EFFECT OF DRYING METHODS AND PACKAGING ON THE NUTRITIONAL VALUES OF ONIONS (*Allium cepa* L.) BULBS IN YOLA, ADAMAWA STATE

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PGD/CPH/17/0936

JUNE, 2019

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A PROJECT SUBMITTED TO THE DEPARTMENT OF CROP PRODUCTION AND HORTICULTURE, SCHOOL OF AGRICULTURE AND AGRICULTURAL TECHNOLOGY, MODIBBO ADAMA UNIVERSITY OF TECHNOLOGY, YOLA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF POSTGRADUATE DIPLOMA (PGD) IN POST HARVEST PHYSIOLOGY AND STORAGE TECHNOLOGY

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Declaration

I hereby declare that this project entitled "Effect of Drying Methods and Packaging on the Nutritional Values of Onion (*Allium cepa* L.) Bulds in Yola, Adamawa State" was written by me and it is a record of my own research work. It has not been presented before in any previous application for higher degree. All references cited have been dully acknowledged.

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AFOLABI, Elizabeth Toyin Date

PGD/CPH/17/0936

DEDICATION

This project is dedicated to Mr. and Mrs. M.O Afolabi

APPROVAL PAGE

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TABLE OF CONTENTS

CHAPTER FIVE : DISCUSSION

CHAPTER SIX: SUMMARY, CONCLUSION AND RECOMMENDATION

ABSTRACT

This research work was designed to give an insight on physiochemical properties of *Allium Cepa*. The purpose of this study was to determine the effects of three drying methods on the physiochemical properties of onion bulbs and to determine the effective packaging material on the physiochemical properties of onion. The experiment was carried out in the Food Science and Technology Department, Modibbo Adama University of Technology, Yola Adamawa State. Freshly harvested onion bulbs at a fully matured stage and fully ripe was purchased from a commercial farm. The experiment consist of six (6) treatment which include oven dryingplastic container,oven dryingpolythene bags, sun dryingplastic container, sun dryingpolythene bags, shade dryingplastic container and shade dryingpolythene bags The experiment was replicated three (3) times Data collected on parameters such as color, bulk density, fat, carbohydrate, fiber The result showed that there was no significant difference (P50.05) among all the packaging materials, because all the packaging materials recorded equal mean value of 0.61 g/ml both at four and twelve weeks respectively- But there was slight difference of the mean values among the drying methods The following recommendations among others, government and communities should ensure that various drying methods used are capable of preserving the nutrients in the food crops without total loss of any nutrient Shade dried and oven dried onion samples were found to be more nutritive. Further study should be carried out on the factors that affect the

LIST OF TABLES

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

Onion (*Album cepa* L) is considered as one of the second most important horticultural crops worldwide and has always been most widely traded than most vegetables (Griffiths et al, 2014) as a seasoning, a food component as well as in medical applications Dried onions are a product of great significance in world trade produced as flaked, mmced, chopped or powdered forms (Arslan and Ozcan, 2010) Generally, onions are dried for efficient storage and processing (Sawhney and others et aL,2009; Sarsavadia, 2007) but also to reduce bulk handling, facilitate transportation, allow for their use during the off-season (Motaetet aL,2010). However, the use of dried onions, which have a decreased mass compared to fresh onions, requires that an efficient and effective dehydration method be developed and employed The color and flavor of dried onions are considered the most important quality attributes affecting the degree of acceptability of the product by the consumer The non- enzymatic browning reactions, measured in terms of an optical index and the loss in pungency, measured in terms of pyruvate concentration, are considered the dominant factors in quality deterioration during drying and storage of dried onions (Vidyavati and et at others 2010)spices are native of India and hence India is known as the land of spices It is biggest exporter of spices and grows over 50 different varieties of spices Total production is around 27 million tons of this, about 025 million tons (8-10 per cent) is exported to more than 150 countries Onion is one of the most important spices of India It is that plant product which is used primarily for seasoning purposes Onions are used in our daily dietary because of its significant role as taste enhancer and flavoring material in the diet It contains essential oils, which provide the flavour and taste Onions are also fair sources of a-carotene, vitamin, calcium and non These are used in whole, ground paste or liquid form mainly for flavoring and seasoning food It is natural food additive which have been in use for thousands of years (Patel and Srinivasan, 2004).

Onion because of its medicinal values used as flavoring agent or as preservative in many pharmaceutical preparations (Lamikanra, 2014). It is highly seasonal and in the peak season sold at throw away prices (Singh et aL,2016) and its abundant supply during the season results in spoilage of large quantities (Lakshmi and Vimla,2000). Preservation of onion can prevent huge wastage and make it available in off season at remunerative prices

(Mandhyanet at, 1988).

According to Chauhan and Sharma (1993), dehydration is one of the convenient methods of preservation of onion. In addition to increasing variety in menu and reducing wastage, labor and storage space, dehydrated onions are simple to use and have longer shelf life than fresh one These can not only be stored for longer period of times but also saves time, money and energy. Moreover, in dehydrated stage, onion powder is less prone to microbial contamination. Considering importance of onion, an attempt was made to develop onion powder using different drying methods and carry out its nutritional evaluation. *Allium cepa* is usually thought of as a vegetable, it also has a long history of medicinal use. Mainly the fleshy bulb that grows below the ground is used medicinally as well as for food but other parts of the plant also has a place in the traditional medicines. Generally, onions are dried for efficient storage and processing (Sawhney et at., 2009; Sarsavadia, 2007) but also to reduce bulk handling, facilitate transportation, allow for their use during the off-season (Mota *et at.*, 2010). However, the use of dried onions, which have a decreased mass compared to fresh onions, requires that an efficient and effective dehydration method be developed and employed. The color and flavor of dried onions are considered the most important quality attributes affecting the degree of acceptability of the product by the consumer (Stavric, 2016).

The non-enzymatic browning reactions, measured in terms of an optical index and the loss in pungency, measured in terms of thiolsulphinate or pyruvate concentration, are considered the dominant factors in quality deterioration during drying and storage of dried onions (Vidyavati et at, 2010). The onion also may be of benefit in cardiovascular disease, as it possesses hypolipidemic effects and has antiplatelet actions, retarding thrombosis (Griffiths *et at.,* 2014). But certain lipid-reducing and blood pressure-lowering effects in humans have not yet been clinically proven. Some studies have been performed concerning diabetes treatment by onion with promising results in animal experimentation. Although more research is needed on the use of onion as a treatment for diabetes in humans, many articles describe onion’s benefits in improving glucose levels. The onion also is a proven antioxidant and may be helpful in treating certain cancers. More clinical research is needed to understand the many medicinal benefits of onion (Sampath Kumar *et at.,* 2010).

This research was carried out with the following objectives;

1. to determine the effects of drying methods on the physiochemical properties of onions bulbs.

2. to determine the effective packaging material on the physiochemical properties of onions

3. to determine the possible effect of the interaction of the above factors using organoleptic test

CHAPTER TWO

LITERATURE REVIEW

2.1 Varieties of Onions

There are more than 500 varieties of onions Onions can be put into two groups, dried and flesh Dried or storage onions are good in cooked dishes Dried onions are good in dishes that need strong flavors Dried onions are added to many dishes Casseroles, quiche, pasta sauces, soups, stews, and pizza are common uses (Amy, 2011).

2.1.1 Yellow Onions(*Sweet Carolin*)

The yellow onion is an onion that has a golden brown, papery skin Use in recipes that call for cooked onions When sauteed, yellow onions turn a dark brown color Yellow onions have a high sulfur content The high sulfur content makes yellow onions too strong to eat raw The sulfur is also what creates tears when chopping This variety is good for caramelizing (Krebs-Smith et al., 2001)

2.1.2 Red Onions (*Bombay Red*)

The red onion is an onion variety that has purple red skin and white rings of flesh Red onions are medium to large in size The flavor is mild and sweet The texture is crisp Red onions are good to eat raw They are used to add color to dishes They can also be grilled or lightly cooked with other foods (Krebs-Smith *et al.*, 2001)

2.1.3 White Onions (*Qellafo*)

A globe shaped onion White onions have white flesh and white skin White onions are sweeter than yellow onions Yet, white onions can often be used in place of yellow onions in recipes This variety has a clean, sharp flavor and firm texture White onions can add a sweet flavor to other foods They can be eaten raw White onions are good in heated dishes, sauteed or as a side dish (Amy, 2011).

2.1.4 Vidalia

Mildly sweet in flavor, vidalia onions have a yellow to tan outer skin and white flesh. They are available from April to June If stored in a cool dry place, Vidalias can last up to months The Vidalia variety is from Vidalia, Georgia (Krebs-Smith *et al.*, 2001)

2.1.5 Pearl onions

The mild sweet-flavored onion with a crisp texture. Pearl onions are actually young onions. They are available as white, red, or yellow onions. This variety is often roasted with meat, or added to soups, stews, and vegetable dishes (Amy, 2011)

2.1.6 Shallots pear-shaped bulbs that grow in a cluster.

Shallots are like garlic except the bulbs are attached at the roots. The shallot has a light flesh with some purple or green. Their flavor is mild. Shallots should not be browned. Browning causes them to become bitter Grate shallots instead of mincing or finely dicing Grating requires only half of the amount of minced shallot required for a recipe (Amy 2011)

2.1.7 Garlic

The gat lie many people don't know that garlic belongs to the onion family Garlic can be found in white, pink or purple varieties When used raw, garlic is slightly bitter But when sautéed or baked, it becomes mild and sweet. Garlic powder can be substituted for fresh. An eighth of a teaspoon of garlic powder is equal to one medium fresh clove of common garlic.

