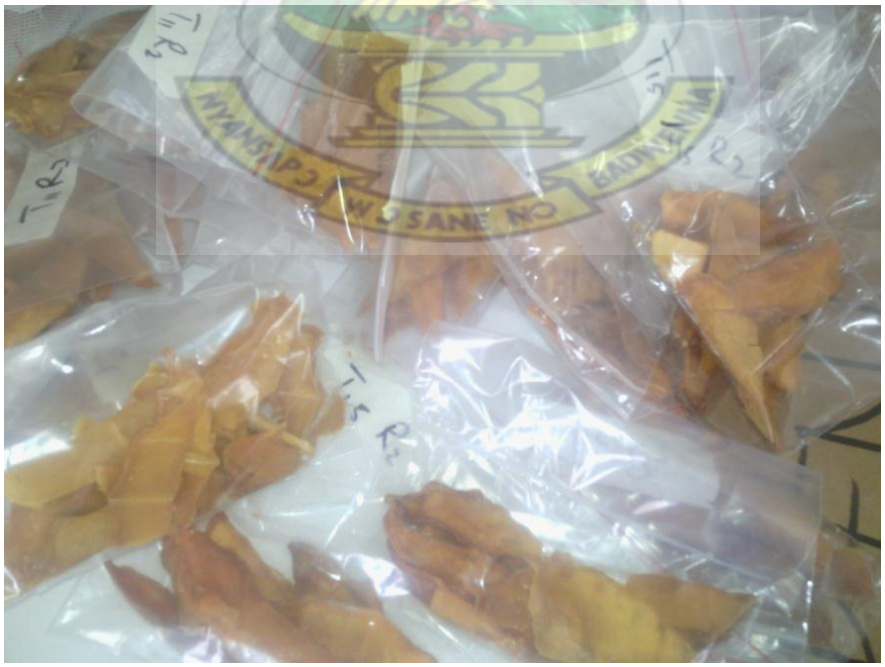

Plate IV: A picture of Keitt mango chips stored in Zip lock bags

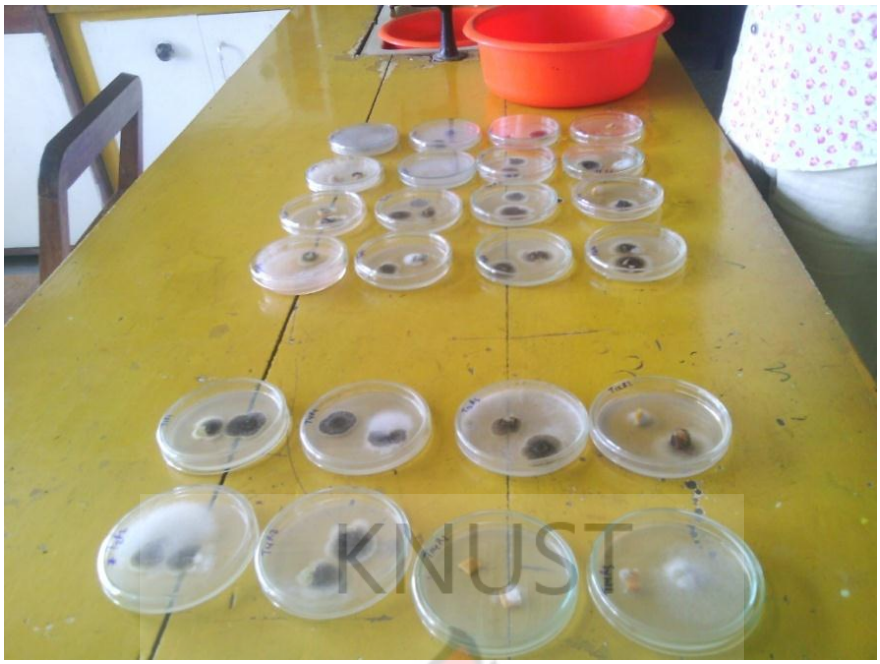

Plate V: A picture of Keitt mango chips showing microbial growth

3.6. LABORATORY ANALYSIS

Proximate and mineral composition, vitamin C contents, pH, sensory evaluation and microbial contamination were carried out on the chips before packaging and after packaging for a period of two months.

3.6.1 PROXIMATE COMPOSITION DETERMINATION

The proximate analysis of samples for moisture content, crude protein, ash and crude fiber were carried out on the chips produced using the standard methods described by (AOAC, 2002). Crude fat was extracted using the Soxhlet procedure with petroleum ether (60- 80^{o}C). Carbohydrate content was determined by difference.

3.6.1.1 Determination of Moisture Content

A 2.0 g 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 50°C for 18 hours. The glass crucibles were removed and transferred into desiccators for cooling after which they were weighed. Moisture content was determined by difference and expressed as a percentage (AOAC, 2002)

3.6.1.2 Determination of Ash Content

A 2.0 g sample was accurately weighed into a pre-ignited and previously weighed porcelain crucible, placing in a muffle furnace (Gallenkamp, England) and ignited for 2hours at 600^0C. After ashing, the crucibles were cooled below 200^0C in a furnance for 20 minutes and further cooled to room temperature in a desiccator. The crucibles and their contents were weighed, and the weight reported as percentage ash content (AOAC, 2002)

3.6.1.3 Determination of Crude Fat Content

A 2.0 g sample was transferred into a paper thimble, plugged at the opening with glass wool to evenly distribute the solvent as it drops on the sample during extraction and placed into a thimble holder. The sample packet was placed in the butt tubes of the soxhlet extraction apparatus. The extraction flask was placed on an oven for about 5min at 110°C then cooled and weighed. The fat was extracted with petroleum ether for 2-3 hours without interruption by gentle heating. The extraction flask was dismantled and allowed to cool. The ether was evaporated on steam or water bath until no odour of ether remains. It was then allowed to cool to room temperature and the extraction flask and its extract were recorded (AOAC, 2002).

3.6.1.4 Determination of Crude Fibre Content

The sample from the crude fat determination was transferred into a digestion flask. A 200ml of boiling sulphuric acid (H_2SO_4) solution and anti- foaming agent (asbestos) was added to the flask and immediately connected to a digestion flask with a condenser and heated. The sample was boiled for 30 min 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 min, 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 200 ml boiling sodium hydroxide (NaOH) solution. The flask was reconnected to the condenser and boiled for 30 min. The content were again filtered through linen cloth in a funnel and washed thoroughly with boiled water, then with 15ml of 95% ethanol. The residue was transferred into previously dried and weighed porcelain, in an oven at 110 ^{0}C to a constant weight. It was then cooled in a desiccator and weighed. The crucible and its contents were ignited in a muffle furnace at 550 ^{0}C for 30 min until the carbonaceous matter has been consumed. Cool in a desiccator and weighed. The loss in weight was recorded as the crude fibre.

3.6.1.5 Determination of Crude Protein Content

There are three main steps involved in the determination of crude protein;

i) Digestion of sample

A 2.0 g sample was placed in a kjeldahl digestion tube together with a small amount of a selenium-based catalyst and a few anti-bumping granules. 25ml 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 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.

ii) Distillation of digest

The distillation apparatus was flushed with distilled water for about 10 min. A 25ml of 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. A 10ml of the digested sample solution and about 50ml 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.

iii) Titration of distillate

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 percentage total nitrogen and the percentage crude protein

3.6.1.6 Determination of Carbohydrate Content

This was calculated by the difference methods

3.6.2 VITAMIN C DETERMINATION

Ascorbic acid reduces oxidation-reduction indicator dye, 2, 6-dichloroindophenol, to colourless solution. At end point, excess unreduced dye is rose pink in acid solution. Vitamin is extracted and titration performed in presence of metaphosphoric acid- acetic acid solution to maintain proper acidity for reaction and to avoid autoxidation of ascorbic acid at high pH (AOAC, 2006)

1. **Reagents**

a. Extracting solution or Metaphosphoric acid-acetic acid solution: dissolve, with shaking 15g Metaphosphoric acid **(**HPO_3) pellets in 40ml acetic acid (CH_3CHOOH) and 200mL H_2O. Dilute to 500ml and filter rapidly.

b. Ascorbic Acid Standard Solution: Weigh 50mg ascorbic acid reference standard. Transfer to50ml volumetric flask and dilute to volume.

c. Indophenol Standard solution: Dissolve 50mg of 2, 6-dichloroindophenol in 50ml H_2O to which has been added 42mg $NaHCO_3$. Dilute to 200ml with H_2O and filter.

2. **TITRATION**

i. Standard ascorbic acid (test solution) titration:2.0ml ascorbic acid standard solution was transferred into 3 beakers containing 5ml of extracting solution and titrated rapidly against indophenols solution until a light but distinct rose pink colour persisted.

ii. Blank Titration:3 blanks composing of 7.0ml of extracting solution was titrated against the indophenols solution.

iii. Sample Titration: 100g of the fruit was homogenized using a blender and the homogenized sample was then filtered. Equal volume of the sample (juice) was added to the HPO_3-CH_3CHOOH (extracting solution) to obtain the total volume of solution.

A sample calculation can be found in Appendix H.

3.6.3 pH DETERMINATION

Five grams of oven dried sample was weighed into a 50ml beaker. Twenty five (25) ml of distilled water was added and stirred vigorously for 20 minutes. Sample water suspension was allowed to stand for 30 minutes by which time most of the suspended ions would have settled out from the suspension. A pH meter was calibrated blank at pH of 7 and 4 respectively. The electrode of the pH meter was inserted into the partly settled suspension. The pH value was read from the pH meter and recorded.

3.6.4PREPARATION AND DRY ASH DIGESTION OF SAMPLES FOR ELEMENTAL ANALYSIS

One (1.0) gram of the sample was weighed into a clean ceramic crucible. An empty crucible was included for a blank in each batch of 24 samples. The samples were arranged in a cool muffle furnace and temperature ramped to 500^{o}C over a period of 2 hours. This temperature was allowed to remain for an additional 2 hours. The samples were allowed to cool down in the furnace.

Samples were then removed from furnace ensuring that the environment is free from breeze. Ashed samples were transferred first into already numbered 50 ml centrifuge tubes. Crucibles were rinsed with 10 ml of distilled water into the centrifuge tubes. More rinsing of the crucible with 10 ml of aqua regia was done. The samples were shaken for 5 minutes for proper mixing on a mechanical reciprocating shaker. Samples were then centrifuged for 10 minutes at 3000 rpm and then transferred into 100 ml volumetric flask and again made up to the 100 ml mark. The clear supernatant digest were decanted into clean reagent bottles for P, Ca, Mg, K, Na, and Mn determinations.

3.6.4.1 Phosphorus (P) Determination

A vanadomolybdate reagent was prepared by dissolving 22.5g of ammonium molybdate in 400 ml of distilled water and 1.25 g of ammonium vanadate in 300ml of boiling distilled water. The vandate solution was added to the molybdate solution and cooled to room temperature. 2 ml of analytical grade HNO_3 was added to the solution mixture and diluted to 1litre with deionized water. The standard phosphate solution was also prepared by dissolving 0.219g of analytical grade KH_2PO_4 in 1000 ml distilled water. This solution contains 50µg P/ml. A standard curve was prepared by pipetting 1, 2, 3, 4, 5 and 10 ml of standard solution (50µg P/ml) in 50ml volumetric flasks. 10ml of vanadomolybdate reagent was added to each flask and the volume made up to 50ml. This gave a P content of the flasks as 1, 2, 3, 4, 5, and 10µg P/ml. These concentrations were measured on the Jenway 6051 colorimeter to give absorbance measurements at a wavelength of 430 nm. A plot of absorbance against concentration was used to prepare the calibration curve. 5ml of the sample solution from 3.4.2.2 was put into a 50ml volumetric flask. 10 ml of vanadomolybdate reagent was added and to make the volume up to 50ml. The sample was kept for 30 minutes for colour development. A stable yellow colour was developed. The sample was read on the colorimeter at 430nm. The observed absorbance was used to determine the P content from the standard curve. The phosphorus content was expressed in percentage (%). A sample calculation is shown in Appendix H.

3.6.4.2 Potassium and Sodium Determination

Analytical grade of KCl (1.908g) and NaCl (2.542g) previously dried in an oven for 4 hours at 105^{o}C were each dissolved in 200ml of deionised water. The two solutions were mixed together and volume made up to 1000ml. This gave a combined standard of 1000ppm. For K, a calibration curve (standard curve) of 200, 400, 600 and 800ppm was prepared. Similarly, a

standard curve of 20, 40, 60 and 80ppm was prepared for sodium. All the absorbance reading was taken using the flame photometer. The sample solution from the $HClO_4$ and HNO_3 was read on the flame photometer. From the standard curve, the concentration of K and Na were calculated using the particular absorbance observed for the sample. A sample calculation is shown in Appendix H.

3.6.4.3 Calcium and Magnesium Determination

Calcium and magnesium determination by EDTA titration involves the addition of several reagents. These reagents were prepared as follows;

Buffer solution: Was prepared by dissolving 60g of ammonium chloride was dissolved in about 200ml of distilled water. Five hundred and seventy milliliters (570ml) of concentrated ammonium hydroxide was added and diluted to 1000ml in a volumetric flask.

Potassium cyanide: 10% KCN (W/V) was prepared by dissolving 50g of KCN in 500ml of distilled water in a volumetric flask. This solution complex off all cations that react with EDTA.

