# EFFECT OF PACKAGING MATERIALS/METHODS ON THE STORAGE OF FRUITS AND VEGETABLES IN A PASSIVE EVAPORATIVE COOLER

*BY*

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# DECLARATION

I, Sunmonu, Musliu Olushola, hereby declare that this project is an original work of mine, and has never been presented elsewhere for the award of any degree. Information derived from published works of others been acknowledged in the write – up.

7/02/07

Sunmonu, Musliu Olushola — Date

## CERTIFICATION

This thesis titled "Effect of Packaging Materials/Methods on the Storage Of Fruit and Vegetables in a Passive Evaporative Cooler'' by Sunmonu, Musliu Olushola (M.ENG/S.E.E.T/2003/999)meets the regulations governing the award of the degree of masters in Engineering (M.ENG) of the Federal Univ ersity of Technology, Minna, and it is approved for its contribution to Scientific knowledge and literary presentation.

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# DEDICATION

This project is dedicated to

My Mother

Alhaja Arinola Nimatallahi Sunmonu

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## ABSTRACT

A study was conducted to assess the effect of packaging materials/methods on the storage of fruits and vegetables in a passive evaporative cooler. Garden egg, banana and tomato were used in this experiment. The produce were stored inside a perforated plastic container and sisal sack before putting them inside the cooler and the result obtained was compared with that of the control in which the produce were stored ordinarily inside the cooler. The shelf life and qualities of the stored produce in the perforated plastic container was much longer and higher than the produce in the sisal sack and the control.. The average temperature of 24.0°C, 24.35°C, 24.80°C, 28.82°C and relative humidity of 88.87%, 88.68%, 86.67% and 69.41% were recorded for perforated plastic container, control, sisal and the ambient respectively. The packaging of produce in perforated plastic container minimizes decay (2.1%) for all stored produce than the control and the sisal sack (9.32% and 8.63% respectively). Also the packaging of produce inside the perforated plastic container retained the highest amount of vitamin c content (13.1%) for all stored produce than the control and the sisal sack (12.5% and 11.7% respectively). A 3 x 3 factorial complete randomized design & F - LSD show that the packaging materials have so significant effect ($p \leq 0.05$) on the stored produce. It can be concluded from this study that storage with perforated plastic container is the best packaging method of storing fruits and vegetables because the storage of fruits and vegetables in this condition loses very little of their qualities as a result of low temperature and high relative humidity in the system.

# CHAPTER ONE
# INTRODUCTION

## 1.1 General Background

Temperature and relative humidity are the most important environmental factors which influence the deterioration rate of harvested perishable crops such as fruits and vegetables. Harvested fruits are living organs; they continue to respire and loose water as if they were still attached to the parent plant; the only differences being that losses are not replaced in the post harvest environment. They therefore, change after harvest. These changes include the utilization of energy reserves through respiration, changes in texture associated with both water loss and biochemical change and the increased ethylene production associated with the ripening of climacteric fruits (Mistral, 1997).

According to Desrosier and Desrosier (1997), fruits and vegetables can maintain an independent existence when detached from the tree or vine. The length of storage is a function of compositions, resistance to attack by microorganisms, the external conditions of temperature and the gasses in the environment.

The evaporative cooler works on the principle of cooling resulting from evaporation of water from the surface of structures. The cooling achieved from this device also results in high relative humidity of the air in the chamber from which the evaporation takes place relative to the ambient air. The atmosphere in the inner chamber therefore becomes more conducive for fruits and vegetables storage. The growth and metabolism of microorganism is slowed down and if the temperature is low enough, growth of all microorganisms virtually ceases.

## 1.2 Mode of Operation of the Evaporative Cooling System

The cold storage system for perishable crops is based on the water cooling system to cool the storage chamber. Water is supplied from the storage tank to a pipe with a gate valve attached to this pipe. As the valve is opened, water flows through the distributions (pipes) placed over the soil to allow for constant flow of water into the soil. The water gets out of the system through the outlets created underneath of the housing. The outcome flow rate is lower and this was done to done to allow for more water retention in the soil. This process is continuous; as the water moves out, it carries along the heat present inside the storage system, hence lowering the internal temperature of the storage chamber of the cold storage system. The cooling achieved by the device resulted in high relative humidity of the air in the chamber, from where the evaporation takes place relative to ambient air. This system also allows for evaporation of water through the surface of soil and as a result the chamber becomes more conducive for fruits and vegetables storage (NSPRI, 1990) as reported by Owuye (1998).