Fresh onions contain more moisture than dried onions. Fresh onions are sweet and mild. They can be eaten raw. They are good when added to salads, hamburgers, and other sandwiches.

They can also be used in dishes where they require light cooking, Fresh onions can be grilled or roasted (Krebs-Smith *et al.***,** 2001)

2.1.8 Spring onions

The spring onion is young onion that can be green, purple, or yellow. Its name refers to its freshness. They have a white base that has not yet grown into a bulb. Long, straight, green tubular leaves create its shape. It is also commonly referred to as salad onions, green onion, and scallions (Krebs-Smith et al., 2001)

2.1.9 *Scallions*

Scallions are different than green onions. Green onions can be any young variety of onions. Scallions have a milder flavor than spring onions. The bulb end of the scallion has straight sides and does not form a rounded bulb (Krebs-Smith *et al.*, 2001)

2.1.10 Maturity

Onions are ready for harvest when the necks are reasonably dry and the tops have fallen over As onions mature, their dry matter content and pungency increase, with a resulting increase in storage potential (Proctor *et al.*, 1972).

2.2 Understanding Produce Maturity

The stage of development at which a product is regarded as mature depends on its final used. Fruit and vegetables are eaten at all stages of development We eat sprouted seeds, vegetative leaves and flowers, whole fruit as well as seeds and nuts There are no general rules when it comes to defining horticultural maturity A lot of research has been done to establish maturity parameters for a whole range of specific horticultural products.

Maturity must be defined for each product in some cases for each variety of a particular product. The use of maturity standards provides consumers with a minimum level of quality assurance. Another reason for establishing maturity standards is that most horticultural products are harvested by hand. A simple colour guide and size can help pickers harvest produce at the correct stage of development (Jobhng, 2014)

Maturity at harvest is the most important factor that determines postharvest-life and final quality such as appearance, texture, flavour, nutritive value of fruit- vegetables. Fruit-vegetables include two groups:(1) immature fruit-vegetables, such as green bell pepper, green chili pepper, cucumber, summer (soft-rind) squash, chayote, lima beans, snap beans, sweet pea, edible-pod pea, okra, eggplant, and sweet corn; and (2) mature fruit-vegetables, such as tomato, red peppers, muskmelons (cantaloupe, casaba, Crenshaw, honeydew, Persian), watermelon, pumpkin, and winter (hard-rind) squash For group (I), the optimum eating quality is reached before full maturity and delayed harvesting results in lower quality at harvest and faster deterioration rate after harvest For group (2) most of the fruits reach peak eating quality when fully ripened on the plant and, with the exception of tomato, all are incapable of continuing their ripening processes once removed from the plant Fruits picked at less than mature stages are subject to greater shriveling and mechanical damage, and are of inferior flavour quality Overripe fruits are likely to become soft and/or mealy in texture soon after harvest. The necessity of shipping mature fruit-vegetables long distances has often encouraged harvesting them at less than ideal maturity, resulting in suboptimal taste quality to the consumer (Kader, 2015). Several factors in addition to maturity at harvest have major impacts on postharvest behavior and quality of fruit-vegetables. Fruits of group (1) normally produce only very small quantities of ethylene. However, they are very responsive to ethylene and can be damaged by exposure to I ppm or higher concentrations. Ethylene exposure accelerates chlorophyll degradation, induces yellowing of green tissues, encourages calyx abscission (eggplant), and accelerates fruit softening. Most of the fruits in group (2) produce larger quantities of ethylene in association with their ripening, and exposure to ethylene treatment will result in faster and more uniform ripening as indicated by loss of chlorophyll (green colour), increase of carotenoids (red, yellow, and orange colours), flesh softening and increased intensity of characteristic aroma volatiles (Proctor et at., 1972).

All fruit-vegetables, except peas and sweet corn, are susceptible to chilling injury if exposed to temperatures below 5°C e.g., cantaloupe, lima bean, snap bean, 7.5°C e.g., pepper, 10°C such as cucumber, soft-rind squash, eggplant, okra, chayote, or 12.5°C e.g., tomato, muskmelons other than cantaloupe, pumpkin, hard-rind squash. A relative humidity range of 90-95% is optimum for all fruit-vegetables except pumpkin and hard-rind squash where it should be 60-70%. Atmospheric modification (low oxygen and/or elevated carbon dioxide concentrations) can be a useful supplement to proper temperature and relative humidity in maintaining postharvest quality of some fruit-vegetables, such as tomato and muskmelons (Kader, 2015). Fruits harvested too early may lack flavour and may not ripen properly, while produce harvested too late may be fibrous or have very limited market life. Similarly, vegetables are harvested over a wide range of physiological stages, depending upon which part of the plant is used as food. For example, small or immature vegetables possess better texture and quality than mature or over-mature vegetables. Therefore, harvesting of fruits and vegetables at proper stage of maturity is of paramount importance for attaining desirable quality. The level of maturity actually helps in selection of storage methods, estimation of shelf life, selection of processing operations for value addition. The maturity has been divided into two categories i.e. physiological maturity and horticultural maturity (Kader, 2000).

2.2.1 *Physiological maturity*

It is the stage when a fruit is capable of further development or ripening when it is harvested i.e. ready for eating or processing (Kader, 2015).

2.2.2 Horticultural maturity

It refers to the stage of development when plant and plant part possesses the prerequisites for use by consumers for a particular purpose **i** e ready for harvest (Dhatt and Mahajan, 2007).

2.2.3 Mature

It is derived from Latin word 'Maturus' which means ripen. It is that stage of fruit development, which ensures attainment of maximum edible quality at the completion of ripening process (Kader, 2015).

2.2.4. Maturation

It is the developmental process by which the fruit attains maturity. It is the transient phase of development from near completion of physical growth to attainment of physiological maturity. There are different stages of maturation e.g. immature, mature, optimally mature, over mature (Arslan and Mehmet, 2010)

2.2.5 Ripe

It is derived from Saxon word 'Ripi', which means gather or reap. This is the condition of maximum edible quality attained by the fruit following harvest. Only fruit which becomes mature before harvest can become ripe (Arslan and Mehmet, 2010).

2.2.6 Ripening

Ripening involves a series of changes occurring during early stages of senescence of fruits in which structure and composition of unripe fruit is so altered that it becomes acceptable to eat. Ripening is a complex physiological process resulting in softening, colouring, sweetening and increase in aroma compounds so that ripening fruits are ready to eat or process. The associated physiological or biochemical changes are increased rate of respiration and ethylene production, loss of chlorophyll and continued expansion of cells and conversion of complex metabolites into simple molecules (Maude, 1983).

2.2.7 Senescence

Senescence can be defined as the final phase in the ontogeny of the plant organ during which a series of essentially irreversible events occur which ultimately leads to cellular breakdown and death (Dhatt and Mahajan, 2007).

2.3 Pre-Harvest Operations

The condition of onion leaves is a good indicator of the maturity and general state of the bulb. Bulb onions which are to be stored should be allowed to mature fully before harvest and this occurs when the leaves bend just above the top of the bulb and fall over. As a practical guide, farmers should conduct sample counts on the number of bulbs, which have fallen over in a field; and when the percentage of bulbs, which have fallen over, reaches about 70-80% then the entire crop should be harvested. Harvesting could commence earlier when 50-80% of the tops have gone over, before it is possible to see split skins exposing onion flesh Storage losses at optimum maturity are normally lower than those harvested before the tops collapse. Bulbs generally mature within 100-140 days from sowing, depending on the cultivar and the weather. Spring onions mature for harvesting after 35-45 days from sowing. Harvested crop should be allowed to dry or cure and ripen in the sun for several days after lifting. Onions can yield up to **5** tha-1 under good growing and management conditions (Ertekin and Gedik
2005)

2.3.1 Harvesting, handling and storage

Harvest onions when the weather is dry; harvesting after a rainfall, or when the humidity is high increases susceptibility to post-harvest disease. At harvest, bulbs must be firm, with mature necks and scales, and must be a good size. Defective onions (i.e. sprouted, insect damaged, sun scalded, green, bruised) should be discarded. For optimum storage quality, onions must be cured soon after harvest by placing them in a drying room at 20-30°C and 70% relative humidity for 12 to 24 h. Curing decreases the incidence of neck rot, reduces water loss during storage, prevents microbial infection, and is desirable for development of good scale colour. The optimum temperature for long-term storage of onions is 0°C with 65- 70%relative humidity. To ensure a storage life of up to 8 months, onions must be promptly stored after curing. Exposure to light after curing will induce greening of the outer scales. Premature sprouting in onions reduces marketing potential. Pre-harvest application of a sprout suppressant, such as maleic hydrazine, retards sprouting and prolongs storage life. Different onion types have different storage potentials. The storage potential of onions follows the order: yellow >red >white >Spanish and sweet (Mande, 1983). Within each colour group there are significant differences between cultivars in their storage potential. For further information on the storage potential of various cultivars, consult the Annual Vegetable Trial results published by (Shika and Doug, 2001) Onions are susceptible to a number of physiological disorders during storage such as, watery scales, translucent scales and freezing injury Symptoms of watery scales include a thick leathery skin with watery glassy scales below, freezing injury resembles watery scales and is characterized by soft water soaked Scales Translucent scales are characterized by a water-soaked translucent appearance These physiological disorders often become entry points for flingal and bacterial rots For control of these problems, effective curing and prompt storage are critical (Maude, 1983)