Potassium hydroxide: 10% KOH (W/V) was prepared by dissolving 100g of KOH in a litre of distilled water. This is necessary when determining Ca^{2+} since it enables it to react with EDTA.

Calcone red (cal red) indicator: This indicator gives red coloration when Ca^{2+} is absent but gives bluish color when Ca^{2+} is present.

Triethanolamine (TEA): 30% (V/V) was prepared by diluting 300ml TEA in a litre of distilled water. This is a viscous solution which is included to maintain pH.

Erichrome Black T (EBT): 0.2g of EBT was weighed and dissolved in a mixture of 50ml methanol (85%) and 2g hydroxylamine hydrochloride. It is an indicator for determining Ca^{2+}

+ Mg^{2+}.It gives a red coloration in the absence of Ca^{2+} + Mg^{2+} and bluish coloration in the presence of Ca^{2+} + Mg^{2+}.

0.02N EDTA Solution (Versenate): 3.723g of reagent grade disodium ethylenediamine tetra acetate dehydrate was dissolved in distilled water. It was diluted to 1000ml and standardized against magnesium solution with EBT indicator (one ml of 0.02N EDTA = 0.4mg Ca = 0.24mg Mg). EDTA complexes with Ca^{2+} and removes it from solution giving a blue end point in the presence of Ca^{2+}.

Calcium standard (0.02N): 1.0g of reagent grade calcium carbonate ($CaCO_3$) was dissolved in 1ml of conc. HCl and diluted to 1000ml with distilled water.

Magnesium standard (0.02N): 2.465g of reagent grade magnesium sulfate heptahydrate was dissolved in 1000ml distilled water.

Determination of calcium content

5.0ml of sample solution from 3.4.2.2 was transferred into a 100 ml Erlenmeyer flask. 10 ml of 10% KOH solution was added followed by 1ml of 30% TEA in addition to three drops of 10% KCN and few drops of EBT indicator solution. The mixture was shaken to ensure homogeneity. The mixture was titrated with 0.02N EDTA solution from a red to blue end point. Calcium content was expressed in percentage (%). A sample calculation is shown in Appendix H.

Determination of magnesium content

Five milliliters (5.0ml) sample solution from 3.4.2.2 was emptied into a 100ml Erlenmeyer flask. 5ml of ammonium chloride – ammonium hydroxide buffer solution was added followed by 1ml 30% TEA, three drops of 10% KCN and a few drops of EBT indicator solution. The mixture was shaken to ensure homogeneity. The mixture was titrated with 0.02

NEDTA solution from a red to blue endpoint. Magnesium content was expressed in percentage (%).A sample calculation in Appendix H.

3.6.5 MICROBIAL CONTAMINATION

Samples were immersed in 4% of Clorox for 30 seconds. With the aid of sterile forceps, the samples were transferred into sterile distilled water to wash off excess Clorox. Samples were further transferred onto a sterile blotter papers and left to dry. Samples were then transferred onto the sterile PDA in Petri dish. Plates incubated at room temperature until growth occurs. Colonies (fungi) developed were counted with the colony counter instrument. Counts were expressed in percentage (Barnett and Hunter, 1972).

3.6.6 SENSORY EVALUATION

The sensory properties of the dried mango pulps were determined using twenty sensory panelists composed of males and females. They were workers from the MOFA western regional office and they were people familiar with mango products. The dried samples were served in random order and the attributes that were looked out for in each sample were colour, flavour, texture and overall acceptance. The panelists were to assign scores to indicate their preference for the various attributes using 9 point hedonic scale from 1, 2,3,4,5,6,7,8 and 9 representing dislike extremely, dislike very much, like slightly, dislike moderately, like moderately, dislike slightly,

like very much, neither like nor dislike, like extremely respectively. The responses were presented on a bar graph and analyzed statistically. The order of presentation of the different samples was randomized and given codes before being tested by the panelists (Mahony, 1985).

3.6.7 DATA ANALYSIS

All data collected for chemical analysis and sensory evaluation was analysed using Statistix 9 statistical Package. Mean separation was done using Lsd at 1% confidence intervals.

CHAPTER FOUR

4.0 RESULTS

The results of proximate minerals , vitamins, microbial contamination and sensory evaluation are presented in this section

4.1 Proximate Constituents of Dried Mango Chips

4.1.1 Moisture Content (%)

The study showed that the moisture content of the sun (19.00%) and the oven dried recorded (16.00%) mango chips were not significantly affected by the method of drying at day 0.

At day 30, significant differences were recorded in the method of packaging. Moisture content of the zip lock (22.58%) was significantly ($p<0.01$) higher than the control (unpackaged) (19.75%). However, Aluminium, PET and Control (unpackaged) were found to be similar ($p>0.01$).

At day 60, significant differences ($p<0.01$) were also recorded between the means of moisture content in the method packaging. Aluminum had the highest moisture content (21.83%) with the Zip lock recording the least (16.75%).

Table 4.1: Effects of drying methods, packaging and storage periods on moisture content of dried mango pulps (%)

Before packaging (day 0)		**After packaging (day 30)**				**After packaging (day 60)**			
Sun Dried	Oven dried	Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
			Sun dried	Oven dried			Sun dried	Oven dried	
19.00a	16.00a	Aluminum	21.33ab	20.83ab	21.08b	Aluminum	21.17ab	22.50a	21.83a
		PET	20.17b	20.50b	20.33b	PET	16.83cd	16.67cd	16.75b
		Zip lock	22.50a	22.67a	22.58a	Zip lock	17.67bcd	16.17d	16.92b
		Control	21.50ab	18.00c	19.75b	Control	22.50a	20.67abc	21.58a
		Mean	21.38a	20.50a		Mean	19.54a	19.00a	
Lsd= 3.76 CV(%)=5.71		Lsd PM=1.36 Lsd DM=0.96 Lsd interaction=1.92				Lsd PM=2.50 Lsd DM=1.41 Lsd interaction=4.18			

*Figures on the same column followed by the same letter are not significantly different

4.1.2 Protein Content (%)

There were significant differences ($p<0.01$) in protein content between the two drying methods at day 0.The oven dried mango pulps recorded (3.94%) and the sun dried mango pulps had (3.06%) which were significantly different from each other.

There were significant differences ($p<0.01$) between the means of the protein content within the method of packaging at day 30. Zip lock recorded the highest protein content of (4.82%) whereas the PET containers recorded the least mean (3.84%).Significant difference ($p<0.01$)was observed among the methods of drying upon packaging and storage. The sun dried mango chips had the higher protein content (4.53%) than the oven dried (3.87%).

However, at day 60 protein content of mango chips were not varying ($p>0.01$) upon packaging and storage. Most of the stored mango chips observed further marginal reductions in protein with the exception of Aluminium (4.08%) and PET (4.10%).

There was significant difference among the means of the drying method. The sun dried the higher protein content (4.15%) with the oven dried having the least (3.10%)

Table 4.2: Effects of drying methods, packaging and storage periods on protein content of dried mango pulps (%)

Before packaging (day 0)		**After packaging (day 30)**				**After packaging (day 60)**			
Sun Dried	Oven dried	Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
			Sun dried	Oven dried			Sun dried	Oven dried	
3.06b	3.94a	Aluminum	4.05bc	3.70b	3.87b	Aluminum	4.81a	3.35a	4.08a
		PET	4.02bc	3.65c	3.84b	PET	4.84a	3.36a	4.10a
		Zip lock	5.54a	4.09c	4.82a	Zip lock	3.15a	2.77a	2.96a
		Control	4.48b	4.03bc	4.26b	Control	3.79a	2.92a	3.36a
		Mean	4.53a	3.87b		Mean	4.15a	3.10b	
Lsd= 3.05 CV(%)=0.29		Lsd PM=0.46 Lsd DM=0.33 Lsd interaction=0.66				Lsd PM=1.30 Lsd DM=0.74 Lsd interaction=2.18			

*Figures on the same column followed by the same letter are not significantly different

4.1.3 Fat Content (%)

From the table 4.3 at day 0 there were no significant differences ($p>0.01$) among the means in terms of fat content between the two drying methods. Both the oven and sun dried mango pulps recorded the same fat content (0.05%); therefore they are not significantly different from each other.

However, upon packaging and storage fat levels did not vary ($p>0.01$) for days 30 and 60.Table

4.3: Effects of drying methods, packaging and storage periods on fat content of dried mango pulps (%)

Before packaging (day 0)		**After packaging (day 30)**				**After packaging (day 60)**			
Sun Dried	Oven dried	Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
			Sun dried	Oven dried			Sun dried	Oven dried	
0.50a	0.50a	Aluminum	0.67a	0.67a	0.67a	Aluminum	0.83a	0.83a	0.83a
		PET	0.83a	0.67a	0.75a	PET	0.67a	0.50a	0.58a
		Zip lock	1.00a	0.50a	0.75a	Zip lock	0.67a	0.50a	0.58a
		Control	0.834	0.67a	0.75a	Control	0.67a	0.50a	0.58a
		Mean	0.83a	0.63a		Mean	0.71a	0.58a	
Lsd= 0.27 CV(%)=14.14		Lsd PM=0.44 Lsd DM=0.31 Lsd interaction=0.63				Lsd PM=0.48 Lsd DM=0.27 Lsd interaction=0.80			

*Figures on the same column followed by the same letter are not significantly different

4.1.4 Fibre Content (%)

There were no significant difference ($p>0.01$) between the means of fibre content after processing. The oven dried mango pulps recorded (1.50%) and the sun dried mango chips had (1.08%) at day 0.

Packing methods and storage periods had effect on the fibre content. At day 30 significant differences ($p<0.01$) were observed in the method of packaging. Aluminium recorded the highest fibre content with the Control (unpackaged) having the least (1.07%). Significant difference ($p<0.01$) was also recorded in the drying methods. The sun dried had high fibre content (1.82%) while the oven dried recorded least (1.40%).

At day 60 of storage, significant differences ($p<0.01$) were recorded among the means of the packaging material. The range of fibre content observed was between 1.18% and 2.01%. The Zip lock recorded the highest fibre value of (2.01%) whereas Control (unpackaged) observed the lowest (1.18%). Significant difference ($p<0.01$) was observed between the drying methods. The oven dried had higher fibre content (1.55%) whereas the sun dried recorded the least (0.08%).

Table 4.4: Effects of drying methods, packaging and storage periods on fibre content of dried mango pulps (%)

Before packaging (day 0)		**After packaging (day 30)**				**After packaging (day 60)**			
Sun Dried	Oven dried	Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
			Sun dried	Oven dried			Sun dried	Oven dried	
1.08a	1.50a	Aluminum	1.97ab	2.17ab	2.07a	Aluminum	1.72a	1.74a	1.82a
		PET	1.74bc	1.37cd	1.56b	PET	1.64bc	1.99abc	1.92a
		Zip lock	2.47a	0.99d	1.74ab	Zip lock	2.14ab	1.70bc	2.01a
		Control	1.09d	1.05d	1.07c	Control	2.30a	1.72abc	1.18b
		Mean	1.82a	1.40b		Mean	0.08d	1.55c	
Lsd=0.27 CV(%)=5.51		Lsd PM=0.34 Lsd DM=0.19 Lsd interaction=0.57				Lsd PM=0.35 Lsd DM=0.20 Lsd interaction=0.59			

*Figures on the same column followed by the same letter are not significantly different

4.1.5 Ash Content (%)

Sun (1.50%) and oven (1.50%) drying resulted in similar ($p>0.01$) ash content after processing.

Significant differences ($p<0.01$) were recorded among the means of the packaging method, at day 30. The ranges were between 1.17% and 2.25%. The sun dried mango chips stored in Aluminium recorded the highest ash content of (2.25%).The PET recorded low ash content of (0.83%).

At day 60, upon packaging and storage ash levels did not vary ($p>0.01$).

Table 4.6: Effects of drying methods, packaging and storage periods on ash content of dried mango pulps (%)

Before packaging (day 0)		**After packaging (day 30)**				**After packaging (day 60)**			
Sun Dried	Oven dried	Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
			Sun dried	Oven dried			Sun dried	Oven dried	
1.50a	1.50a	Aluminum	2.83a	1.67a	2.25a	Aluminum	1.50a	1.33a	1.42a
		PET	1.17b	1.17b	1.17c	PET	1.17a	1.67a	1.42a
		Zip lock	1.83ab	1.67b	1.75ab	Zip lock	1.17a	1.67a	1.42a
		Control	1.67b	0.83b	1.25bc	Control	1.67a	1.331	1.50a
		Mean	1.88a	1.33b		Mean	1.37a	1.50a	
Lsd= 0.38 CV(%)=6.67		Lsd PM=0.55 Lsd DM=0.39 Lsd interaction=0.78				Lsd PM=0.75 Lsd DM=0.42 Lsd interaction=1.25			

*Figures on the same column followed by the same letter are not significantly different

4.1.6 Carbohydrate Content (%)

No significant differences ($p>0.01$) were recorded among the means of carbohydrate content at day 0 after processing. The oven dried mango pulps recorded fibre content of (76.56%) whereas that of sun dried recorded (75.53%).

The results of the means showed that there were significant difference ($p<0.01$) between the methods of packaging, at day 30.The highest carbohydrate content was recorded by the Control (unpackaged) (93.01%). The zip lock had the least carbohydrate value of (90.95 %). Significant difference ($p<0.01$) was observed between the drying methods. The oven dried had higher carbohydrate content (92.78%) whereas the sun dried recorded the least (91.12%).