2.3.2 Harvesting and transport

Manual harvesting is the most common practice in most developing countries This is normally carried out by levering the bulbs with a fork to loosen them and pulling the tops by hand In developed countries, especially in large scale farms, mechanical harvesting is commonly used The harvesting techniques adopted are influenced by weather condition at harvest time In areas where warm, dry weather occurs reliably, the curing and bagging of the crop can be done in the field (two phase harvesting) In wetter, temperate regions, mechanical harvesting and artificial heating and ventilation for drying are essential for reliable production of high quality bulbs on a large scale The following steps are followed during two- phase harvesting of onions (a) mowing the leaves (if necessary), (b) stubbing, undercutting and sieving the onions to remove stones and clods, (c) roll the soil in the row to get a plane surface, (d) drying the bulbs (windrowing) 8 to l0 days in the field, (e) turning the bulbs into 2 times, (f) harvesting, sieving and hand grading, overloading into a trailer or in crates, and (g) transport For one phase harvesting usually commercial potato harvesters have been adapted After mowing the leaves, the crop is immediately harvested, sieved, hand graded and loaded onto the trailer Because of the additional operations involved, labor costs for two-phase harvesting are about 30 to 100 %higher than for one phase harvesting The main disadvantage of one-phase harvesting is the high energy consumption required for mechanical drying Using combine harvesting, the standardized working hours has been calculated to be 2 7 to 2 9 hr ha-1 for stubbing, 2 4 to 2 6hr ha-1 for turning and 8 9 to 11 hr ha-1 (KTBL, 1993) Harvested bulbs are placed in containers (basket, bins) or tied into bunches and placed directly on the floor of a trailer for transport These trailers can be pulled by an animal (such as donkey) or mechanical transport such as a tracere. Both packageing and transporting systems must be selected to ensure minimum handling damage to produce. Hard surfaces should becushioned with leaves, foam or other appropriate force decelerators (Shika and Dong, 2001).

2.4 Storage Diseases

Onions are susceptible to Botrytis neck rot during storage. The disease is characterized by grey fungal growth, often watery in nature, at the neck area and on the outer scales The infection usually spreads quickly through the whole onion Bruising of onion bulbs during harvesting, storing under humid conditions, and exposing the inner tissues due to breakage of outer scales increase the incidence of Botrytis neck rot Curing onions prior to storage will reduce the incidence of this disease Black mould, caused by Aspergillus Niger, is characterized by black discolouration at the necks of onions (Shika and Dong, 2001). The black discolouration can sometimes be found on the outer scales. Bruised onions are more susceptible to this fungus. Black mould causes the tissues to become water soaked which often induces bacterial soft rot. Although low temperature storage delays growth of the fungus, exposure of infected onions to temperatures above 15°C, as occurs during marketing, will accelerate its growth. Stored onions are also susceptible to blue mould, caused by Penicillium. Penicillium moulds induce watery soft rot of onion tissues and/ or caused by Erwinia often occur during storage of onions. Onions infected by bacterial soft rots often appear healthy on the outside but when cut open some of the inner scales are brown, water-soaked and have a cooked appearance. A characteristic foul smell often occurs and the centre core of the onion often slips out when pressure is applied at the base of the onion. Bacterial rots caused by Pseudomonas infects outer scales and are characterized by yellow slime which produce a sour odour. Control of fungal and bacterial rots of onions can be achieved by Pre-harvest application of a registered fungicide such as Rovral.

1. Harvesting at proper maturity
2. Minimizing bruising of bulbs
3. Discarding defective onions
4. Prompt and effective curing
5. Storing as quickly as possible (Tucker and Drew, 2017)

2.5. Curing and drying

Both curing and drying remove excess moisture from the outer layers of the bulb prior to storage. The dried skin provides a surface barrier to water loss and microbial infection, thereby preserving the main edible tissue in a fresh state. Drying also reduces shrinkage during subsequent handling, reduces the occurrence of sprouting, and allows the crop to ripen before fresh consumption or long-term storage (Opara and Geyer, 1 999). This process of dehydration is sometimes called ‘curing’, but the use of the word ‘curing’ for onion drying is rather inaccurate since no cell regeneration or wound healing occurs as in other root crops such as yam and cassava. Drying reduces bulb weight and since they are sold mostly on a weight basis, achieving the desired level of dehydration is critical Weight losses of 3-5% are normal under ambient drying conditions and up to 10 % with artificial drying. In traditional small-scale operations, onion drying is carried out in the field in a process commonly called ‘windrowing’. It involves harvesting the mature bulbs and laying them on their sides (in windrows) on the surface of the soil to dry for I or 2 weeks. In hot tropical climates, the bulbs should be windrowed in such a way to reduce the exposed surface to minimize damage due to direct exposure to the sun. In wet weather, the bulbs can take longer time to dry and may develop higher levels of rots during storage (Ruoyi, 2005). The side of the bulb in contact with wet soil or moisture may also develop brown strains or pixels, which reduce the appearance quality and value. Obviously, successful windrowing is weather dependent and therefore cannot be relied upon for large scale commercial onion production business (Ertekin and Gedik, 2005).

Bulbs harvested for storage require in total 14-20 days of ripening or drying before being stored. Harvested onions may also be placed in trays, which are then stacked at the side of the field to dry. In some tropical regions, the bulbs are tied together in groups by plaiting the tops, which are then hung over poles in sheds to dry naturally. Harvested bulbs can also be taken straight from the field and dried artificially either in a store, shed, barns, or in a purpose built drier. This method is commonly used when crops are stored in bulk but it can also be applied to bags, boxed or bins. Under this method, bulbs are laid on racks and heated air is rapidly passed across the surface of the bulbs night and day (O’Connor, 1979; Brice et at, 2016). Drying may take 7-10 days and is considered complete when the necks of the bulbs have dried out and are tight and the skins shriek when held in the hand. The control of humidity level in the store is critical. Under very high humidity, drying is delayed and fungal infection can increase. However, if relative humidity is too low (below6o%), excessive water loss and splitting of the bulb outer skins can occur, resulting in storagelosses and reduction of bulb value Placing onions on wire mesh in well ventilated conditions and using air at about 30°C, 60-75% rh and 150 m3 h-i m-3 is generally recommended for mechanical drying of onions (Yang and Lee, 2000).

2.6 Cleaning

Freedom from any impurity, which may materially alter the appearance or eating quality, is essential. Soil and other foreign materials must be removed and badly affected produce must be discarded. Cleaning may be carried out using air or by manually removing unwanted materials on the bulb surface. Care should be taken to avoid physical injury on the bulb during these operations.

2.7 Packaging

Good packaging for onions must meet the following criteria: (a) strong enough to retain the required weight of onions under the conditions of transport and storage, (b) allow sufficient ventilation for the air around the bulbs to maintain relative humidity in the required range, and (c) in many circumstances, provide a means of displaying legally required and commercially necessary information (Brice et al.,20l6).There are many traditional methods of holding onions for transportation and/or storage that do not fit into conventional packaging classifications. These include string of onions', shelves and loose bulk in 'string of onions' packing, the bulbs are tied together by means of their tops to produce a bunch of bulbs is also a form of packaging. This is suitable for transporting small quantity of crop, and during storage, the bunches are hung from the roof or from special racks. Shelves for onion handling and storage are made from either wooden slats or metal mesh on a wooden or metal frame, and are usually fixed in position with the bulbs loaded and unloaded in the store (Proctor *et al.*, 1972). Ventilation (natural or forced) is usually achieved by passing air o ver the shelves. To achieve adequate aeration of the bulbs, the depth of bulbs on the shelves should be limited to 10 cm. Onions are also stored loose bulk (instead of containers) by heaping the bulbs directly on the floor or elevated platform Because they are not restrained, the bulbs roll during store loading to completely fill the storage space Bulk storage permits maximum utilization of store space, and uniform aeration is easier to achieve than in stacks of bags or other rigid packaging. However, where bulk storage is to implemented, the retaining walls must be strengthened when storing larger quantities of bulbs, and arrangements need to be made for retagging before subsequent marketing It is also difficult to inspect bulbs regularly under these storage conditions Loose bulk handling of onion is most suitable for large-scale operations where forced ventilation can be provided during long-term storage (Bix *et al*, 2000).

Soft cultivars (which are also generally sweet) 'Vidalia Sweets' should not be stored in loose bulk because of their high susceptibility to compression and impact damage. Onions can be packaged and stored in a variety of containers such as boxes, cartons, bags, bulk bins, pre packs plastic film bags, and stretch-wrapped trays. Packages typically contain 25 kg and above, especially for transporting crop from field to store and/or during storage. The same 25kg bags or smaller bags may be used from store to market place. Decision on which type of packaging to use depends on crop size, length of storage and marketing requirements. A problem with packaging onions in boxes, net bags and bulk bins is that if they are too large, and airflow pattern tends to be around rather than through them. Under this condition, the respiration heat of the bulb results in a warm, humid environment in the centre of the package, which can result in decay or sprouting. To avoid these problems in larger stores, the capital investment in packaging may be quite substantial (Stillwell, 2016)

2.8 Onion Bags

Sacks and nets used for onion packaging fall into three groups: (i) general-purpose jute sacks, as used for many agricultural commodities, (ii) open-weave sacks of sisal-like fibres, (iii) open-mesh nets, normally of plastic materials and (iv) big bags, used alternatively to crates, containing up to 1000 kg. Jute sacks are readily available in most developing countries, but their disadvantages include: (i) generally too large - may contain 100 kg onions, hence difficult to handle and an increased risk of mechanical damage; (ii) bulbs are not visible through the fabric, and it is difficult to monitor condition during storage; (iii) there is some resistance to airflow if they are used in an aerated store; (iv) difficult to label effectively; and (v) recycled sacks may encourage spread of postharvest diseases. Sisal sacks are made from sisal-like hard fibres and have an open weave, with thick threads spaced between about 10 and 15 cm apart. The rough nature of the fibre provides a sufficiently stable weave. These sacks are similar to jute sacks, but will allow limited visibility of the onions and impedance to airflow is less. Open-mesh nets are the most widely used package for onions, and they are normally red or orange in colour. The slippery nature of plastics can result in the movement of the threads allowing large holes to open up. To overcome this problem, alternative nets are industrially produced to give fully stablç mesh and stronger bag. The principal techniques include: (i) using extruded net from high-density PVC, (ii) knitted (warp-knitted) and asymmetric construction, and (iii) special weave in which weft threads are double, and twisted. They area also slowly degraded by sunlight, and should not be left outdoors for long period before use. In comparison with the other types of bags, they offer several advantages, including (i) lightweight, small bulk when empty, (ii) usually available in 12 5 and 25 kg sizes, (iii) fairly good visibility of bulbs, (iv) excellent ventilation, (v) hygienic, (vi) easy closing (draw-string types only), (vii) and crop brand and marketing information may be printed around the middle of the bag for easy identification.

2.8.1 Rigid packages

A range of rigid containers is used to package onions for transportation, marketing, and/or storage (Opara and Geyer, 1999). The principal rigid containers are trays (10-15 kg of onions each), boxes (up to 25 kg), and bulk bins (up to 1000 kg). These types of packaging enable segregation of onions into different cultivars or sources. Choice of packaging material is important as wooden bins, for example, are liable to termite attack, and weathering during off-season. Rigid containers are also expensive, need regular maintenance and a forklift is required for handling larger containers. Where rigid containers are used for onion storage, building design is simpler than that for large-scale loose bulk storage as reinforcement of retaining walls are not required to support the bulbs. Handling damage of bulbs during filling and emptying can be high, but damage is reduced during store loading and unloading operations in comparison with loose bulk handling and storage. Stacking of containers must be carried out with care and to ensure that the ventilation air is forced through the containers of bulbs and not around them. One of the main advantages of rigid containers is that they facilitate regular inspection of produce, and when problems occur with the stack, the area affected is often limited to a few trays, boxes or bins which may be more easily isolated and removed than in loose bulk handling system.

2.8.2 Onion pre-packs

Onions are commonly sold in retail outlets in pre-packs with a capacity of 0.5-1.5 kg. Prepacking offers the following advantages over single bulbs in heaps or bags: (1) price can be attached to produce, (ii) the collation of a number of pieces into one unit of sale may promote sale of a larger quantity than would be purchased otherwise, (iii) provides a clean odorless unit for the customer to handle, and (iv) reduces time spent at the check-out. The use of weight/price labeling machines and bar-coding has reduced the need to pack to fixed nominal weights. During preparation for retail, the quantity of produce is measured by hand or machine and filled into the pack. Then the actual weight and price and/or bar-code are automatically calculated and printed on a label, which is attached to the package. This mechanized weighing and labeling system assists the packer in accurate record keeping and avoids losses due to inaccurate pack weights. The three main types of onion pre-packs are nets, plastic film bags, and stretch-wrapped trays (Stillwell, 2016).

2.8.3 Butk storage

General Requirements, The objectives of onion storage are to extend the period of availability of crop, maintain optimum bulb quality and minimize losses from physical, physiological, and pathological agents. Bulbs selected for storage should be firm and the neck dry and thin. Discard thick necked bulbs because they are most likely to have high moisture content than optimum for storage, and therefore would have short storage life. Skin colour should be typical of the cultivar. Microbial infections such as Aspergillums Niger occur during production of onions but these will only develop on the bulbs during storage where the storage environment is conducive for their growth. Prior to storage, crop must be cleaned and graded, and all damaged or diseased bulbs removed. Careful harvest and pre-storage treatments with minimal mechanical loads are important to achieve a long storage period. Both store room temperature, relative humidity, and atmospheric composition affect the length of storage that can be achieved. Several technology options are available for bulk storage of onions, including low-temperate storage, high-temperature storage, ‘direct harvest’ storage and the use of controlled atmosphere (CA) stores The recommended storage conditions under these systems are summarized below (Amy,201 1)

2.8.4 Storage at low temperature

For successful low temperature storage, good ventilation and a low level humidity in the range of 70-75% is essential To maintain good quality crop, the period of storage varies but may be up to 200 days For maximum storage period and minimum losses bulbs should be fully mature at harvest, and dried until the ‘neck’ of the bulb is tight For large-scale commercial storage, onions are usually stored under refrigeration and the most commonly recommended conditions are 0°C with 70-75% rh Regular ventilation and monitoring of both temperature and relative humidity in the store are necessary to avoid significant fluctuations in environmental conditions During the first few days of storage the fans should provide an adequate airflow, to remove water in the outer skins and to dry bruises (Amy, 2011) High air speed is needed for a period of up to 1 week, until the skin of the upper onion layers in the bulk rustles Excessive humidity in-store will lead to the development of roots and promote rotting while higher temperatures will result in sprouting and promote development of pathological disorders such as Botrytis rots e Bulbs freeze below -3°C and a range of storage temperatures and relative humidifies have been recommended for safe storage of onions Spring (green) onions store best at about 0°C and very high humidity(95%) The maximum length of storage under these conditions varies from just a few days to about 3 weeks Ventilation must be carefully applied inside the store to achieve the required temperature and humidity levels without inducing condensation of water on the surface.

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Table: 1 Recommended Refrigerated Storage Conditions for Onion bulb

Temperature (°C)	Relative humidity (%)	Length of storage
-3-0	70-75	6 months
-3	85-90	5-7 month
-2	75-85	300 days
(-2)-(-0.6)	70-80	6 months &
-1-0	78-81	6-8 months
-0.6	75-85	6-7 months
0	75-85	6 months
0	65-75	-
0	70-75	20-24 weeks*
0	70-75	-
0	65-70	1-2 months#
0	65-70	6-8 months†
0	-	230 days
0	70-75 or 90-95	Up to 120 days
0	80-85	30-35 weeks§
1-2	80-85	30-35 weeks¥
1	87	-
1.1	70-75	16-20 weeks‡
4	-	170 days
8	-	120 days
12	-	about 90 days
20	-	25 days

*= With 16.3% loss (red onion); #= Bermuda cultivar; †= Globe cultivar; ‡= With 14.2% loss (red onion); = Superba cultivar; **§**= Optimum storage conditions, 7% maximum water loss before becoming unsaleable; ¥= Probable practical storage conditions, 7-10 days' shelf-life (approx.) at 20°C after storage, 7% maximum water loss before becoming unsaleable.

Compiled from (Thompson, 2006, Thompson, 2008)

2.9.2 Onion Storage at High-temperature

Onions can be stored at high temperatures of over 25°C at a range of relative humidity (75-85%) which is necessary for minimizing water loss. Storage at temperatures of 25-30°C has been shown to reduce sprouting and root growth compared to low-temperature storage (10-20°C). However, weight loss, desiccation of bulbs, and rots occurred at high temperatures, making the system uneconomic for long periods of storage that is required for successful onion marketing (Thompson *et al.,* 2006; Stow, 1975). In tropical climates, high-temperature storage of onions can be achieved under both ambient and heated storage conditions. Under these conditions, ventilation must be carefully applied inside the store to achieve the required temperature and humidity levels.

2.9.3 Direct Harvest Storage

The need to cure onions can pose considerable challenges in situations where the climatic condition is unpredictable during the harvest period. To overcome these problems, the 'direct harvest system' has been developed and used extensively, particularly by growers in the UK, since the early 1980s. The bulbs are harvested while green, topped, loaded into store, dried and cured using well controlled ventilation system, and thereafter held in long-term low temperature storage as required. During stage I, removal of excessive surface moisture is achieved at high airflow rates, ignoring the rh of the air. Stage II is completed when the skins have been cured on the bulb. Adequate control of the storage condition at the various stages is critical to the success of this storage system in maintaining required bulb quality.

2.10 Concept of Post-harvest

Postharvest physiology is the scientific study of the physiology of living plant tissues after they have denied further nutrition by picking. It has direct applications to postharvest handling in establishing the storage and transport conditions that best prolong shelf life. An example of the importance of the field to post-harvest handling is the discovery that ripening of fruit can be delayed, and thus their storage prolonged, by preventing fruit tissue respiration. This insight allowed scientists to bring to bear their knowledge of the fundamental principles and mechanisms of respiration, leading to post-harvest storage techniques such as cold storage, gaseous storage, and waxy skin coatings. Another well-known example is the finding that ripening may be brought on by treatment with ethylene (Jobling, 2014).

2.10.1 Postharvest management

Postharvest management is a set of post-production practices that includes: cleaning, washing, selection, grading, disinfection, drying, packing and storage. These eliminate undesirable elements and improve product appearance, as well as ensuring that the product complies with established quality standards for fresh and processed products. Postharvest practices include the management and control of variables such as temperature and relative humidity, the selection and use of packaging, and the application of such supplementary treatments as fungicides (FAO, 2009) After they are harvested, the value of fruits and vegetables is added in successive stages up to the point when someone eats them. The aim of postharvest management is to maximize this added value. This ultimately should benefit the whole community, whether through increased export earnings or extending the availability of fresh produce through the year. Conversely losses hurt everyone. Kader (2017) has estimated that from 5 to 25 % of fruit and vegetables leaving the farm gate is never consumed, but has to be thrown away. Obviously, disease and oversupply contribute to this, but there are many other reasons for the losses. Postharvest management can influence all them, with the two most important areas being temperature management and packaging. Another point to remember is that the loss of value of a downgraded product is likely to be substantially greater for highly differentiated branded products which sell at a premium in the market. All the hard work that has gone into promoting and raising the profile of a branded product can be quickly eroded if there are postharvest quality problems with some lines of that product **(**Jobling**,** 2014).