At day 60, no significant differences ($p>0.01$) were recorded among the packaging method. The carbohydrate range was between 78.07% and 93.05%. The control (unpackaged) recorded the highest carbohydrate value of (93.05%) with the PET recording the least (78.07%).

Table 4.5: Effects of drying methods, packaging and storage periods on carbohydrate content of dried mango pulps (%)

Before packaging (day 0)		**After packaging (day 30)**				**After packaging (day 60)**			
Sun Dried	Oven dried	Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
			Sun dried	Oven dried			Sun dried	Oven dried	
75.53a	76.56a	Aluminum	90.48 bc	91.80a b	91.14 b	Aluminum	92.49a	91.21a	91.85a
		PET	92.24a b	93.15a	92.69 d	PET	91.35a	64.78a	78.07a
		Zip lock	89.15c	92.76a b	90.95 b	Zip lock	92.72a	93.34a	93.03a
		Control	92.60a b	93.43a	93.01	Control	93.07a	94.03a	93.56a
		Mean	91.12 b	92.78a		Mean	92.09a	86.16a	
Lsd= 0.04 CV(%)=1.07		Lsd PM=1.46 Lsd DM=0.83 Lsd interaction=2.45				Lsd PM=36.33 Lsd DM=20.50 Lsd interaction=60.83			

*Figures on the same column followed by the same letter are not significantly different

4.2. Mineral Composition of Dried Mango Chips

4.2.1 Potassium Content (mg/100g)

The study showed that the potassium content of the mango chips was significantly affected by the method of drying at day 0. Oven dried mango chips had higher potassium content (1.93mg/100g) than sun dried (1.75mg/100g).

However, upon packaging and storage potassium levels did not vary ($p>0.01$) for days 30 and 60.

Table 4.7: Effects of drying methods, packaging and storage periods on potassium content of dried mango pulps (mg/100g)

Before packaging (day 0)		**After packaging(day 30)**				**After packaging (day 60)**			
Sun Dried	Oven dried	Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
			Sun dried	Oven dried			Sun dried	Oven dried	
1.75b	1.93a	Aluminum	1.54a	1.10a	1.32a	Aluminum	1.68a	1.40a	1.54a
		PET	1.26a	1.24a	1.25a	PET	1.24a	1.11a	1.17a
		Zip lock	1.43a	1.15a	1.30a	Zip lock	1.40a	1.05a	1.23a
		Control	1.35a	1.03a	1.19a	Control	1.32a	1.18a	1.25a
		Mean	1.39a	1.12a		Mean	1.41a	1.19a	
Lsd= 0.15 CV(%)=2.23		Lsd PM=1.30Lsd DM=0.73 Lsd interaction=2.17				Lsd PM=0.85Lsd DM=0.48 Lsd interaction=1.42			

*Figures on the same column followed by the same letter are not significantly different

4.2.2 Magnesium Content (mg/100g)

Sun (0.24mg/100g) and oven (0.15mg/100g) drying resulted in similar ($p>0.01$) magnesium content after processing. This trend was observed in both the 30 and 60 days storage period. However, upon packaging and storage magnesium levels did not vary ($p>0.01$) for days 30 and 60.

Table 4.8: Effects of drying methods, packaging and storage periods on magnesium content of dried mango pulps (mg/100g)

Before packaging (day 0)		**After packaging(day 30)**				**After packaging (day 60)**			
Sun Dried	Oven dried	Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
			Sun dried	Oven dried			Sun dried	Oven dried	
0.24a	0.15a	Aluminum	0.16a	0.10a	0.13a	Aluminum	0.17a	0.13a	0.15a
		PET	0.10a	0.10a	0.10a	PET	0.14a	0.12a	0.13a
		Zip lock	0.14a	0.11a	0.13a	Zip lock	0.18a	0.12a	0.15a
		Control	0.07a	0.15a	0.11a	Control	0.14a	0.16a	0.15a
		Mean	0.12a	0.12a		Mean	0.16a	0.13a	
Lsd= 0.27 CV(%)=36.65		Lsd PM=0.12Lsd DM=0.07 Lsd interaction=0.20				Lsd PM=0.07 Lsd DM=0.04 Lsd interaction=0.12			

*Figures on the same column followed by the same letter are not significantly different

4.2.3 Sodium Content (mg/100g)

After mango chips processing sodium content was not significantly affected by the method of drying. Both the oven and sun dried mango chips recorded sodium content of (0.07mg/100g). This trend was observed in both the 30 and 60 days storage period.

However, upon packaging and storage magnesium levels did not vary ($p>0.01$) for days 30 and 60.

Table 4.9: Effects of drying methods, packaging and storage periods on sodium content of dried mango pulps (mg/100g)

Before packaging (day 0)		**After packaging (day 30)**				**After packaging (day 60)**			
Sun Dried	Oven dried	Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
			Sun dried	Oven dried			Sun dried	Oven dried	
0.07a	0.07a	Aluminum	0.14a	0.07a	0.11a	Aluminum	0.09a	0.05a	0.07a
		PET	0.09a	0.07a	0.08a	PET	0.05a	0.05a	0.05a
		Zip lock	0.10a	0.08a	0.09a	Zip lock	0.07a	0.07a	0.07a
		Control	0.12a	0.07a	0.10a	Control	0.05a	0.13a	0.09a
		Mean	0.11a	0.07a		Mean	0.07a	0.08a	
Lsd= 0.03 CV(%)=11.39		Lsd PM=0.09 Lsd DM=0.05 Lsd interaction=0.15				Lsd PM=0.14 Lsd DM=0.08 Lsd interaction=0.24			

*Figures on the same column followed by the same letter are not significantly different

4.2.4 Phosphorus Content (mg/100g)

From the Table 4.10 there was no significant difference ($p<0.01$) between the oven dried (0.12mg/100g) and the sun dried (0.10mg/100g).

However, upon packaging and storage no significant differences ($p>0.01$) were recorded for day 30 and 60.

Table 4.10: Effects of drying method, packaging and storage periods on phosphorus content of dried mango pulps (mg/100g)

Before packaging (day 0)		**After packaging (day 30)**				**After packaging (day 60)**			
Sun Dried	Oven dried	Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
			Sun dried	Oven dried			Sun dried	Oven dried	
0.10a	0.12a	Aluminum	0.09a	0.06a	0.08a	Aluminum	0.13a	0.07a	0.10a
		PET	0.08a	0.06a	0.07a	PET	0.10a	0.12a	0.11a
		Zip lock	0.06a	0.06a	0.06a	Zip lock	0.09a	0.07a	0.08a
		Control	0.07a	0.06a	0.06a	Control	0.10a	0.07a	0.08a
		Mean	0.08a	0.06a		Mean	0.11a	0.08a	
Lsd= 0.04 CV(%)=9.97		Lsd PM=0.04 Lsd DM=0.02 Lsd interaction=0.07				Lsd PM=0.10 Lsd DM=0.06 Lsd interaction=0.17			

*Figures on the same column followed by the same letter are not significantly different

4.2.5 Calcium Content (mg/100g)

The study revealed that the calcium content of the mango chips was significantly affected by the method of drying at day 0. The oven dried recorded higher calcium content of (0.27mg/100g) and the sun dried mango chips had (0.13mg/100g) at day 0.

However, upon packaging and storage magnesium levels did not vary ($p>0.01$) for days 30 and 60.

Table 4.11: Effects of drying methods, packaging and storage periods on calcium content of dried mango pulps (mg/100g)

Before packaging (day 0)		**After packaging(day 30)**				**After packaging (day 60)**			
Sun Dried	Oven dried	Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
			Sun dried	Oven dried			Sun dried	Oven dried	
0.13b	0.27a	Aluminum	0.12a	0.08a	0.10a	Aluminum	0.08a	0.06a	0.07a
		PET	0.13a	0.09a	0.11a	PET	0.07a	0.07a	0.07a
		Zip lock	0.10a	0.10a	0.10a	Zip lock	0.07a	0.04a	0.06a
		Control	0.14a	0.12a	0.13a	Control	0.09a	0.06a	0.08a
		Mean	0.12a	0.10a		Mean	0.08a	0.06a	
Lsd= 0.04 CV(%)=5.00		Lsd PM=0.12 Lsd DM=0.07 Lsd interaction=0.21				Lsd PM=0.06 Lsd DM=0.03 Lsd interaction=0.10			

*Figures on the same column followed by the same letter are not significantly different

4.2.6 Vitamin C Content (mg/100g)

Sun (4.36mg/100g) and oven (4.88mg/100g) drying resulted in similar ($p>0.01$) vitamin C content after processing. This trend was observed in both the 30 and 60 days storage periods.

At day 30, significant differences were observed in the method of packaging. Vitamin C content in the Zip lock (4.36mg/100g) was significantly ($p<0.01$) higher than the Control (unpackaged)(2.95mg/100g).

However, Aluminium (4.11mg/100g), PET (4.11mg/100g) and Zip lock were found to be similar.

Table 4.12: Effects of drying method, packaging and storage periods on vitamin C content of dried mango pulps (mg/100)

Before packaging (day 0)		**After packaging (day 30)**				**After packaging (day 60)**			
Sun Dried	Oven dried	Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
			Sun dried	Oven dried			Sun dried	Oven dried	
4.36a	4.88a	Aluminum	4.36a	3.85a	4.11ab	Aluminum	4.36a	3.85a	4.11a
		PET	4.36a	4.11a	4.11ab	PET	4.11a	4.11a	4.11a
		Zip lock	4.36a	4.36a	4.36a	Zip lock	4.36a	4.36a	4.36a
		Control	4.36a	3.08a	2.95b	Control	2.82a	3.08a	2.95a
		Mean	4.36a	3.85a		Mean	3.91a	3.85a	
Lsd= 2.64 CV(%)=2.64		Lsd PM=1.15 Lsd DM=0.65 Lsd interaction=1.92				Lsd PM=1.33 Lsd DM=0.75 Lsd interaction=2.22			

*Figures on the same column followed by the same letter are not significantly different

4.2.7 pH Content

There were significant differences ($p<0.01$) between the two drying methods at day 0.The oven dried (5.48) was significantly higher than the sun dried (5.17).

However, upon packaging and storage no significant differences ($p>0.01$) were recorded for day 30 and 60.

Table 4.13: Effects of drying methods, packaging and storage periods on pH content of dried mango pulps

Before packaging (day 0)		**After packaging (day 30)**				**After packaging (day 60)**			
Sun Dried	Oven dried	Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
			Sun dried	Oven dried			Sun dried	Oven dried	
5.17b	5.48a	Aluminum	5.34a	5.09a	5.21a	Aluminum	5.37a	5.13a	5.25a
		PET	5.31a	4.09a	4.70a	PET	5.29a	5.04a	5.17a
		Zip lock	5.29a	5.12a	5.21a	Zip lock	5.22a	5.06a	5.14a
		Control	5.34a	5.21a	5.28a	Control	5.26a	5.12a	5.19a
		Mean	5.32a	4.88a		Mean	5.28a	5.09a	
Lsd= 0.02 CV(%)=0.11		Lsd PM=1.38 Lsd DM=0.78 Lsd interaction=2.31				Lsd PM=0.32 Lsd DM=0.18 Lsd interaction=0.54			

*Figures on the same column followed by the same letter are not significantly different

4.3. Microbial Contamination of dried mango pulps at 60 days of storage

4.3.1 Rhizopus sp (%)

At day 60, packaging and storage period revealed no significant differences ($p>0.01$) on the drying method. The *Rhizopus sp* count of oven dried was 0.17% and that of sun dried was 0.00%. No significant differences ($p>0.01$) were observed in the method of packaging. Both Zip lock and Control recorded 0.17% count.

4.3.2 Penicillin sp (%)

The study showed that upon packaging and storage no significant differences ($p>0.01$) were recorded in packaging method at day 60. The *Penicillin sp* count of the mango chips was not significantly affected by the method of drying. The sun dried mango pulps stored in PET containers recorded the highest counts of (3.00%).

Table 4.14: Effects of drying methods, packaging and storage periods on texture on total counts of *Rhizopus sp* and *Penicillin sp* in dried mango pulps at day 60 of storage (%)

Rhizopus sp (%)				*Penicillin sp* (%)			
Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
	Sun dried	Oven dried			Sun dried	Oven dried	
Aluminum	0.00a	0.00a	0.00a	Aluminum	1.33a	2.00a	1.67a
PET	0.00a	0.00a	0.00a	PET	3.00a	0.33a	1.67a
Zip lock	0.00a	0.33a	0.17a	Zip lock	0.67a	0.00a	0.33a
Control	0.00a	0.33a	0.17a	Control	0.00a	0.00a	0.00a
Mean	0.00a	0.17a		Mean	1.08a	0.75a	
Lsd PM= 0.65a Lsd DM=0.36a Lsd interaction=1.08				Lsd PM=1.97 Lsd DM=1.11 Lsd interaction=3.29			

*Figures on the same column followed by the same letter are not significantly different

4.3.3 Mucor sp (%)

The *Mucor sp* counts of the stored mango chips at day 60 were not significantly affected by the drying method. Both the sun and oven dried had similar percentage counts (0.17%). There was no significant difference ($p>0.01$) among the packaging methods. The percentage count range was between 0.00% and 0.33%.

4.3.4 Aspergillus niger (%)

At day 60, no significant difference ($p>0.01$) was observed in the method of drying. The oven dried had percentage counts of 1.00% with the sun dried recording 1.33%. The fungus count of the mango chips was not significantly affected packaging method. The percentage count range was between 0.05% and 1.67%.