2.10.2 The nature of postharvest management

The horticultural produce includes fruits, vegetables, flowers and other ornamental plants, plantation crops, aromatic and medicinal plants and spices. According to Oxford English Dictionary, fruit can be defined as 'the edible product of a plant or tree, consisting of seed and its envelope, especially the latter when it is juicy or pulpy'. The consumer definition of fruit would be 'plant products with aromatic flavours, which are either naturally sweet or normally sweetened before eating. The classification of fruits and vegetables is arbitrary and according to usage. Botanically many crops, defined as vegetables, are fruits e.g., tomato, capsicum, melons etc. Morphologically and physiologically the fruits and vegetables are highly variable, may come from a root, stem, leaf, immature or fully mature and ripe fruits. They have variable shelf life and require different suitable conditions during marketing. All fresh horticultural crops are high in water content and are subjected to desiccation (wilting, shriveling) and to mechanical injury. Various authorities have estimated that 20—30 % of fresh horticultural produce is lost after harvest and these losses can assume considerable economic and social importance. That is why, these perishable commodities need very careful handling at every stage so that deterioration of produce is restricted as much as possible during the period between harvest and consumption (Dhatt and Mahajan, 2007).

Horticultural produce is alive and has to stay alive long after harvest. Like other living material it uses up oxygen and gives out carbon dioxide. It also means that it has to receive intensive care. For a plant, harvesting is a kind of amputation. In the field it is connected to roots that give it water and leaves which provide it with the food energy it needs to live. Once harvested and separated from its sources of water and nourishment it must inevitably die. The role of postharvest handling is to delay that death for as long as possible. Horticultural managers must possess many skills to succeed in this. They need a keen appreciation of horticultural diversity. For example, spinach and apples, bananas and potatoes each have their own requirements. The optimum postharvest management of horticultural products is not the same for all products. Growers, wholesalers, exporters and retailers must all be aware of the specific needs of a product if the postharvest shelf life and quality is to be maximized (Jobling,2014).

2.12 Postharvest Factors Affecting Structural Deterioration

The major postharvest problem with storage of fruits and vegetables is the excessive softening. Ripening of many fruits is mainly orchestrated by biosynthesis of ethylene that triggers a serial biochemical and physiological process inducing the softening in texture. The most important factors affecting structural deterioration of fruits and vegetables can be summarized as follows:

2.12.1 Processing

At low extraction percentages (up to 33 %), pectic polysaccharides and hemicellulose xyloglucans were the main type of polymers affected, suggesting the modification of the cell wall matrix, although without breakage of the walls. At higher extraction rates (up to 64 %), a major disruption of the cell wall occurred as indicated by the losses of all major types of cell wall polysaccharides, including cellulose. At higher extraction rates, fatty acid chains are able to exit the cells either through unbroken walls, or the modification of the pectin-hemicellulose network might have increased the porosity of the wall. Due to high pressure, a progressive breakage of the cell walls was observed, which allows the free transfer of the fatty acid chains from inside the cells (Negi and Handa, (2008)

2.12.2 Heat

Postharvest heat treatments lead to an alteration of gene expression, and fruit ripening can sometimes be either delayed or disrupted. Cell wall-degrading enzymes and ethylene production are frequently the most disrupted, and their appearance is delayed following heating. Fruit sensitivity to heat treatments is modified by pre-harvest weather conditions, cultivar, rate of heating, and subsequent storage conditions. Pre-storage heat treatment appears to be a promising method of postharvest control of decay. Heat treatments against pathogens may be applied to fresh harvested commodities by hot water dips, by vapour heat, by hot dry air, or by a very short hot water rinse and brushing. Pre-storage heat treatment could delay the ripening of “Gala” and “Golden Delicious” apples and maintain storage quality. Heating “Golden Delicious” apples for 4 days at 38 °C reduced decay and maintained fruit firmness during 6 months of storage at 0 °C. Cooking resulted in an increase in the water-soluble pectins and a decrease in the pectins associated with cellulose. The total cell wall polysaccharide and galactose content of the squash cultivars remained unchanged for up to 2 months of storage and decreased later (Negi and Handa, 2008).

2.12.3 Physiological disorders

Water soaking developed during the late stages of fruit ripening. The major changes were observed in a protein implicated in calcium signaling processes. While the amount of total calmodulin, the ubiquitous calcium-binding protein, was not modified, a particular calmodulin-binding protein (CaM-BP) was absent in water-soaked but not in sound mature tissues. This CaM-BP may be a marker or a determinant of this physiological disorder. Gel breakdown in inner mesocarp tissue of plums was associated with high viscosities of water- soluble pectin with low levels of extractable juice. In outer mesocarp tissue where extractable juice levels were higher, over-ripeness developed. Cell walls of inner tissue were thicker and had a better developed middle lamella than outer tissue Inner mesocarp tissue was compose of larger cells than outer tissue (Negi and Handa, 2008)

2.12.4 Chilling and freezing injury

Insoluble pectin levels declined during ripening and cold storage of plum fruit with a contaminant increase in soluble pectin levels Neither harvest maturity nor storage time had a significant effect on the concentration of calcium pectate, and this pectic fraction did not appear to influence development of gel breakdown (GB) Water-soluble pectin and availability of cell fluids indicated a high gel potential in plums Significant levels of GB developed only in plums harvested at post optimum maturity In GB fruit, higher sugar levels and loss of cell membrane integrity probably enhanced formation of pectin sugar gels as cell fluids bind with pectin in cell walls The initial response to low temperature is considered to involve physical factors such as membrane alteration and protein/enzyme diffusion, but physiological changes that lead to losses of structural integrity and overall fruit quality also occur During softening, dissolution of the ordered arrangement of cell wall and middle lamella polysaccharides occur As the fruit ripens, a substantial portion of its cell wall pectin are converted to a water-soluble form affecting the texture The major changes involved in softening and chilling injury in peaches are the catabolism of cell walls and the development of an intercellular matrix containing pectin(Lurie *et al.,* 2003) Gel- like structure formation in the cell wall (Lurie **et** al,2003) Ruoyi *et al.,* (2005) showed that combination of chitosan coating, calcium chloride, and intermittent warming partially inhibited PG activity, slowed down the increase in soluble pectinefic substances Addition of calcium chloride and intermittent warming could keep the intactness of cell wall and reduce fruit sensitivity to injury in peach Endo-PG, PE, and endoglucanase (EGase) activities of delayed- storage nectarines fruit were same as the control fruit at the beginning of storage, although exo-PG was higher Endo-PG activity was lower in control than delayedstorage fruit at the end of storage, while PB activity was higher, and exo-PG and EGase activities were similar Prevention of chilling injury by delayed storage (DS) appears to be due to the ability of the fruit to continue progressive and slow cell wall degradation in storage, which allows normal ripening to proceed when the fruits are rewarmed (Negi and Handa, 2008).

2.l3 Causes of PostHarvest Losses

Severe losses occur because of poor facilities, lack of know-how, poor management, market dysfunction, or simply the carelessness of farmers or workers. Post-harvest losses may also occur at consumers' homes, in the kitchen or on dining tables. However, losses after produce has left the retail market are generally difficult to control by agricultural means and, will not be covered in this research. Believed that improper post-harvest sanitation, poor storage and packaging practices and mechanical damage during harvesting, handling and transportation resulting from vibration by undulation and irregularities on the road mechanical can enhance losses. It is important to note that lack of proper information or poor decisions could lead to food loss, for example, agricultural policy which overestimates production may cause glut which in turn leads to greater food and economic losses to actors in production and marketing system (Idah, 2007) It has been contended by most researchers on this topic that many post-harvest losses are a direct result of production management. Vegetables that are affected by weeds, pests and diseases, inappropriately irrigated and fertilized, generally of poor quality before harvesting or harvested past optimum maturity can never be improved by post-harvest treatments. Furthermore, Bartz and Brecht, (2014). Pointed out that biological (internal) causes of deterioration include respiration rate, ethylene production and action, rates of compositional changes (associated with color, texture, flavor, and nutritive value), mechanical injuries, water stress, sprouting and rooting, physiological disorders, and pathological breakdown. According to them, the rate of biological deterioration depends on several environmental (external) factors, including temperature, relative humidity, air velocity, and atmospheric composition (concentrations of oxygen, carbon dioxide, and ethylene), and sanitation procedures. The researcher opines that post-harvest losses largely arose from multiple sources, namely pests and diseases, natural disasters, careless human actions and inadequate storage and processing facilities (Kader, 2014).

According to Expert Consultation (2010), losses occur due to poor preproduction and post-harvest management as well as lack of appropriate processing and marketing facilities. These losses have several adverse impacts on farmer income, consumer prices and nutritional quality of the produce. Because of the poor planting material, cultural practices including harvesting methods and handling practices, the quality of harvested produce is below standard. Absence of farm storage facility and proper pack house/packing station results in the perishable produce being marketed immediately after harvesting without primary processing and adequate packaging. The solid wastes originating from agricultural crops in metro cities, can create drainage problems and cause water logging, as well as invite stray animals near garbage dumps These bio-wastes also deteriorate very rapidly causing unhygienic conditions, increasing atmospheric pollution and provide a breeding ground for pests. Atanda *et al*, (2011) shared the same view on the causes of post-harvest food losses. According to them, post-harvest losses can be grouped under the headings of primary and secondary causes. Primary causes of loss are the causes that directly affect the food. These causes will form the basis of discussion. Biological cause is as a result of consumption of food by rodents, birds, monkeys and other large animals. This causes direct disappearance of food. Sometimes the level of contamination of food by the excreta, hair and feathers of animals and birds is so high that the food is condemned for human consumption. Insects cause both weight losses through consumption of the food and quality losses because of their webbing, excreta, heating, and unpleasant odours that they can impart to food (Atanda et aL,2011).

Microbiological factor that leads to post-harvest losses is consumption of food by microbes such as molds, bacteria and yeasts. Micro-organisms cause damage to stored foods (e.g., fungi and bacteria). Micro-organisms usually directly consume small amount of the food but they damage the food to the point that it becomes unacceptable because of rotting or other defects. Toxic substances elaborated by molds (known as mycotoxins), cause some food to be condemned and hence lost. The best known mycotoxins are aflatoxin (a liver carcinogen), which is produced by the mold Aspergillusfiavus. Another factor is chemical. Were of the view that many of the chemical constituents naturally present in stored foods spontaneously react causing losses of colour, flavour, texture and nutritional value. An example is the ‘Millard relation’ that causes browning and discoloration in dried fruits and other product, there can also be accidental or deliberate contamination of food with harmful chemicals such as pesticides or obnoxious chemicals such as lubricating oil. Biochemical reactions that lead to post-harvest losses are as a result of a number of enzyme-activated reactions in foods, in storage giving rise to off-flavors, discoloration and softening. One example of this problem is the unpleasant flavors that develop in frozen vegetables that have not been blanched to inactivate these enzymes before freezing (Amy, 2011).

Bruising, cutting, excessive trimming of agricultural products are mechanical factors that also bring about losses whereas, physical factors on the other hand are excessive or insufficient heat or cold and improper atmosphere in closely confined storage at times causes losses and Psychological factor is simply human aversion, such as “I don’t fancy eating that today’ In some cases, food will not be eaten because of religious taboos According to Atanda *et at.,* (2011), microbiological, mechanical and physiological factors cause most of the losses in perishable crops Physiological factors that lead to post-harvest losses are caused by natural respiratory losses which occur in all living organisms This accounts for a significant level of weight loss and moreover, the process generates heat Changes which occur during ripening, senescence, including wilting and termination of dormancy (e g, sprouting) may increase the susceptibility of the commodity to mechanical damage or infection by pathogens A reduction in nutritional level and consumer acceptance may also arise with these changes Production of ethylene results in premature ripening of certain crops Secondary causes of loss are those that lead to conditions that encourage a primary cause of loss They are usually the result of inadequate or non-assistant capital expenditures, technology and quality control Some examples are inadequate harvesting, packaging and handling skills, lack of adequate containers for the transport and handling of perishables, storage facilities inadequate to protect the food, transportation inadequate to move the food to market before it spoils, inadequate refrigerated storage, inadequate drying equipment or poor drying season, traditional processing and marketing systems can be responsible for high losses, legal standards can affect the retention or rejection of food for human use by being too lax or unduly strict, conscientious, knowledgeable management is essential for maintaining tool in good condition during marketing and storage, and bumper crops can overload the post-harvest handling system or exceed the consumption need and cause excessive wastage (Bix *et at.,* ,2018)

2.14 Drying.

Drying is a mass transfer process that consists of water moisture evaporation from foodstuffs. Moisture (or dry matter) content is defined as the quantity of moisture (or dry matter) contained in the product and water activity describes the amount of water available for hydration of foods and is defined as the vapour pressure of water in the food divided by that of pure water at the same temperature The initial moisture content of the product influences on the drying rate During drying, the moisture contained in the product is vaporized under the effect of heat and transferred to the ambient air Air flow helps heat application through the product and removal of humidity Relative humidity is defined as the ratio of water vapor in air to water vapor The lower the relative humidity in the air, the more capacity to remove moisture from the product it would have There is also a relationship between temperature and relative humidity The temperature of the air affects the relative humidity (as temperature increases, relative humidity decreases in adiabatic conditions) and this is described on a psychometric chart (ITDG, 1988) At atmospheric pressure, the efficiency of drying therefore depends of the temperature/relative humidity and air flow through the product Drying is a critical process, more than the other traditional methods of processing **(i** e boiling and steaming) Indeed, the removal of water affects the internal cell structure of the vegetable food leading to higher losses of micronutrients such as vitamin A.

In order to control better provitamin A loss in drying and storage, improved techniques of drying and storage are required However, these technologies should be adapted to the local environment When working with small-scale farmers, **it** is necessary to consider issues such as lack of infrastructure, lack of finance, distance from markets, low income and lack of expertise Technologies for flour processing on a large scale such as drum or spray drying are not appropriate because they require large amounts of energy, high technology and high capital cost (Van Hal, 2000, Woolfe,2017) Drying technologies suitable for farming areas should have a low initial capital cost, be easy to construct with available natural materials and be easy to operate and maintain (Chua and Chou, 2003) There are two types of dryers, artificial or natural (solar or sun) that are suitable in that respect and these are described below.

2.14.1 Artificial drying

Artificial drying can be conducted in a cabinet or tunnel dryer where air is heated by a fuel or electricity (Van Hal, 2000) Air flow can be perpendicular (cross flow, for example, in a fluidized bed system) or parallel to the product Other types of dryers that are used with cassava in West Africa include bin and flash dryers With artificial dryers, temperature, drying time and air velocity are controlled leading to consistent, high quality products. Cabinet dryers expose sweet potato slices to temperatures between 50 and 80°C for a period of 2 5-24 h (Van Hal 2000). The disadvantage of this system is the high expenditure of energy increasing production costs (Van Hal, 2000). An alternative to this type of dryer is the biomass dryer cabinet or tunnel dryer using firewood or charcoal. This also requires investment in fuel. These dryers can be expensive to build, but manufacturing costs can be reduced by using materials available in rural places. The disadvantages of these dryers are that the quality of product can be affected by smoke and using firewood contributes to deforestation unless it is produced on a sustainable basis

2.14.2 Sun drying

Sun-drying is the most affordable means of drying and is widely practiced in many developing countries. Kosambo (2004) reported trans-! -carotene losses in open air sun-drying and cabinet drying of 83% and 28% respectively Lower retention in open air sun-drying was explained by the destructive effect of sunlight and the non-controlled environmental conditions Kosambo(2004). Sun dryers are more environmentally friendly systems and are cheaper to operate than artificial dryers because they use natural free energy. Consequently, sun drying is one of the lowest-cost preservation methods and is the most commonly used drying method. However, traditional open air sun drying involves a number of risks for product quality including dust, insects, mammals, rain and provitamin A damaging UV sun radiation because of poor control over environmental factors Improved sun drying was therefore proposed by FAO (1985) in their “Expert consultation on planning the development of sun drying techniques in Africa”.

2.14.3 Shade drying

An alternative to sun drying to limit degradation by sun-light of product nutritional quality is shade drying A critical factor in shade drying is air circulation around the product and the thickness of the layer of product should be limited in order to facilitate drying (FAO 2001). The disadvantage of this dryer is longer drying times that can lead to off-odors (fermentation) if the temperature is low or humidity high.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Experimental Site

The experiment was carried out in the Laboratory of Food Science and Technology Department, Modibbo Adama University of Technology, Yola Adamawa State. The Food Science and Technology Laboratory is located at latitude 9° 20' 43" N and longitude 12° 30' 8" E, at an altitude 203.5m above sea level. Yola has an annual mean minimum and maximum temperature of 15 2°C and 39°C respectively (Adebayo, 1999).

3.2 Sample Collection

Freshly harvested onion bulbs at a fully matured stage and fully ripe was purchased from a commercial farm at Loko, Song L.G.A of Adamawa State. The onion bulbs were of almost uniform colours, undamaged, free from any diseases and buries, which were selected for the experimental purpose. They were then cleaned and partially socked in salt water for 10mm, so as to deactivate microbial loads.

3.3 Treatment and Experimental Design

The experiment consist of six (6) treatment which include oven dryingplastic container,oven dryingpolythene bags, sun dryingplastic container, sun dryingpolythene bags, shade dryingplastic containerand shade dryingpolythene bags. And it was laid in Completely Randomized Design (CRD). The experiment was replicated three (3) times as shown in Figure 1

3.4 Preparation of Onion bulbs for Drying

The selected onion bulbs was cleaned and socked into salt water for 10mm to deactivate microbial activity on the surface of the bulbs. The bulbs would be slices into uniform pieces so as to maintain uniform drying. After drying, the dried product was packaged in into two packaging materials (polythene bags and plastic containers)

Figure I: Experimental layout

R_1	R_1	R_1
SUPC	OVPB	OVPC
SHPC	SHPB	SUPC
OVPC	SUPB	OVPB
SUPB	OVPC	SHPB
SHPB	SHPC	SUPB
OVPB	SUPC	SHPC

KEYS:

SH = Shaded Dried

SU = Sun Dried

OV = Oven Dried

PB = Polythene

PC = Plastic Container

3.4.1 Drying procedures

3.4.2 Open sun drying

The sliced of onion bulbs was evenly spread on wide white polythene and placed under open sun so as to allow good absorption of solar energy. Dried samples was crushed into smaller flask and passed 1.0 mm sieve and packaged in the packaging materials provided.

3.4.3 Shade drying

The sliced of onion bulbs was properly spread on a wide white polythene and place it in a well-ventilated zero energy chamber where. Natural current of air was used to dry the samples.

3.4.4 Hot Air oven

The laboratory hot air oven was used to dry the samples. The oven was run for 25 minutes so as to obtain a stable condition before placing the sample in the chamber. The dry samples was .crushed and be packaged in an air tight packaging material

3.5 Data Collection

The samples was taken to Food Chemistry laboratory and data were collected on physicochemical parameters such as color, bulk density, fat, carbohydrate, fiber, ascorbic acids (vitamin C). The parameters were recorded at 4, 8, and 12 weeks' intervals respectively under ambient condition

3.5.1 Physical/functional properties

1. Colour determination

The colour of dried onion samples was determined using visual organoleptic method by trained laboratory technologist, caterers and marketers who are familiar with the sample (Iwe, 2014).