Table 4.15: Effects of drying methods, packaging and storage periods on texture on total counts of *Mucor sp* and *Aspergillus niger* in dried mango pulps at day 60 of storage (%)

Mucor sp (%)				*Aspergillus niger* (%)			
Packaging material	Drying methods		Mean	Packaging material	Drying methods		Mean
	Sun dried	Oven dried			Sun dried	Oven dried	
Aluminum	0.67a	0.00a	0.33a	Aluminum	1.00a	1.67a	1.33a
PET	0.00a	0.67a	0.33a	PET	1.00a	1.33a	1.17a
Zip lock	0.00a	0.00a	0.00a	Zip lock	0.00a	1.00a	0.50a
Control	0.00a	0.00a	0.00a	Control	2.00a	1.33a	1.67a
Mean	0.17a	0.17a		Mean	1.00a	1.33a	
Lsd PM= 1.29 Lsd DM=0.73 Lsd interaction=2.16				Lsd PM= 1.77 Lsd DM=0.10 Lsd interaction=2.96			

*Figures on the same column followed by the same letter are not significantly different

4.3.5 Aspergillus flavus (%)

From table 4.16 there was no significant difference ($p>0.01$) among the means of the drying methods at day 60 of storage. The sun dried recorded 0.33% whereas the oven dried mango chips had 0.08%.Packaging method also recorded no significant difference ($p>0.01$). Microbial percentage counts ranges from 0.00% to 0.33%.

Table 4.16: Effects of drying methods, packaging and storage periods on total counts of *Aspergillus flavus* in dried mango pulps at day 60 of storage (%)

Aspergillus flavus (%)			
Packaging material	Drying methods		Mean
	Sun dried	Oven dried	
Aluminum	0.67a	0.00a	0.33a
PET	0.67a	0.00a	0.33a
Zip lock	0.00a	0.33a	0.17a
Control	0.00a	0.00a	0.00a
Mean	0.33a	0.08a	
Lsd PM=1.28 Lsd DM=0.72 Lsd interaction=2.14			

*Figures on the same column followed by the same letter are not significantly different

4.4 Sensory Evaluation of Dried Mango Chips

4.4.1 Appearance

The appearance of the mango chips were significantly affected ($p<0.01$) by the two different drying methods used in producing the chips. Sun dried mango chips scored the highest value of (7.00) with the oven dried mango chips scoring the least (5.50) at day 0.

At day 30, significant differences ($p<0.01$) in appearance were recorded among the treatments means. The sun dried PET significantly scored higher (7.55) than both oven dried Control (unpackaged) (4.00) and oven dried zip lock (4.00).

Table 4.17: Effects of drying methods, packaging and storage periods on appearance of dried mango pulps

Before packaging (day 0)		**After packaging (day 30)**		
Sun dried	Oven dried	Packaging material	Drying methods	
			Sun dried	Oven dried
7.00a	5.50b	Aluminum	4.65b	4.10b
		PET	7.55a	5.30b
		Zip lock	4.75b	4.00b
		Control	4.45b	4.00b
Lsd= 1.45 CV(%)=27.10		Lsd= 1.81		

*Figures on the same column followed by the same letter are not significantly different

4.4.2 Aroma

The method of drying had significant differences ($p<0.01$) on the aroma of mango chips produced as shown in table 4.18.were recorded among the treatment means. The aroma of oven dried mango chips were highly preferred with a mean score of (6.45) whiles sun dried mango chips (5.45) was the least preferred at day 0.

The aroma of oven dried mango chips in PET containers had highest mean score of (8.10) whereas the oven dried mango chips Control (unpackaged) scored the least (3.55) at day 30 of storage.

Table 4.18: Effects of drying methods, packaging and storage periods on aroma of dried mango pulps

Before packaging (day 0)		**After packaging (day 30)**		
Sun dried	Oven dried	Packaging material	Drying methods	
			Sun dried	Oven dried
5.60a	6.45a	Aluminum	3.80b	4.10b
		PET	4.25b	8.10a
		Zip lock	4.05b	3.85b
		Control	3.75b	3.55b
Lsd= 1.35 CV(%)=26.07		Lsd= 1.61		

*Figures on the same column followed by the same letter are not significantly different

4.4.3 Overall Acceptability

Mean scores for overall acceptability for oven dried and sun dried mango chips were 6.75 and 5.45for oven and sun dried mango chips respectively, at day 0. Differences in overall acceptability of mango chips produced suing the two different drying methods were insignificant ($p>0.01$).

However, upon packaging and storage significant differences ($p<0.01$) were scored in the overall acceptability of mango chips for at day 30. The oven dried PET containers had the highest score of (7.75). Comparatively the oven dried Control (unpackaged) had the least score (3.90).

Table 4.19: Effects of drying methods, packaging and storage periods on overall acceptability of dried mango pulps

Before packaging (day 0)		**After packaging (day 30)**		
Sun dried	Oven dried	Packaging material	Drying methods	
			Sun dried	Oven dried
5.45a	6.75a	Aluminum	4.20b	4.70b
		PET	4.35b	7.75a
		Zip lock	4.05b	4.05b
		Control	4.05b	3.90b
Lsd= 1.53 CV(%)=29.22		Lsd= 1.33		

*Figures on the same column followed by the same letter are not significantly different

4.4.4 Taste

The taste of the mango chips was not significantly affected ($p>0.01$) by the two different drying methods, at day 0. The oven dried mango chips (6.00) scored the highest value while the sun dried (5.25) scored the least.

The taste of the mango chips were significantly affected ($p<0.01$) by the different packaging methods, at day 30. Significant differences were recorded among the treatment means. The oven dried PET containers recorded the highest score (7.80). Whereas the oven dried Control (unpacked) scored the least value (3.55)

Table 4.20: Effects of drying methods, packaging and storage periods on taste of dried mango pulps

Before packaging (day 0)		**After packaging (day 30)**		
Sun dried	Oven dried	Packaging material	Drying methods	
			Sun dried	Oven dried
6.00a	5.25a	Aluminum	3.75b	3.95b
		PET	7.80a	4.25b
		Zip lock		3.90b
		Control	4.05b	3.55b
			3.95b	
Lsd= 2.02 CV(%)=41.97		Lsd= 1.80		

*Figures on the same column followed by the same letter are not significantly different

4.4.5 Texture

There were no significant differences ($p>0.01$) in texture between the two drying methods after processing, at day 0. The least texture was scored by the sun dried mango chips (4.95) as compared to the oven dried (5.95) which scored the highest value.

At day 30, a significant differences ($p<0.01$) were recorded in texture between the different packaging methods. The oven dried in PET recorded the highest score (8.00).The least mean texture was scored by both the sun dried Control (unpackaged) (3.80) and the oven dried Aluminium (3.80).

Table 4.21: Effects of drying methods, packaging and storage periods on texture of dried mango pulps

Before packaging (day 0)		**After packaging (day 30)**		
Sun dried	Oven dried	Packaging material	Drying methods	
			Sun dried	Oven dried
4.95a	5.95a	Aluminum	4.15b	3.80b
		PET	4.30b	8.00a
		Zip lock	4.25b	4.45b
		Control	3.80b	4.30b
Lsd= 1.54 CV(%)=32.86		Lsd= 1.91		

*Figures on the same column followed by the same letter are not significantly different

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 Proximate Constituents of Dried Mango Chips Packaging

5.1.1 Moisture content

From table 4.1 the results suggest that the moisture content difference between oven and sun drying were not significantly different ($p>0.01$).This indicates that the method of drying mango chips were not significant. Works done by Mahunu *et al.* (2012)showed that higher decrease in the oven dried Keitt mango chips could be attributed to the faster pronounced drying as investigated. According to Oduro *et al.* (2009) since oven dried pulp had lower moisture content, it was expected to have longer shelf life than the solar dried pulp.

The results of the moisture content showed a general increase in moisture content with increasing storage time. The moisture content was significantly different ($p<0.01$) with storage periods and method of packaging. The results of the moisture content show that there were significant differences in the amount of moisture gained in the 30 days of stored dried mango chips. There was also a significant effect of method of packaging on moisture content. The high moisture content observed with the Zip lock were due to the fact that they have high permeability to oxygen and water vapour diffusion as compared to PET container and Aluminium packs.

At day 60, of storage the mango chips there was also a significant ($p<0.01$) effect of packaging method on moisture content.

The increase in moisture with storage time could be attributed to the fact that the dried products picked up moisture from its surroundings (Dennis, 1993). Deterioration and

chemical reactions could be higher in Controls (unpackaged) and Aluminium bags with increasing storage time (Dennis, 1993).

An increase was observed in moisture content of all the packaged samples. This result is similar to the findings of (Fagbohun *et al.* 2010) who reported a significant increase in moisture content of sun dried melon seed during storage. The increase in the moisture content with storage time might be due to the metabolic water as indicated by (Ladele *et al*, 1984). The difference between packaging materials may be due to their thermal conduction properties which affect the internal decomposition reactions in the products during storage.

As regards the packaging material, PET was the material of choice since it gave low moisture content for day 60.This study showed that Keitt mango chips could be kept up to 60 days using PET containers.

5.1.2 Protein content

The study has shown that the different method of drying had effect on protein content at processing and during storage. Sun drying of mango pulp resulted in significantly higher protein content than oven drying. This finding is contrary to the report of Oduro *et al.* (2009) who reported that oven drying preserved protein than sun drying. The result indicates that sun dried Keitt mango chips could keep its protein content up to 30 days without significant reduction. This is good because processors and consumers can store their mango for longer periods.

For the packaging material, Zip lock was the material of choice since it gave the highest protein content at day 30 even though this was lost in day 60.

This is in agreement with the findings of (Amadioha, 1998) who reported quantities of proteins decrease appreciably during storage and infection of potato tubers. The reduction

suggested that the fungi isolated utilized the nutrient for their successful establishment, cellular growth, reproduction and survival with the tissues of groundnut.

5.1.3 Fat

The study has shown that the different methods of drying did not affect the fat content at processing and storage. Similarly (Amadioha, 1998) reported the quantities of protein and fats to decrease appreciably during storage and infection of potato tubers. The reduction suggested that the fungi isolated utilized the nutrient for their successful establishment, cellular growth, reproduction and survival with the tissues of groundnut.

Research conducted by (Kammerow, 1960) showed that fat contribute to energy and palatability of foods.

5.1.4 Fibre

The result of the study has shown that the methods of drying did affect the fibre content both at processing and storage. The faster rate of drying in the oven compared to the solar dried could result in reduced fibre breakdown reflecting in the higher fibre content of the oven dried pulp. Intake of fibre has been reported to improve stool passage in the digestive tract by providing bulk, reducing stool transmit time according to Marlett and Johnson, (1986). Shankar and Lanza (1991) reported that it also reduce colon cancer incidence. Therefore the oven dried pulp would be more useful in providing the health benefits derived from fibre since it has high fibre content.

The increases of the fibre content were not in agreement with the findings of (Fagbohun *et al.* 2010) who reported the decrease in the percentage fibre content of sun dried plantain chips. The packaging material might have restricted the conversion of fibre into sugars in chemical reactions because of their better packaging conditions during storage. This suggests that Keitt mango chips dried using oven could keep its fibre content up to 60 days without significant reduction.

As regards the packaging material, Zip lock was the material of choice since it gave the highest fibre content for both day 30 and 60.

5.1.5 Ash

The study has shown that the different drying method did not affect the affect the ash content at processing. This is in contrast to the report of McClemerle, (2003) who reported lower ash content of the sun dried mango chips could be as a result of dripping of moisture containing dissolved salts from the pulp since minerals essentially constitute ash.

This suggest that Keitt mango chips dried using sun drying could keep its ash content up to 30 days with significant increase.

Regarding the packaging material, Aluminium was the material of choice since it gave the highest ash content for day 30 although this was lost in day 60.

5.1.6 Carbohydrate

The result has shown that during processing the drying method did not affect the carbohydrate content.

This indicates that Keitt mango chips dried using either sun or oven could keep its carbohydrate content up to 60 days without significant reduction. This is desirable as processers and consumers can store their mango for longer periods.

As regards the packaging, Control (unpackaged) was the material of choice since it gave the highest carbohydrate content for day 60.

5.2. Mineral Composition of Dried Mango Chips

5.2.1 Potassium Content

The different method of drying had effect on potassium content at processing. From Table 4.7 the potassium content of sun dried Keitt mango pulps are lower than the oven dried. There were significant differences ($p<0.01$) among the means of the treatments. Sun dried Keitt mango pulps had lower potassium content since the drying took a longer time than the oven dried one resulting in more extensive juice drip. If mango pulp is to be dried, the method of choice for preserving potassium should be the use of the oven. The high potassium content suggests it could be suitable for ameliorating hypertension when consumed as noted by (Whelton *et al.* 1997).

This suggest that Keitt mango chips dried using either oven or sun could not keep potassium content up to 60 days without no significant reduction. No packaging material was ideal for maintaining of the potassium content.

5.2.2 Magnesium

The study has shown that the different methods of drying did not affect the magnesium content at processing and during storage. Magnesium has been reported to be useful in promoting nerve transmission by (Ferrao*et al.* 1987). Therefore consuming sun dried mango pulp would help supplement by contributing to the daily recommended intake of 320-420mg/day for adults of over 33 years old (National Institute of Health, 2011a).