2. Bulk density

Bulk density was determined as described by Filli (1999). Ten grams (10 g) of sample will be weighed in 25 cm3 graduated measuring cylinder and was firmly tapped 30 times on a bench top to settle the sample volume.

Bulk density $\left(\frac{g}{m^3}\right) = \frac{mass}{volume}$

Shrinkage is expressed by the ratio of the volume of onion slice before and after drying

Shrinkage ratio was calculated at each instant of the drying according to Equation 3 (Dissaet al, 2010)

$SR(\%) =$ X 100

Where; SR (%) is shrinkage ratio,

Vi (cm3) is the apparent volume of the raw sample before drying, and

VJ(cm3) is the apparent volume of the sample after drying.

3.5.2 Chemical composition

a) Determination offal content

Five grams (5g) of sample was placed in a timble and inserted into soxlet apparatus and the oil extracted using hexane as solvent. The mass of soxietwas noted before extraction. The mass of flask and oil after extraction would be noted from which the mass and percentage mass of oil was calculated (Fi11i1999)

$$\% \text{ oil content} = \text{x } 100 \quad = \frac{\text{mass of flask} + \text{mass of oil}}{\text{mass of sample}} \text{ X } 100$$

b) Determination of Fiber

Five grams (5g) of sample was poured into 600m1 beaker and 200m1 hot H2S04 was added. The beakers will be placed on digestion apparatus with pre-heated plates. It was boil and filter through white man GF/F paper by gravity. The beaker was rinse with distilled water. The residue was wash on the paper with distilled water until the filtrate is neutral.

3. Carbohydrate determination

This was determining by obtaining the differences, by subtracting from 100 the sum of the percentage moisture, ash, protein, fat and fiber.

% carbohydrate = 100 - (sum of moisture, ash, protein, fat, fiber)

4. Moisture content

The moisture contents of each sample were determined according to the method elaborated in AOAC (2011) 925.09 and calculated as percent loss in weight using Equation 5. Moisture (%) = $\frac{M_i - M_d}{M_i}$ X 100 when; M_i = initial befor drying, and M = final mass after drying (Sadasivam and Manickam 2005).

3.6 Data Analysis

The data was subjected to the analysis of variance (ANOVA) using Statistical Analysis System and means separated using Least Significance Difference at 5% level of significance

CHAPTER FOUR
RESULTS

4.l The Effect of Drying Methods and Packaging Materials on Chemical Composition of Dried Onions

The result of the effects of drying methods and packing material on chemical composition of dried onions is presented in Table 1, the result shows highly significant (ps 001) difference in all the parameters measured in the chemical composition

4.1.1 Moisture content

The result in Tables 1, showed that the result further revealed that combination of oven drying and plastic container had the highest moisture content of 25.0% followed by shade dried plastic container and sun-drying and plastic container with values of 22 6% each The least moisture content was however recorded in oven drying and polyethylene bag packaging (18.33%).
The interaction between shade dried and sun dried as well as oven dried + polythene bag got higher mean values.

4.1.2 Ash content

The result of ash content can be found in Table 1. Ash content also increase as storage period increases. The result showed a significant difference (p 0.05) among all the treatment combination. Sun-dried onions package in polybag was more superior than other treatment which had a value of 1867% while the least value was obtained in oven dried onions package in polythene bag (4.33%).

4.1.3 Protein content

The result of protein content of dried onions can be seen in Table I. which shows a significant difference ($p < 0.05$) among the treatment for protein content the result indicated that the combination of shade drying and plastic container retained highest percentage of protein **(6.57%)** followed by shade dried polythene bags and sun dried polythene bags

(5.50%) respectively, oven dried plastic container however, had the lowest value of 4.05% of protein content.

The result. showed that there was increase in protein content as the storage period increase. Likewise, shade dried plastic container prove to be better in terms of maintaining protein content during the storage period.

4.1.4 Lipid content

The result of lipid content of dried onions is presented in Table 2. The result showed that drying method by oven had the better lipid content than shade and sun drying. There was no much difference of lipid content between the interactions shade dried and sun dried. Oven dried plastic container retain highest amount of lipid content with (1.10%) followed by sundried plastic bag with (0.96%) and the least was shade dried plastic bags with (0.64%).

4.1.5 Fiber content

The fiber content of dried onions at different drying methods is shown in Table. In terms of fiber content however, the result indicated highly significant (pS 0.05) difference with shade- drying and polythene bag having the highest fiber content value of 7.00%, followed by Sun Dried Polythene Bags and Oven Dried Polythene Bags with values of 5.47% and 5.03% respectively. The least value was however recorded in Shade Dried Plastic Container (2.03%).

4.1.6 Carbohydrate content

The carbohydrate content of onions is presented in Table 2. The result of the carbohydrate composition of dried onions revealed a significant difference (p 0 05) in all the treatment with oven drying and plastic bags having the highest carbohydrate (66.07%) content when compared with other treatment. The least value was however obtained in sun-drying and plastic bag (48.23%) but was not significantly different with all other treatments.

Table 1. Effect of drying methods and packaging materials on chemical composition of dried onions

Samples	% M.C	% Ash	% Fiber	% Protein	%CHO	%DM	Lipid
SHPB	2257	647	700	550	6187	7720	064
SHPC	2260	440	203	657	4420	7803	085
SUPB	2133	1867	547	550	4823	7907	096
SUPC	2260	653	238	540	6383	7920	075
OVPB	1833	433	503	503	6607	7720	075
OVPC	2500	633	347	405	5990	7517	110
P>F	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD	0.64	0.59	0.49	0.45	4.04	1.18	0.12

KEYS:

SH = Shade Dried

SU = Sun dried

OV =Oven Dried

PB = Polythene

PC = Plastic Container

4.1.7 Dry Matter content

For dry matter content, the result also shows a significant difference for all the treatment. The result shows in table 2, that oven drying and polythene bag packaging gave the best dry matter content of 89 50% with the least value obtained in oven drying and plastic container packaging (59 90%)

4.2 Storage Stability

The effect of storage on colour, taste, aroma and consistency are presented in Tables2, 3, 4, and 5. The result showed that almost all the parameters evaluated, shade dried sample had higher mean value followed by oven and sundried respectively Likewise, oven dried recorded the highest mean value in almost all the parameters evaluated followed by plastic container and polythene bag respectively.

4.3 Sensory Evaluation

The mean sensory scores of colour, taste, aroma, consistency and overall acceptability of stew maid from dried onions are presented in Tables 3, 4, 5 and 6 The result shows that the stew prepared from Sun Dried Plastic Container had higher scores for all the attributes. Followed by Shade Dried Polythene Bags. The least of the entire attribute was Oven Dried Plastic Containers.

Table 5: Effect of Drying Method and Packaging Material On Sensory Evaluation of Dried onions.

Samples	Aroma	Colour	Taste	Texture	0/A
SHPB	7.60	7.833	7.27	7.47	7.60
SHPC	727	770	707	730	783
SUPB	720	743	783	743	753
SUPC	790	803	807	740	790
OVPB	747	727	720	767	760
OVPC	5.33	6.90	7.30	7.60	7.90
P<F	<0.15 1	<0.003	<0.248	<0.364	<0.529
LSD	0.548	0.498	0.986	0.377	0.603

KEYS:	Score scale	
SH = Shade Dried	Like Extremely = (I) Dislike Slightly	=(D)
SU = Sun Dried	Like Very Much = (H) Dislike Moderately	=(C)
OV= Oven Dried	Like Moderately = (G) Dislike Very Much	=(B)
PB = Polythene Bag	Like Slightly = (F) Dislike Extremely	= (A)
PC = Plastic Container	Not Like Nor Dislike = E	

CHAPTER FIVE
DISCUSSION

5.1 Chemical Composition

5.1.1 Effect of drying methods and packaging materials on moisture content of dried onions

The moisture of dried samples was significantly difference(P O 05) among all the three drying methods During the storage period shade dried sample the highest mean value of 22 58% while sun dried sample and oven dried sample recorded the least mean value at 21 96% and 21 67% respectively at four weeks On the other hand, polythene bag recorded the lowest value of moisture percentage with 15 50% while plastic container recorded the highest mean at twelve weeks and this could be attributed to the low density of PC than PB as a result of migration of moisture from the storage environment to the packaging materials This results agreed with that of Brice ci’ at (2016), that the polythene bag recorded the lowest value of moisture percentage while plastic container recorded the highest mean at twelve weeks and this could be attributed to the low density of PC than PB as a result of migration of moisture from the storage environment to the packaging materials.

5.1.2 Effect of drying methods and packaging materials on protein content of dried onions

The protein content of shade dried sample recorded the highest mean values with **5** 50% and 6 57% while sun dried sample recorded the least mean values with **5 50%** and 5 40% at four and twelve weeks This may be attributed to the enclosed drying environment and lower drying temperature of shade dried sample On the other hand, Likewise, the interaction between shade dried and polythene bag and as well as sun dried and polythene bag samples recorded the highest mean values with while the interaction between oven dried and polythene bag and as well as oven dried and plastic container recorded least mean values at 12 weeks and the result showed significant difference (PS0.05). This results is in agreement with that of Mota *et al*., (2010), whose study recorded that there are effects of drying methods and packaging materials on protein contents of dried onions

5.1.3 Effect of drying methods and packaging materials on ash content of dried onions

The effect of drying methods and packaging materials on ash content of dried onions result showed that there was increase of ash content as the drying temperature increase and this result in agreement with the findings of Hassan ci at (2007) who reported that ash content increases as the drying temperature increased, but the result disagreed with Morris **ci at** (2004) who reported that the decrease in ash content could be as a result of moisture removal which tends to increase the concentration of other nutrients. Sun dried polythene bag sample recorded the highest value with 18.67% which differ significantly (PS0.05) from sun dried plastic container with 6.53%. The interaction between shade dried and oven dried sample recorded the lowest mean value with 8.00% and 5.33%respectivtily which differ significantly from interaction of sun dried that recorded the highest value with 12.60% at 12 weeks. This study agrees with Hassan ci at (2007) who recorded that the ash content of onion is affected due to the drying methods and packaging materials.