This suggest that Keitt mango chips dried using either oven or sun could not keep magnesium content up to 60 days without no significant reduction. No packaging material would be an ideal choice since none was able to maintain magnesium content.

5.2.3 Sodium

The study has shown that the different drying method did not affect the affect the ash content at processing. Sodium help muscles and nerves work properly by assisting muscular contraction and transmission of nerve signals. It also helps in the regulation of blood pressure and volume. Excess sodium in the diet has many serious, dangerous side effects like high blood pressure.

This suggests that Keitt mango chips dried using either oven or sun could not keep sodium content up to 60 days without any significant reduction. No packaging material was ideal for maintaining the sodium content.

5.2.4 Phosphorus

From the table 4.10 it could be seen that the different drying methods did not affect the phosphorus content at processing and during storage. Phosphorus performs a number of important functions. It combines with calcium to form a relatively insoluble compound calcium phosphate, which gives strength and rigidity to bones and teeth. It also helps in growth and the maintenance of skeleton.

This indicates that Keitt mango chips dried using either oven or sun could not keep potassium content up to 60 days without any significant reduction. No packaging material was ideal for keeping the phosphorus content.

5.2.5 Calcium

The different methods of drying had effect on the calcium content during processing of the mango chips. The result suggests that consuming oven dried mango pulps would help meet the recommended calcium intake of 1000mg/day for adults of between 19 and 50 years of age (National institute of Health, 2011b) because they contain high content of calcium.

Keitt mango chips dried using either oven or sun could not keep potassium content up to 60 days without any significant reduction. No packaging material was an ideal choice for maintaining of the calcium content.

5.2.6 Vitamin C

The study has shown that the different methods of drying did not affect the vitamin C content at processing and during storage. This finding is contrary to the report of (Fennema, 1996) who indicated that processing methods and cooking methods can result in significant losses of vitamin C .The higher temperature at which the samples were prepared is probably responsible for this, the loss of ascorbic acid having been reported to be corresponding to temperature (Garangyo *et al.* 1992). Vitamin C protects against endothelial dysfunction, high blood pressure and blood vessel changes that precede heart diseases. Some primary symptoms of Vitamin C are: tiredness, physical and mental weakness. Psychic disturbances like depressions or hysteria may also be possible due to the deficiency of Vitamin C, it is also a strong reducing substance. That plays an important role in hydroxylation reactions, i.e. in the synthesis collagen. So it is rather important for bone, cartilage tooth ascorbic acid and for the healing of wounds. Another important role is that of antioxidants that means it protects other substances from the oxidizing effects of oxygen. This suggests that Keitt mango chips using either sun or oven could keep its vitamin C up to 60 days without significant reduction. This is desirable as producers and consumers can store their mango for longer periods.

Reduction in the vitamin C could be attributed to the fact that, increasing moisture content increases water activity a condition suitable for oxidative degradation of vitamins C as noted by Meza *et al.* (1995) and Salunkhe *et al.* (1991). Vitamin C is sensitive to air, light and heat.

Some of the packaging materials were more permeable to oxygen and water vapour. The presence of oxygen could also initiate the conversion of vitamin C to dehydroascorbic acid and other oxidized products. Alzamora *et al.* (2000) reported that light has a significant effect on the stability of vitamin C during storage. This could also be a contributory factor for the loss in vitamin C in some of the four package types. Losses are high at high temperatures and with longer storage duration.

As regards the packaging material, Zip lock was the material of choice since it gave the highest vitamin C content for day 30 although this was lost in day 60.

5.2.7 pH

The different method of drying had effect on pH content at processing. From Table 4.13 the pH content of sun dried Keitt mango pulps were lower than the oven dried. The food acidity (pH) is an important parameter in food. Besides factor affecting the growth and survival of bacteria and other microorganism in foods, food acidity also affects flavour. Water ionizes as temperature rises, so hydrogen ion concentration rises that means that pH decreases. From this it could be deduced that sun dried mango pulps would have longer shelf life than the oven dried ones. Matazu *et al.* (2002) explained that the pH values of vegetables being weakly acidic allow growth of certain microorganisms.

Keitt mango chips dried using either oven or sun could not keep potassium content up to 60 days without any significant increases. This observation disagrees with the work of (Garangyo *et al.* 1992) who attributed that the decrease in acidity is probably due to the effect of organisms responsible for the spoilage, some of which can release basic substances into the samples. No packaging material was ideal for keeping the pH content.

5.3 Microbial Contamination of Dried Mango Pulps at Day 60 of Storage

The study showed the different dying methods did not affect the microbial load at processing and during storage. This finding is contrary to the report of Salunkhe *et al.* (1991) reported the effect of water activity on the microbial load of dried foods that increase in the microbial load during storage could be attributed to the water activity as the samples picked up moisture. Also (Dennis, 1993) reported the differences in microbial load could be attributed to several factors including moisture absorption, permeability of the package to oxygen and water vapour among others (Dennis, 1993).According to Matazu *et al.* (2002) they explained that the pH values of vegetables being weakly acidic allows the growth of certain microorganisms. These confirm that pH and moisture content are some of the conditions that influence the growth of microorganisms.

Five fungi were isolated namely *Rhizopus sp*, *Mucor sp* ,*Penicillium sp*, *Aspergillus niger* and *Aspergillus flavus*. This result is in agreement with the findings of (Abdel-Sater and Erasky, 2001) who reported the isolation of *Aspergillus spp, Penicillium spp, Fusarium sp* and *Rhizopus spp* from stored onion bulbs. Similarly (Youssef , 2008) also reported of *A. niger, A. flavus ,A .fumigates* , *Fusarum sp, Rhizopus oryzae* and *Penicillium sp* from sun dried Jew's mallow leaves and okra fruit. Some of the fungi associate with stored products have been reported to released chemicals that are hazardous to man and animals (Richard and Wallace, 2001). Consumption of excessive amount of the chemicals can cause illness and fatality. Many of these toxic chemicals have been reported by (Youssef and Palmateer, 2008) in okra fruits to include aflatoxin B_I, B_2, G_1 and G_2, zearalenone and diacetoxyscirpenol. These pathogens posses the ability to produce extracellular hydrolytic enzymes that are capable of breaking down these stored products according to (Amadioha, 1998). They are also associated with diseases such as keratitis, endocarditis, endophtalmitis, otomycosis,

infarction, neuroperia and hepatocellular carcinoma as researched by (Lueg*et al.* 1996; Mitchell *et al.* 1996, Crawford and Kumor, 2005).

However, the study revealed that Keitt chips dried using either sun or oven could keep microbial load up to 60 days without adverse effects.

All the packaging materials were ideal since each had insignificant microbial contamination.

5.4 Sensory Evaluation of Dried Mango Chips

The response of panelists on appearance (colour) indicated that the sun dried mango products for both varieties were highly preferred because the samples looked brighter and retained much of the natural colour than the oven dried samples. The difference in the appearance (colour) of the dried mango chips of the two drying method were basically due to difference in the processing methods. The low temperature of the sun method also helped the mango chips in maintaining its yellow colour.

Aroma of oven dried PET (8.10) was the most preferred. The drying process may have contributed to the aroma as well as the varietal differences because the mango fruit contains some aromatic compounds which influence aroma.

The oven dried PET was adjudged the most acceptable with overall acceptability score of (7.75). The results from the overall acceptability may be attributed to the impact of the other parameter on the treatment.

Generally there was variation in taste among the treatments samples. Sun dried PET mango chips were the most accepted scoring (7.80). The low temperature during sun drying process may have enhanced the taste of the mango chips. Also taste may be attributed to fat content in the mango chips. Research conducted by (Kammerow,1960) and (Alyesanmi and Oguntokum1996) showed that fat contribute to energy and palatability of foods.

However in terms of texture oven dried PET (8.00) was the most preferred. The low moisture content (16.75%) as shown in table 4.1 may have an influence on its texture.

Reduction in sensory scores of dried apple slices during storage was also reported by (Sharma *et al.* 1998). However, there was hardly any spoilage or degradation in any sample in the study. Reduction in sensory quality during storage may be attributed to increase in moisture in samples resulting in the non- enzymatic browning, oxidation and changes in other chemical constituents of products.

For the packaging material, PET was the material of choice because it scored the highest value for each parameter during the sensory evaluation.

CHAPTER SIX

6.0 CONCLUSION

The study has shown that different drying and packaging methods have varying effect on proximate, mineral, microbial and sensory qualities on Keitt mango pulps. The oven drying was superior in preserving potassium, calcium, protein, fibre, and pH. Oven drying therefore showed superior capacity in preserving the nutritional composition of mango pulps and it should be the method of choice. It was observed that storage period and packaging methods influenced both nutritional and proximate composition of dried mango pulps. Aluminium packs were the best packaging material for maintaining ash content. Zip lock bags were the ideal packaging material with respect to protein, fibre and vitamin C content retention of the mango chips samples with storage period. The results showed that PET containers were better materials for storing dried mango pulps as compared to Zip lock bags, aluminium packs and Control (unpackaged) as these packaging materials formed good moisture barrier. Packaging materials also determined the presence of particular microbes and microbial counts during storage. *Mucor sp* were identified in PET containers and Aluminium packs. *Rhizopus sp* was found in Zip lock bags and Control (unpackaged). *Aspergillus niger* was identified in PET containers, aluminium and zip lock bags. *Penicillium sp* and *Aspergillus niger* were identified in all the packaged material except the Control (unpackaged).oven dried mango chips stored in zip lock bags and control.

To maintain the economic use of stored products, storage should be done under controlled environment that will not favour the growth of spoilage microorganisms. The sun dried PET containers gave better appearance whereas the oven dried PET containers had the highest score of the other parameters.

This work has open room for further investigations into the effects of different drying and packaging methods on the shelf life of dehydrated mangoes.

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APPENDIX 1A

DEPARTMENT OF HORTICULTURE
(COLLEGE OF AGRICULTURE AND NATURAL RESOURCES)

SENSORY EVALUATION FORM 1

SEX…….. DATE……..

PRODUCT: DRIED MANGO CHIPS

Please, you are provided with two varieties of dried mango pulps produced using two different drying methods (sun and oven drying). You are requested to make an independent and fair judgment on the following attributes given below for each coded products.
Using the nine point hedonic scale with number 1, 2, 3 ... (as shown below), please indicate your preference by marching each attribute with an appropriate score or number.

A NINE POINT HEDONIC SCALE

1-Dislike extremely;2- Dislike very much; 3- Like slightly
4- Dislike moderately; 5- Like moderately; 6- Dislike slightly
7- Like very much; 8- Neither like nor dislike; 9- Like extremely

CODE	APPEARANCE(COLOUR)	TASTE	AROMA	TEXTURE	OVERALL ACCEPTABILITY
T1					
T2					
T3					
T4					

Thank you for your co-operation.

APPENDIX 1B

DEPARTMENT OF HORTICULTURE
(COLLEGE OF AGRICULTURE AND NATURAL RESOURCES)
SENSORY EVALUATION FORM2

SEX…….. DATE……..

PRODUCT: DRIED MANGO CHIPS PACKAGED IN DIFFERENT MATERIALS

Please, you are provided with two varieties of dried mango pulps using two different drying methods which are packaged in different materials. You are requested to make an independent and fair judgment on the following attributes given below for each coded products.

Using the nine point hedonic scale with number 1, 2, 3 ... (as shown below), please indicate your preference by marching each attribute with an appropriate score or number.

A NINE POINT HEDONIC SCALE

1-Dislike extremely;2- Dislike very much; 3- Like slightly
4- Dislike moderately; 5- Like moderately; 6- Dislike slightly
7- Like very much; 8- Neither like nor dislike; 9- Like extremely

CODE	APPEARANCE(COLOUR)	TASTE	AROMA	TEXTURE	OVERALL ACCEPTABILITY
T1					
T2					
T3					
T4					
T5					
T6					
T7					
T8					
T9					

Thank you for your co-operation.

APPENDIX 2A

MICROBIAL CONTAMINATION AT DAY 60

Analysis of Variance Table for Aflavus

Source	DF	SS	MS	F	P
REPS	2	1.08333	0.54167		
DRYING	1	0.37500	0.37500	1.07	0.3190
PACKAGES	3	0.45833	0.15278	0.44	0.7313
DRYING*PACKAGES	3	1.12500	0.37500	1.07	0.3943
Error	14	4.91667	0.35119		
Total	23	7.95833			

Grand Mean 0.2083 CV 284.45

Analysis of Variance Table for Aniger

Source	DF	SS	MS	F	P
REPS	2	0.5833	0.29167		
DRYING	1	0.6667	0.66667	0.99	0.3364
PACKAGES	3	4.3333	1.44444	2.15	0.1400
DRYING*PACKAGES	3	2.3333	0.77778	1.16	0.3611
Error	14	9.4167	0.67262		
Total	23	17.3333			

Grand Mean 1.1667 CV 70.30

Analysis of Variance Table for Mucor

Source	DF	SS	MS	F	P
REPS	2	0.33333	0.16667		
DRYING	1	0.00000	0.00000	0.00	1.0000
PACKAGES	3	0.66667	0.22222	0.62	0.6122
DRYING*PACKAGES	3	1.33333	0.44444	1.24	0.3310
Error	14	5.00000	0.35714		
Total	23	7.33333			

Grand Mean 0.1667 CV 358.57

Analysis of Variance Table for Penicilli

Source	DF	SS	MS	F	P
REPS	2	0.08333	0.04167		
DRYING	1	0.16667	0.16667	1.87	0.1934
PACKAGES	3	0.16667	0.05556	0.62	0.6122
DRYING*PACKAGES	3	0.16667	0.05556	0.62	0.6122
Error	14	1.25000	0.08929		
Total	23	1.83333			

Grand Mean 0.0833 CV 358.57

Analysis of Variance Table for Rhizopus

Source	DF	SS	MS	F	P
REPS	2	0.3333	0.16667		
DRYING	1	0.6667	0.66667	0.80	0.3862
PACKAGES	3	13.8333	4.61111	5.53	0.0102
DRYING*PACKAGES	3	11.3333	3.77778	4.53	0.0202
Error	14	11.6667	0.83333		
Total	23	37.8333			

Grand Mean 0.9167 CV 99.59

APPENDIX 2B

MINERALS AT DAY 30

Analysis of Variance Table for Ca

Source	DF	SS	MS	F	P
REP	2	0.00503	0.00251		
PM	3	0.00343	0.00114	0.35	0.7919
TRT	1	0.00427	0.00427	1.29	0.2745
PM*TRT	3	0.00170	0.00057	0.17	0.9137
Error	14	0.04618	0.00330		
Total	23	0.06060			

Grand Mean 0.1100 CV 52.21

Analysis of Variance Table for K

Source	DF	SS	MS	F	P
REP	2	1.62691	0.81345		
PM	3	0.05663	0.01888	0.05	0.9836
TRT	1	0.42135	0.42135	1.17	0.2984
PM*TRT	3	0.14655	0.04885	0.14	0.9374
Error	14	5.05829	0.36131		
Total	23	7.30973			

Grand Mean 1.2617 CV 47.64

Analysis of Variance Table for Mg

Source	DF	SS	MS	F	P
REP	2	0.00176	0.00088		
PM	3	0.00341	0.00114	0.37	0.7775
TRT	1	0.00004	0.00004	0.01	0.9139
PM*TRT	3	0.01528	0.00509	1.65	0.2239
Error	14	0.04331	0.00309		
Total	23	0.06380			

Grand Mean 0.1179 CV 47.17

Analysis of Variance Table for Na

Source	DF	SS	MS	F	P
REP	2	0.00166	0.00083		
PM	3	0.00221	0.00074	0.44	0.7247
TRT	1	0.01084	0.01084	6.54	0.0228
PM*TRT	3	0.00218	0.00073	0.44	0.7292
Error	14	0.02321	0.00166		
Total	23	0.04010			

Grand Mean 0.0929 CV 43.82

Analysis of Variance Table for P

Source	DF	SS	MS	F	P
REP	2	0.00143	0.00071		
PM	3	0.00075	0.00025	0.77	0.5323
TRT	1	0.00135	0.00135	4.13	0.0615

PM*TRT	3	0.00075	0.00025	0.77	0.5323
Error	14	0.00458	0.00033		
Total	23	0.00885			

Grand Mean 0.0675 CV 26.78

Analysis of Variance Table for Ph

Source	DF	SS	MS	F	P
REP	2	0.9787	0.48933		
PM	3	1.2745	0.42485	1.04	0.4036
TRT	1	1.1748	1.17484	2.89	0.1114
PM*TRT	3	1.2199	0.40664	1.00	0.4220
Error	14	5.6967	0.40691		
Total	23	10.3447			

Grand Mean 5.0996 CV 12.51

APPENDIX 2C

MINERALS AT DAY 60

Analysis of Variance Table for Ca

Source	DF	SS	MS	F	P
REP	2	0.00061	0.00030		
PM	3	0.00125	0.00042	0.58	0.6390
TRT	1	0.00184	0.00184	2.56	0.1321
PM*TRT	3	0.00065	0.00022	0.30	0.8251
Error	14	0.01006	0.00072		
Total	23	0.01440			

Grand Mean 0.0679 CV 39.47

Analysis of Variance Table for K

Source	DF	SS	MS	F	P
REP	2	0.19011	0.09505		
PM	3	0.47841	0.15947	1.04	0.4054
TRT	1	0.30150	0.30150	1.97	0.1827
PM*TRT	3	0.05125	0.01708	0.11	0.9520
Error	14	2.14723	0.15337		
Total	23	3.16850			

Grand Mean 1.2971 CV 30.19

Analysis of Variance Table for Mg

Source	DF	SS	MS	F	P
REP	2	0.00697	0.00349		
PM	3	0.00183	0.00061	0.58	0.6395
TRT	1	0.00327	0.00327	3.08	0.1009
PM*TRT	3	0.00690	0.00230	2.17	0.1369
Error	14	0.01483	0.00106		
Total	23	0.03380			

Grand Mean 0.1450 CV 22.44

Analysis of Variance Table for Na

Source	DF	SS	MS	F	P
REP	2	0.00756	0.00378		

PM	3	0.00483	0.00161	0.38	0.7693
TRT	1	0.00082	0.00082	0.19	0.6677
PM*TRT	3	0.01208	0.00403	0.95	0.4438
Error	14	0.05944	0.00425		
Total	23	0.08473			

Grand Mean 0.0717 CV 90.92

Analysis of Variance Table for P

Source	DF	SS	MS	F	P
REP	2	0.00343	0.00172		
PM	3	0.00375	0.00125	0.54	0.6608
TRT	1	0.00282	0.00282	1.22	0.2873
PM*TRT	3	0.00535	0.00178	0.77	0.5273
Error	14	0.03223	0.00230		
Total	23	0.04758			

Grand Mean 0.0942 CV 50.96

Analysis of Variance Table for pH

Source	DF	SS	MS	F	P
REP	2	0.04778	0.02389		
PM	3	0.04031	0.01344	0.61	0.6184
TRT	1	0.23010	0.23010	10.48	0.0060
PM*TRT	3	0.01375	0.00458	0.21	0.8887
Error	14	0.30743	0.02196		
Total	23	0.63936			

Grand Mean 5.1863 CV 2.86

APPENDIX 2D

MINERALS BEFORE PACKAGING (DAY 0)

Completely Randomized AOV for Ca

Source	DF	SS	MS	F	P
TRT	1	0.02940	0.02940	294.00	0.0001
Error	4	0.00040	0.00010		
Total	5	0.02980			

Grand Mean 0.2000 CV 5.00

Homogeneity of Variances	F	P
Levene's Test	0.00	1.0000
O'Brien's Test	0.00	1.0000
Brown and Forsythe Test	0.00	1.0000

Welch's Test for Mean Differences

Source	DF	F	P
TRT	1.0	294.00	0.0001
Error	4.0		

Component of variance for between groups 0.00977
Effective cell size 3.0

TRT	Mean
oven	0.2700
sun	0.1300

Observations per Mean 3
Standard Error of a Mean 5.774E-03
Std Error (Diff of 2 Means) 8.165E-03

Completely Randomized AOV for K

Source	DF	SS	MS	F	P
TRT	1	0.04860	0.04860	28.87	0.0058
Error	4	0.00673	0.00168		
Total	5	0.05533			

Grand Mean 1.8433 CV 2.23

Homogeneity of Variances	F	P
Levene's Test	0.01	0.9371
O'Brien's Test	0.00	0.9580
Brown and Forsythe Test	0.01	0.9148

Welch's Test for Mean Differences

Source	DF	F	P
TRT	1.0	28.87	0.0058
Error	4.0		

Component of variance for between groups 0.01564
Effective cell size 3.0

TRT	Mean
oven	1.9333
sun	1.7533

Observations per Mean 3
Standard Error of a Mean 0.0237

Std Error (Diff of 2 Means) 0.0335

Completely Randomized AOV for Mg

Source	DF	SS	MS	F	P
TRT	1	0.01215	0.01215	2.30	0.2040
Error	4	0.02113	0.00528		
Total	5	0.03328			

Grand Mean 0.1983 CV 36.65

Homogeneity of Variances	F	P
Levene's Test	3.90	0.1196
O'Brien's Test	1.73	0.2585
Brown and Forsythe Test	1.31	0.3166

Welch's Test for Mean Differences

Source	DF	F	P
TRT	1.0	2.30	0.2657
Error	2.1		

Component of variance for between groups 0.00229
Effective cell size 3.0

TRT	Mean
oven	0.1533
sun	0.2433

Observations per Mean 3
Standard Error of a Mean 0.0420
Std Error (Diff of 2 Means) 0.0593

Completely Randomized AOV for Na

Source	DF	SS	MS	F	P
TRT	1	1.667E-05	1.667E-05	0.25	0.6433
Error	4	2.667E-04	6.667E-05		
Total	5	2.833E-04			

Grand Mean 0.0717 CV 11.39

Homogeneity of Variances	F	P
Levene's Test	1.60	0.2746
O'Brien's Test	0.71	0.4466
Brown and Forsythe Test	0.50	0.5185

Welch's Test for Mean Differences

Source	DF	F	P
TRT	1.0	0.25	0.6495
Error	3.2		

Component of variance for between groups -1.667E-05
Effective cell size 3.0

TRT	Mean
oven	0.0733
sun	0.0700

Observations per Mean 3
Standard Error of a Mean 4.714E-03
Std Error (Diff of 2 Means) 6.667E-03

Completely Randomized AOV for P

Source	DF	SS	MS	F	P
TRT	1	4.167E-04	4.167E-04	3.57	0.1318
Error	4	4.667E-04	1.166E-04		
Total	5	8.833E-04			

Grand Mean 0.1083 CV 9.97

Homogeneity of Variances	F	P
Levene's Test	4.00	0.1161
O'Brien's Test	1.78	0.2533
Brown and Forsythe Test	3.00	0.1583

Welch's Test for Mean Differences

Source	DF	F	P
TRT	1.0	M	0.0000
Error	M		

Component of variance for between groups 1.000E-04
Effective cell size 3.0

TRT	Mean
oven	0.1167
sun	0.1000

Observations per Mean 3
Standard Error of a Mean 6.236E-03
Std Error (Diff of 2 Means) 8.819E-03

Completely Randomized AOV for Ph

Source	DF	SS	MS	F	P
TRT	1	0.13802	0.13802	4140.50	0.0000
Error	4	0.00013	0.00003		
Total	5	0.13815			

Grand Mean 5.3250 CV 0.11

Homogeneity of Variances	F	P
Levene's Test	0.00	1.0000
O'Brien's Test	0.00	1.0000
Brown and Forsythe Test	0.00	1.0000

Welch's Test for Mean Differences

Source	DF	F	P
TRT	1.0	4140.50	0.0000
Error	4.0		

Component of variance for between groups 0.04599
Effective cell size 3.0

TRT	Mean
oven	5.4767
sun	5.1733

Observations per Mean 3
Standard Error of a Mean 3.333E-03
Std Error (Diff of 2 Means) 4.714E-03

APPENDIX 2E

PROXIMATE AT DAY 30

Analysis of Variance Table for Ash

Source	DF	SS	MS	F	P
REP	2	0.39583	0.19792		
PM	3	4.53125	1.51042	14.71	0.0001
TRT	1	1.76042	1.76042	17.14	0.0010
PM*TRT	3	1.36458	0.45486	4.43	0.0218
Error	14	1.43750	0.10268		
Total	23	9.48958			

Grand Mean 1.6042 CV 19.98

Analysis of Variance Table for Fat

Source	DF	SS	MS	F	P
REP	2	0.08333	0.04167		
PM	3	0.03125	0.01042	0.16	0.9221
TRT	1	0.26042	0.26042	3.98	0.0660
PM*TRT	3	0.19792	0.06597	1.01	0.4185
Error	14	0.91667	0.06548		
Total	23	1.48958			

Grand Mean 0.7292 CV 35.09

Analysis of Variance Table for Moisture

Source	DF	SS	MS	F	P
REP	2	0.4375	0.21875		
PM	3	27.0312	9.01042	14.45	0.0001
TRT	1	4.5937	4.59375	7.37	0.0168
PM*TRT	3	14.3646	4.78819	7.68	0.0028
Error	14	8.7292	0.62351		
Total	23	55.1562			

Grand Mean 20.938 CV 3.77

Analysis of Variance Table for Protein

Source	DF	SS	MS	F	P
REP	2	1.3845	0.69226		
PM	3	3.7276	1.24254	17.06	0.0001
TRT	1	2.6136	2.61360	35.88	0.0000
PM*TRT	3	1.2776	0.42586	5.85	0.0083
Error	14	1.0197	0.07283		
Total	23	10.0230			

Grand Mean 4.1950 CV 6.43

Analysis of Variance Table for FIBRE

Source	DF	SS	MS	F	P
REPS	2	0.12691	0.06345		
DRYINGMET	1	1.06682	1.06682	42.66	0.0000
PACKAGING	3	3.11563	1.03854	41.53	0.0000
DRYINGMET*PACKAGING	3	2.49968	0.83323	33.32	0.0000
Error	14	0.35009	0.02501		
Total	23	7.15913			

Grand Mean 1.6067 CV 9.84

Analysis of Variance Table for NFE

Source	DF	SS	MS	F	P
REPS	2	3.7074	1.8537		
DRYINGMET	1	16.7167	16.7167	36.34	0.0000
PACKAGING	3	19.9849	6.6616	14.48	0.0001
DRYINGMET*PACKAGING	3	7.7324	2.5775	5.60	0.0097
Error	14	6.4401	0.4600		
Total	23	54.5815			