5.1.4 Effect of drying methods and packaging materials on fiber content of dried onions

The fiber content of all the drying method in polythene bags sample had highest mean had value them the plastic sensation followed by sun dried sample with 40.65% while the sun dried sample recorded the least mean value with 3.93%. The result showed less significant difference (P 0.05) among all the three drying methods. But all the three drying methods differ significantly which shows that Shade Dried Polythene Bags Dried sample recorded the highest fiber content with 7.0% followed by 5.47 and **5.03%** for sun and oven dried plastic container samples at twelve weeks respectively while the interaction between shade dried and plastic container and sun dried and plastic container recorded the least mean values with 2.03% and 2.38% at four and twelve weeks respectively. This results is in agreement with that of ldah **et** at (2007), whose study recorded that there are effects of drying methods and packaging materials on fiber contents of dried onions.

5.1.5 Effect of drying methods and packaging materials on lipid content of dried onions.

The percentage of lipid content decreases as the drying temperature increased, this result showed less significant difference ($P \leq 0.05$) among the drying methods at initial stage but all the drying methods differ significantly from each other. The oven dried sample recorded the highest value with 1.10 % while sun dried and oven dried sample recorded

0.76% and 0.86%. This result agreed with finding of Chou (2001) who reported decrease of lipids content in spinach due to the application of heat that is capable of destroying them. All the two packaging materials recorded similar value with 2.88% at four weeks but at twelve weeks there was significant difference (P≤0.05) among the two packaging materials.

5.1.6 Effect of drying methods and packaging materials on carbohydrate content of dried onions

The carbohydrate content increases as the drying temperature increased, the oven dried sample recorded the highest mean value with 63.30% followed by 56.4% and 63.04% for oven, sun and shade drying 12 weeks respectively. This result showed less significant difference (P≤0.05) between oven dried and sun dried samples, but there was less significant difference between oven dried and shade dried. Fruits and vegetable have poor source of carbohydrate at fresh form. However, after drying, the carbohydrate content of vegetables increases as reported by (Kolawale *et al.*, 2011). This result agreed with Kolawale et al., (2011) reported that low carbohydrate content of fresh vegetables showed that they supply little or no energy value when consumed except when supplanted with other foods. The recorded highest mean value with 66.07% in oven dried polythene bags while the recorded the lowest mean value with 48.23% in sun dried polythene bags.

5.1.7 Effect of drying method and packaging material on dry matter of dried onions

nitrogen and potassium on the mist important materials influencing dry matter contents of onions bulb according to Hansen (2010) the dry mater of onions bulb and composition different in inside the onions depending on the length of storage period. The percentage dry matter content result shows that leave was less significant different (P≤0.05) among the drying methods of and packaging materials. Oven dried, polythene bags have the highest mean value with 89.50% while sun dried polythene bag with 79.07%. The interaction between the SHPC and SUPC show no significant different with 77.20%. The lowest mean value with 75.17 in oven dried and plastic container

5.2 Effect of drying methods and packaging materials on storage stability of dried onions

The storage period least for twelve weeks in polythene bag and plastic container During the storage time, samples were evaluated for colour, taste, aroma, consistency and as well as overall acceptability There was less significant difference ($P \leq 0$ 05) among the drying methods and packaging materials on the overall acceptability, at four, eight and twelve weeks respectively Similarly, there was less significant difference on aroma and taste between the interaction at four and twelve weeks respectively But the interaction between shade dried and plastic container, oven dried and plastic container and as well as sun dried and plastic container recorded highest mean values with 8.07% and 8.03% equally on colour and taste at twelve weeks respectively On the other hand, oven dried plastic container hand the recorded lowest mean value with 5.33% at twelve weeks

5.2.1 Effect of drying methods and packaging materials on colour of dried onions

Colour is an important attribute because it is usually the first physical property that the consumer observes, retention of food colour after some processing may be used to predict the extent of quality or deterioration of food resulting from exposure to heat Bhomic and Shin, (2015) Orishagbeme *et al.*, (2000) reported that, for good desirable colour quality, the over ripened and under ripened fruits resulted in off colour and off flavour after processing The degree of ripeness of the fruit prior to drying affects the final colour of dried products In this result agreed with Salunlche *et al.*, (2009) reported that rapid loss of colour of fruits and vegetables was attributed to their exposure to atmospheric gasses which result in fading out the desirable colour. At four weeks, sun dried plastic container has the highest mean 8.1 and oven dried and shade dried samples have less mean value of 7.2 and 7.7 respectively.

But all the three drying methods have different mean value of shade dried with 8 0 and sun dried 7 4 while oven dried 7 2 after twelve weeks of storage and this could be attributed the exposure of onions fruits to salt treatment prior to drying Moreover, the odourless and static chemical property of plastic that ensures unimpaired taste and colour of the content make it advantageous for food packaging. Likewise, the interaction between shade dried and glass as well as sun dried and glass recorded the highest and equal mean value of 8.00 at four weeks of storage, shade dried and polythene bag, sun dried and polythene bag and as well as oven dried and polythene bag recorded the least and equal mean value of 7.00 at four weeks of storage

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

The harvested onions fruits were subjected to three different drying methods (shade, sun and oven) and two packaging materials (polythene bag, and plastic container) at the department of crop production and horticulture while the physical and chemical analysis was conducted at the department of food science and technology, and Fisheries, Modibbo Adama University of Technology, Yola, Adamawa state. Food drying is one of the method that is used to preserve some perishable agricultural produce; in order to ensure their availability almost all year round, and to reduce postharvest losses and achieve food security.

6.2 Conclusion

In this study, the various drying methods used were capable of preserving the nutrients in the food crops without total loss of any nutrient. Shade dried and oven dried samples were found to be more nutritive, on the other hand, oven drying and sun drying were faster than the shade drying method. Oven drying was more cost effective and gave the lowest moisture content in this study, suggesting higher capacity to prevent microbial growth and decay in the dried samples, thus confers a greater increase in shelf-life on the dried samples. On the other hand, plastic container packaging was found to be better in terms of maintaining physical and chemical properties of the dried samples followed by polythene bags. 6 3 Recommendations

It is therefore, recommended that;

1. There is need to process and preserve onions during it peak period so as to make it availability almost all year round.

2. The use of shade or oven drying and glass jar or plastic container should be adopted for proper preservation of nutritive value.

3. Onions for immediate processing should be harvested at fully ripe stage and free from decay and disease for better quality during processing and storage.

4. Further studies should be carried out on the factors that affect the storability of both dried onions for its availability to the increasing demand

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APPENDECIES

APPENDIX 1:Specimen Evaluation Sheet for Effect of Some Drying Methods And Packaging on the Nutritional Values Of Onions (Alliums cepa cv bombayred onions) Bulbs Samples

Name:………………………………………………. Date ……………………………….

You are presented with coded samples of stew, please you are to assess each at a time and score the degree of difference using the scale below

Like Extremely = (1)

Like Very Much = (H)

Like Moderately = (G)

Like Slightly = (F)

Not Like Nor Dislike = (E)

Dislike Slightly = (D)

Dislike Moderately = (C)

Dislike Very Much = (B)

Dislike Extremely = (A)

ATTRIBTE	A	B	C	D	E	F	G	H
Colour								
Consistency								
Taste								
Aroma								
Overall Acceptability								

APPENDIX II: Effect of Drying Methods on Functional Properties of Dried onions at Initial Stage

Samples	Water Absorption Capacity (sg/ml)	Bulk Density (g.ml
SH	13.4	0.60
SU	2.77	0.61
OV	3.20	0.63

KEYS:

SH = Shade Dried

SU = Sun Dried

OV = Oven Dried

APPENDIX III: Mean square from the analysis of variance for chemical composition dried onions

SOURCE OF VARIATION	DF	%MC	%ASH	%FIBER	%PROTEIN	%CHO	%DM	LIPID
Treatment	5	14.339*	88.317**	11.207**	1.394**	124.972**	78.949**	0.105**
Error	12	0.128	0.109	0.077	0.063	5.149	0.412	0.004

**Highly significant * Significant

KEYS:

SH = Shade Dried

SU = Sun Dried

OV = Oven Dried

PB = Polythene Bag

PC =Plastic Container

APPENDIX IV: Mean square Aroma Analysis of Variance of Sensory Evaluation of Dried Onions

Source of variation	Aroma	Colour	Taste	Texture	O/A
Treatment	0.190	0.510	0.476	0.510	0.101
Error	0.095	0.76	0.307	0.045	0.115

KEYS:

SH = Shade Dried

SU = Sun Dried

OV = Oven Dried

PB = Polythene Bag

PC =Plastic Container

Like Extremely = (I)

Like Very Much =(H)

Like Moderately =(G)

Like Slightly =(F)

Not like Nor Dislike =(E)

Dislike Slightly =(D)

Dislike Moderately =(C)

Dislike Very Much =(B)

Dislike Extremely =(A)