Grand Mean 91.950 CV 0.74

APPENDIX 2F

PROXIMATE AT DAY 60

Analysis of Variance Table for FIBRE

Source	DF	SS	MS	F	P
REPS	2	0.01991	0.00995		
DRYINGMET	1	0.00202	0.00202	0.08	0.7876
PACKAGING	3	2.59317	0.86439	32.33	0.0000
DRYINGMET*PACKAGING	3	1.82935	0.60978	22.81	0.0000
Error	14	0.37429	0.02674		
Total	23	4.81873			

Grand Mean 1.7317 CV 9.44

Analysis of Variance Table for NFE

Source	DF	SS	MS	F	P
REPS	2	599.47	299.733		
DRYINGMET	1	210.93	210.930	0.74	0.4027
PACKAGING	3	987.35	329.117	1.16	0.3592
DRYINGMET*PACKAGING	3	852.41	284.137	1.00	0.4204
Error	14	3965.90	283.279		
Total	23	6616.06			

Grand Mean 89.123 CV 18.89

Analysis of Variance Table for FAT

Source	DF	SS	MS	F	P
REPS	2	0.14583	0.07292		
DRYINGMET	1	0.09375	0.09375	1.91	0.1887
PACKAGING	3	0.28125	0.09375	1.91	0.1745
DRYINGMET*PACKAGING	3	0.03125	0.01042	0.21	0.8863
Error	14	0.68750	0.04911		
Total	23	1.23958			

Grand Mean 0.6458 CV 34.31

Analysis of Variance Table for PROTEIN

Source	DF	SS	MS	F	P
REPS	2	0.3386	0.16928		
DRYINGMET	1	6.5835	6.58354	18.07	0.0008
PACKAGING	3	5.6900	1.89668	5.20	0.0127
DRYINGMET*PACKAGING	3	1.2674	0.42247	1.16	0.3601
Error	14	5.1020	0.36443		
Total	23	18.9816			

Grand Mean 3.6246 CV 16.66

Analysis of Variance Table for Ash

Source	DF	SS	MS	F	P
REP	2	1.386E-30	6.933E-31		
PM	3	0.03125	0.01042	0.09	0.9657
TRT	1	0.09375	0.09375	0.79	0.3898
PM*TRT	3	0.86458	0.28819	2.42	0.1094
Error	14	1.66667	0.11905		
Total	23	2.65625			

Grand Mean 1.4375 CV 24.00

Analysis of Variance Table for Moisture

Source	DF	SS	MS	F	P
REP	2	2.771	1.3854		
PM	3	142.865	47.6215	35.60	0.0000
TRT	1	1.760	1.7604	1.32	0.2706
PM*TRT	3	9.365	3.1215	2.33	0.1183
Error	14	18.729	1.3378		
Total	23	175.490			

Grand Mean 19.271 CV 6.00

APPENDIX 2G

PROXIMATE BEFORE PACKAGING(DAY 0)

Completely Randomized AOV for Ash

Source	DF	SS	MS	F	P
TRT	1	0.00000	0.00000	0.00	1.0000
Error	4	0.04000	0.01000		
Total	5	0.04000			

Grand Mean 1.5000 CV 6.67

Homogeneity of Variances	F	P
Levene's Test	0.00	1.0000
O'Brien's Test	0.00	1.0000
Brown and Forsythe Test	0.00	1.0000

Welch's Test for Mean Differences			
Source	DF	F	P
TRT	1.0	0.00	1.0000
Error	4.0		

Component of variance for between groups -0.00333
Effective cell size 3.0

TRT	Mean
oven	1.5000
sun	1.5000

Observations per Mean 3
Standard Error of a Mean 0.0577
Std Error (Diff of 2 Means) 0.0816

Completely Randomized AOV for Fat

Source	DF	SS	MS	F	P
TRT	1	0.00000	0.00000	0.00	1.0000
Error	4	0.02000	0.00500		
Total	5	0.02000			

Grand Mean 0.5000 CV 14.14

Homogeneity of Variances	F	P
Levene's Test	4.00	0.1161
O'Brien's Test	1.78	0.2533
Brown and Forsythe Test	4.00	0.1161

Welch's Test for Mean Differences			
Source	DF	F	P
TRT	1.0	M	0.0000
Error	M		

Component of variance for between groups -0.00167
Effective cell size 3.0

TRT	Mean
oven	0.5000
sun	0.5000

Observations per Mean 3
Standard Error of a Mean 0.0408
Std Error (Diff of 2 Means) 0.0577

Completely Randomized AOV for Fibre

Source	DF	SS	MS	F	P
TRT	1	0.26460	0.26460	52.40	0.0019
Error	4	0.02020	0.00505		
Total	5	0.28480			

Grand Mean 1.2900 CV 5.51

Homogeneity of Variances	F	P
Levene's Test	3.92	0.1188
O'Brien's Test	1.74	0.2573

Brown and Forsythe Test 3.21 0.1478

Welch's Test for Mean Differences

Source	DF	F	P
TRT	1.0	52.40	0.0176
Error	2.0		

Component of variance for between groups 0.08652
Effective cell size 3.0

TRT	Mean
oven	1.5000
sun	1.0800

Observations per Mean 3
Standard Error of a Mean 0.0410
Std Error (Diff of 2 Means) 0.0580

Completely Randomized AOV for Moisture

Source	DF	SS	MS	F	P
TRT	1	13.5000	13.5000	13.50	0.0213
Error	4	4.0000	1.0000		
Total	5	17.5000			

Grand Mean 17.500 CV 5.71

Homogeneity of Variances	F	P
Levene's Test	0.00	1.0000
O'Brien's Test	0.00	1.0000
Brown and Forsythe Test	0.00	1.0000

Welch's Test for Mean Differences

Source	DF	F	P
TRT	1.0	13.50	0.0213
Error	4.0		

Component of variance for between groups 4.16667
Effective cell size 3.0

TRT	Mean
oven	16.000
sun	19.000

Observations per Mean 3
Standard Error of a Mean 0.5774
Std Error (Diff of 2 Means) 0.8165

Completely Randomized AOV for NFE

Source	DF	SS	MS	F	P
TRT	1	1.60167	1.60167	2.44	0.1934
Error	4	2.62707	0.65677		
Total	5	4.22873			

Grand Mean 76.043 CV 1.07

Homogeneity of Variances	F	P
Levene's Test	4.00	0.1161
O'Brien's Test	1.78	0.2533
Brown and Forsythe Test	0.99	0.3750

Welch's Test for Mean Differences

Source	DF	F	P
TRT	1.0	2.44	0.2588
Error	2.0		

Component of variance for between groups 0.31497
Effective cell size 3.0

TRT	Mean
oven	76.560
sun	75.527

Observations per Mean 3
Standard Error of a Mean 0.4679
Std Error (Diff of 2 Means) 0.6617

Completely Randomized AOV for Protein

Source	DF	SS	MS	F	P
TRT	1	1.16160	1.16160	11616.0	0.0000
Error	4	0.00040	0.00010		
Total	5	1.16200			

Grand Mean 3.5000 CV 0.29

Homogeneity of Variances	F	P
Levene's Test	0.00	1.0000
O'Brien's Test	0.00	1.0000
Brown and Forsythe Test	0.00	1.0000

Welch's Test for Mean Differences

Source	DF	F	P
TRT	1.0	11616.0	0.0000
Error	4.0		

Component of variance for between groups 0.38717
Effective cell size 3.0

TRT	Mean
oven	3.9400
sun	3.0600

Observations per Mean 3
Standard Error of a Mean 5.774E-03
Std Error (Diff of 2 Means) 8.165E-03

APPENDIX 2H

Analysis of Variance Table for VITC AT DAY 30

Source	DF	SS	MS	F	P
REP	2	0.79053	0.39527		
PM	3	1.38343	0.46114	1.63	0.2267
TRT	1	1.58107	1.58107	5.60	0.0329
PM*TRT	3	1.38343	0.46114	1.63	0.2267
Error	14	3.95267	0.28233		
Total	23	9.09113			

Grand Mean 4.1067 CV 12.94

APPENDIX I

Analysis of Variance Table for VITC AT DAY 60

Source	DF	SS	MS	F	P
REP	2	0.6423	0.32115		
PM	3	7.1889	2.39630	6.35	0.0061
TRT	1	0.0247	0.02470	0.07	0.8018
PM*TRT	3	0.4694	0.15646	0.41	0.7454
Error	14	5.2867	0.37762		
Total	23	13.6120			

Grand Mean 3.8821 CV 15.83

APPENDIX J

Completely Randomized AOV for VITC before packaging (0 DAY)

Source	DF	SS	MS	F	P
TRT	1	0.39527	0.39527	0.80	0.4216
Error	4	1.97633	0.49408		
Total	5	2.37160			

Grand Mean 4.6200 CV 15.21

Homogeneity of Variances	F	P
Levene's Test	2.12	0.2193
O'Brien's Test	0.94	0.3869
Brown and Forsythe Test	0.20	0.6779

Welch's Test for Mean Differences

Source	DF	F	P
TRT	1.0	0.80	0.4382
Error	2.9		

Component of variance for between groups -0.03294
Effective cell size 3.0

TRT	Mean
oven	4.8767
sun	4.3633

Observations per Mean 3
Standard Error of a Mean 0.4058
Std Error (Diff of 2 Means) 0.5739

APPENDIX K

SENSORY EVALUATION BEFORE PACKAGING (0 DAY)

Completely Randomized AOV for appearance

Source	DF	SS	MS	F	P
treatment	1	22.500	22.5000	7.84	0.0080
Error	38	109.000	2.8684		
Total	39	131.500			

Grand Mean 6.2500 CV 27.10

Homogeneity of Variances	F	P
Levene's Test	4.02	0.0521

O'Brien's Test	3.81	0.0584
Brown and Forsythe Test	5.27	0.0273

Welch's Test for Mean Differences

Source	DF	F	P
treatment	1.0	7.84	0.0086
Error	31.6		

Component of variance for between groups 0.98158
Effective cell size 20.0

treatment	Mean
keitt oven	7.0000
keitt sun	5.5000

Observations per Mean 20
Standard Error of a Mean 0.3787
Std Error (Diff of 2 Means) 0.5356

Completely Randomized AOV for aroma

Source	DF	SS	MS	F	P
treatment	1	7.225	7.22500	2.93	0.0952
Error	38	93.750	2.46711		
Total	39	100.975			

Grand Mean 6.0250 CV 26.07

Homogeneity of Variances	F	P
Levene's Test	1.17	0.2856
O'Brien's Test	1.11	0.2986
Brown and Forsythe Test	1.53	0.2240

Welch's Test for Mean Differences

Source	DF	F	P
treatment	1.0	2.93	0.0957
Error	35.6		

Component of variance for between groups 0.23789
Effective cell size 20.0

treatment	Mean
keitt oven	6.4500
keitt sun	5.6000

Observations per Mean 20
Standard Error of a Mean 0.3512
Std Error (Diff of 2 Means) 0.4967

Completely Randomized AOV for overall

Source	DF	SS	MS	F	P
treatment	1	16.900	16.9000	5.32	0.0266
Error	38	120.700	3.1763		
Total	39	137.600			

Grand Mean 6.1000 CV 29.22

Homogeneity of Variances	F	P
Levene's Test	0.02	0.8954
O'Brien's Test	0.02	0.8982
Brown and Forsythe Test	0.20	0.6545

Welch's Test for Mean Differences

Source	DF	F	P
treatment	1.0	5.32	0.0266
Error	37.9		

Component of variance for between groups 0.68618
Effective cell size 20.0

treatment	Mean
keitt oven	6.7500
keitt sun	5.4500

Observations per Mean 20
Standard Error of a Mean 0.3985
Std Error (Diff of 2 Means) 0.5636

Completely Randomized AOV for taste

Source	DF	SS	MS	F	P
treatment	1	5.625	5.62500	1.01	0.3214
Error	38	211.750	5.57237		
Total	39	217.375			

Grand Mean 5.6250 CV 41.97

Homogeneity of Variances	F	P
Levene's Test	0.17	0.6843
O'Brien's Test	0.16	0.6924
Brown and Forsythe Test	1.14	0.2933

Welch's Test for Mean Differences

Source	DF	F	P
treatment	1.0	1.01	0.3214
Error	37.8		

Component of variance for between groups 0.00263
Effective cell size 20.0

treatment	Mean
keitt oven	6.0000
keitt sun	5.2500

Observations per Mean 20
Standard Error of a Mean 0.5278
Std Error (Diff of 2 Means) 0.7465

Completely Randomized AOV for texture

Source	DF	SS	MS	F	P
treatment	1	10.000	10.0000	3.12	0.0855
Error	38	121.900	3.2079		
Total	39	131.900			

Grand Mean 5.4500 CV 32.86

Homogeneity of Variances	F	P
Levene's Test	1.20	0.2801
O'Brien's Test	1.14	0.2931
Brown and Forsythe Test	1.18	0.2841

Welch's Test for Mean Differences

Source	DF	F	P

treatment	1.0	3.12	0.0859
Error	36.1		

Component of variance for between groups 0.33961
Effective cell size 20.0

treatment	Mean
keitt oven	5.9500
keitt sun	4.9500

Observations per Mean 20
Standard Error of a Mean 0.4005
Std Error (Diff of 2 Means) 0.5664

APPENDIX L

SENSORY EVALUATION AT DAY 60

Completely Randomized AOV for appearanc

Source	DF	SS	MS	F	P
treatment	7	194.200	27.7429	10.43	0.0000
Error	152	404.200	2.6592		
Total	159	598.400			

Grand Mean 4.8500 CV 33.62

Homogeneity of Variances	F	P
Levene's Test	2.02	0.0566
O'Brien's Test	1.91	0.0719
Brown and Forsythe Test	2.03	0.0551

Welch's Test for Mean Differences

Source	DF	F	P
treatment	7.0	21.58	0.0000
Error	64.7		

Component of variance for between groups 1.25418
Effective cell size 20.0

treatment	Mean
ovenkit co	7.5500
ovenkitalu	4.1000
ovenkitpet	4.0000
ovenkitzip	4.0000
sunkit con	5.3000
sunkitalum	4.6500
sunkitpet	4.7500
sunkitzipl	4.4500

Observations per Mean 20
Standard Error of a Mean 0.3646
Std Error (Diff of 2 Means) 0.5157

Completely Randomized AOV for aroma

Source	DF	SS	MS	F	P
treatment	7	314.494	44.9277	21.42	0.0000
Error	152	318.750	2.0970		
Total	159	633.244			

Grand Mean 4.4313 CV 32.68

Homogeneity of Variances	F	P
Levene's Test	1.66	0.1241
O'Brien's Test	1.57	0.1492
Brown and Forsythe Test	1.51	0.1691

Welch's Test for Mean Differences

Source	DF	F	P
treatment	7.0	57.23	0.0000
Error	64.3		

Component of variance for between groups 2.14153
Effective cell size 20.0

treatment	Mean
ovenkit co	8.1000
ovenkitalu	4.1000
ovenkitpet	3.5500
ovenkitzip	3.8500
sunkit con	4.2500
sunkitalum	3.8000
sunkitpet	3.7500
sunkitzipl	4.0500

Observations per Mean 20
Standard Error of a Mean 0.3238
Std Error (Diff of 2 Means) 0.4579

Completely Randomized AOV for overallac

Source	DF	SS	MS	F	P
treatment	7	230.894	32.9848	23.17	0.0000
Error	152	216.350	1.4234		
Total	159	447.244			

Grand Mean 4.6312 CV 25.76

Homogeneity of Variances	F	P
Levene's Test	1.36	0.2284
O'Brien's Test	1.28	0.2623
Brown and Forsythe Test	1.66	0.1216

Welch's Test for Mean Differences

Source	DF	F	P
treatment	7.0	43.73	0.0000
Error	64.8		

Component of variance for between groups 1.57807
Effective cell size 20.0

treatment	Mean
ovenkit co	7.7500
ovenkitalu	4.7000
ovenkitpet	3.9000
ovenkitzip	4.0500
sunkit con	4.0500
sunkitalum	4.2000
sunkitpet	4.0500
sunkitzipl	4.3500

Observations per Mean 20

Standard Error of a Mean 0.2668
Std Error (Diff of 2 Means) 0.3773

Completely Randomized AOV for taste

Source	DF	SS	MS	F	P
treatment	7	270.100	38.5857	14.73	0.0000
Error	152	398.300	2.6204		
Total	159	668.400			

Grand Mean 4.4000 CV 36.79

Homogeneity of Variances	F	P
Levene's Test	1.68	0.1185
O'Brien's Test	1.59	0.1430
Brown and Forsythe Test	1.39	0.2134

Welch's Test for Mean Differences

Source	DF	F	P
treatment	7.0	46.42	0.0000
Error	63.8		

Component of variance for between groups 1.79827
Effective cell size 20.0

treatment	Mean
ovenkit co	7.8000
ovenkitalu	3.9500
ovenkitpet	3.5500
ovenkitzip	3.9000
sunkit con	4.2500
sunkitalum	3.7500
sunkitpet	3.9500
sunkitzipl	4.0500

Observations per Mean 20
Standard Error of a Mean 0.3620
Std Error (Diff of 2 Means) 0.5119

Completely Randomized AOV for texture

Source	DF	SS	MS	F	P
treatment	7	267.194	38.1705	12.89	0.0000
Error	152	450.050	2.9609		
Total	159	717.244			

Grand Mean 4.6312 CV 37.15

Homogeneity of Variances	F	P
Levene's Test	2.48	0.0192
O'Brien's Test	2.35	0.0262
Brown and Forsythe Test	1.98	0.0614

Welch's Test for Mean Differences

Source	DF	F	P
treatment	7.0	37.49	0.0000
Error	64.2		

Component of variance for between groups 1.76048
Effective cell size 20.0

treatment	Mean

```
ovenkit co  8.0000
ovenkitalu  3.8000
ovenkitpet  4.4500
ovenkitzip  4.3000
sunkit con  4.1500
sunkitalum  4.3000
sunkitpet   3.8000
sunkitzipl  4.2500
Observations per Mean           20
Standard Error of a Mean    0.3848
Std Error (Diff of 2 Means) 0.5441
```

APPENDIX M

Formulae

1.0 The % P was calculated as:

P content (g) in 100 g sample (% P) = $\frac{C\ x\ df\ x\ 100}{1\ 000\ 000} = \frac{C\ x\ 1000\ x\ 100}{1\ 000\ 000} = \frac{C}{10}$

Where C = concentration of P (µg /ml) as read from the standard curve;

df= dilution factor, which is 100 *10 = 1000, as calculated below:

1 g of sample made to 100 ml (100 times);

5 ml of sample made to 50 ml (10 times)

1 000 000 = factor for converting µg to g

2.0 From the standard curve, the concentration of K and Na were calculated using the particular absorbance observed for the sample.

Calculation:

K, Na content (µg) in 1.0 g of plant sample = C x df

K, Na content (g) in 100 g plant sample, (% K, Na) = $\frac{C \times df \times 100}{1000\ 000} = \frac{C \times 100 \times 100}{1000\ 000}$

$= \frac{C}{100}$

Where

C = concentration of K (µg / ml) as read from the standard curve

df = dilution factor, which is 100 x1 = 100, calculated as :

- 1.0 g of sample made up to 100 ml (100 times)
- 1000 000 = factor for converting µg to g.

3.0 Calcium in mg = Titre value of EDTA x 0.40

% Calcium = $\frac{mg\ Calcium}{Sample\ wt} x\ 100$

4.0 Magnesium in mg = Titre value of EDTA x 0.24

% Mg = $\frac{mg\ Magnesium}{Sample\ wt} x\ 100$

5.0 The ascorbic acid content of the fruit was calculated as follows:

Ascorbic acid (mg/100g) = (X-B) x (F/E) x (V/Y)

F = mg ascorbic acid equivalent to 1.0ml indophenols standard solution

X = Average ml for test solution titration

B = Average ml for test blank titration

E = Volume of sample taken

V = Total Volume of solution

Y = Volume of test solution taken

VITAMIN C CONTENT OF SAMPLES

A. Standard Ascorbic Acid Titration(Titre value) =13ml

B. Blank Titration (Titre value) = 0.10ml

C. Treatment Titre Values

Treatments	Titre Value (ml)		
	Rep.1	Rep.2	Rep.3
Fresh Keitt	3.7	3.7	3.5
Fresh Kent	3.5	3.8	3.8
T_1	0.8	0.6	0.8
T_2	0.6	0.5	0.7
T_3	0.7	0.5	0.8
T_4	0.7	0.5	0.7

F = mg ascorbic acid equivalent to 1.0ml indophenols standard solution

X = Average ml for test solution titration

B = Average ml for test blank titration

E = Volume of sample taken

V = Total Volume of solution

Y = Volume of test solution taken

Ascorbic acid Determination

1. **Fresh Keit**

Ascorbic acid (mg/100g) = (X-B) x (F/E) x (V/Y)

F=0.154ml, B=0.10ml, E= 20ml, V=100ml, Y=10ml

Ascorbic acid (mg/g) = (X-0.10) x (0.154/20) x (100/10)

=(X-0.10) x 0.077

Rep.1 (X=3.7ml) = (3.7-0.10) x 0.077

Ascorbic acid (mg/g) = 0.2772mg/g

Ascorbic acid (mg/100g) = 27.72mg/100g

Rep.2 (X=3.7ml) = (3.7-0.10) x 0.077

Ascorbic acid (mg/g) = 0.2772mg/g

Ascorbic acid (mg/100g) = 27.72mg/100g

Rep.3 (X=3.5ml) = (3.5-0.10) x 0.077

Ascorbic acid (mg/g) = 0.2618mg/g

Ascorbic acid (mg/100g) = 26.18mg/100g

2. **Fresh Kent**

Ascorbic acid (mg/100g) = (X-B) x (F/E) x (V/Y)

F=0.154ml, B=0.10ml, E= 20ml, V=100ml, Y=10ml

Ascorbic acid (mg/g) = (X-0.10) x (0.154/20) x (100/10)

=(X-0.10) x 0.077

Rep.1 (X=3.5ml) = (3.5-0.10) x 0.077

Ascorbic acid (mg/g) = 0.2618mg/g

Ascorbic acid (mg/100g) = 26.18mg/100g

Rep.2 (X=3.8ml) = (3.8-0.10) x 0.077

Ascorbic acid (mg/g) = 0.2849mg/g

Ascorbic acid (mg/100g) = 28.49mg/100g

Rep.3 (X=3.8ml) = (3.8-0.10) x 0.077

Ascorbic acid (mg/g) = 0.2849mg/g

Ascorbic acid (mg/100g) = 28.49mg/100g

3. **T_1**

Ascorbic acid (mg/100g) = (X-B) x (F/E) x (V/Y)

F=0.154ml, B=0.10ml, E= 20ml, V=100ml, Y=10ml

Ascorbic acid (mg/g) = (X-0.10) x (0.154/20) x (100/10)

=(X-0.10) x 0.077

Rep.1 (X=0.8ml) = (0.8-0.10) x 0.077

Ascorbic acid (mg/g) = 0.0539mg/g

Ascorbic acid (mg/100g) = 5.39mg/100g

Rep.2 (X=0.6ml) = (0.6-0.10) x 0.077

Ascorbic acid (mg/g) = 0.0385mg/g

Ascorbic acid (mg/100g) = 3.85mg/100g

Rep.3 (X=0.8ml) = (0.8-0.10) x 0.077

Ascorbic acid (mg/g) = 0.539mg/g

Ascorbic acid (mg/100g) = 5.39mg/100g

4. **T_2**

Ascorbic acid (mg/100g) = (X-B) x (F/E) x (V/Y)

F=0.154ml, B=0.10ml, E= 20ml, V=100ml, Y=10ml

Ascorbic acid (mg/g) = (X-0.10) x (0.154/20) x (100/10)

=(X-0.10) x 0.077

Rep.1 (X=0.6ml) = (0.6-0.10) x 0.077

Ascorbic acid (mg/g) = 0.0462mg/g

Ascorbic acid (mg/100g) = 4.62mg/100g

Rep.2 (X=0.5ml) = (0.5-0.10) x 0.077

Ascorbic acid (mg/g) = 0.0385mg/g

Ascorbic acid (mg/100g) = 3.85mg/100g

Rep.3 (X=0.7ml) = (0.7-0.10) x 0.077

Ascorbic acid (mg/g) = 0.462mg/g

Ascorbic acid (mg/100g) = 4.62mg/100g

5. **T_3**

Ascorbic acid (mg/100g) = (X-B) x (F/E) x (V/Y)

F=0.154ml, B=0.10ml, E= 20ml, V=100ml, Y=10ml

Ascorbic acid (mg/g) = (X-0.10) x (0.154/20) x (100/10)

=(X-0.10) x 0.077

Rep.1 (X=0.7ml) = (0.7-0.10) x 0.077

Ascorbic acid (mg/g) = 0.0462mg/g

Ascorbic acid (mg/100g) = 4.62mg/100g

Rep.2 (X=0.5ml) = (0.5-0.10) x 0.077

Ascorbic acid (mg/g) = 0.0305mg/g

Ascorbic acid (mg/100g) = 3.05mg/100g

Rep.3 (X=0.8ml) = (0.8-0.10) x 0.077

Ascorbic acid (mg/g) = 0.539mg/g

Ascorbic acid (mg/100g) = 5.39mg/100g

6. **T_4**

Ascorbic acid (mg/100g) = (X-B) x (F/E) x (V/Y)

F=0.154ml, B=0.10ml, E= 20ml, V=100ml, Y=10ml

Ascorbic acid (mg/g) = (X-0.10) x (0.154/20) x (100/10)

=(X-0.10) x 0.077

Rep.1 (X=0.6ml) = (0.6-0.10) x 0.077

Ascorbic acid (mg/g) = 0.0462mg/g

Ascorbic acid (mg/100g) = 4.62mg/100g

Rep.2 (X=0.5ml) = (0.5-0.10) x 0.077

Ascorbic acid (mg/g) = 0.0385mg/g

Ascorbic acid (mg/100g) = 3.85mg/100g

Rep.3 (X=0.7ml) = (0.7-0.10) x 0.077

Ascorbic acid (mg/g) = 0.462mg/g

Ascorbic acid (mg/100g) = 4.62mg/100g

Summary of Results

Treatments	Vitamin C content(mg/100g)		
	Rep.1	**Rep.2**	**Rep.3**
Fresh Keitt	27.72	27.72	26.18
Fresh Kent	26.18	28.49	28.49
T_1	5.39	3.85	5.39
T_2	4.62	3.85	4.62
T_3	4.62	3.08	5.39
T_4	4.62	3.85	4.62

6.0 Microbial contamination = Number of Colonies
Dilution Factor