## 1.3 Flowchart Analysis of the System

The pressure inside the storage tank is high because of the height of the tank and also due to the atmospheric pressure acting on the tank. As a result of these, there is going to be a pressure increase before the opening of the valve. Once the valve is opened, water flows through the pipes with pressure decrease at each joint (head loss experienced). The pressure inside the pipes will also be decreased because of the perforations done underneath the pipe in the storage chamber.

The initial velocity of flow will be zero before the opening of the valve but decreases along the pipes due to the presence of joints at various points. The flow will however be uniform as the water gets to the pipes on the storage chamber due to the perforations done on the pipes. The excess water flows out as the soil is saturated through the outlets constructed underneath the housing (Figure 1).

The best technical method of preserving perishable crops is through the use of refrigeration, which supplies low temperature and high relative humidity space for perishable crops. Refrigeration involves mechanical components, electricity and/or other forms of energy input. However, because refrigerator system is rather complex, energy intensive and expensive to purchase and also difficult to operate and maintain, its application for fresh perishable crops storage is thus not feasible under the prevailing socio–economic status of the rural remote areas. This therefore necessitates the need for the development of an alternative, inexpensive and easy to operate cooling system without electricity for preserving the various types of perishable crops produced by the several small-scale farmers.

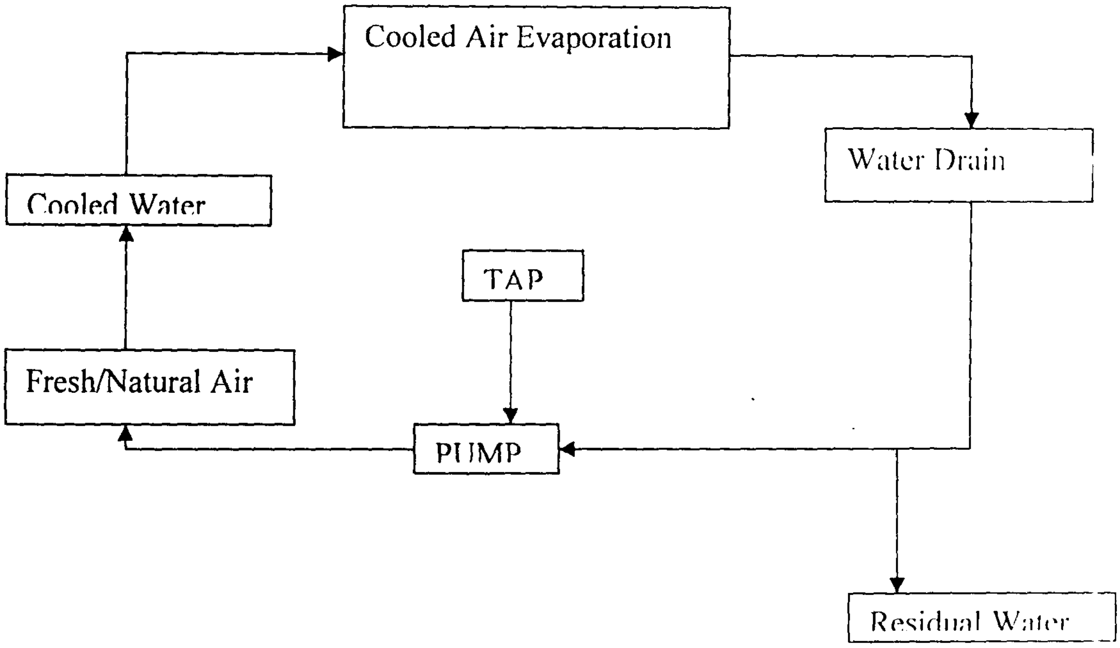



Figure 1: Flowchart of the evaporative cooler

The cold storage of nearly all foods, fresh or preserved is beneficial to the retention of quality. Unrefrigerated fruits or vegetables usually spoil rapidly and soon, it has little food value for man. If similar fruits and vegetables are held temporarily in cool storage, life processes are retarded but the net result is a longer period in which the food is acceptable for man to eat. It could be expected that cold storage will make extremely perishable foods non-perishable. Although cooling increases production cost, it is essential to maintaining high product quality. No amount of cooling however, will improve poor quality produce. If high quality produce is desired after cooling and storage, it is essential to start with high quality produce.

Maintaining quality requires harvesting the crops at the correct stage, handling it with tender, loving care and quickly cooling it to the proper storage temperature. A method of achieving low temperature in a space is to bring it in thermal contact with a cooler substance. This can be done by the application of cooling system (Heat transfer medium). Heat from any region can be carried away by constant supply of cold substance around the region.

## 1.4 Benefits of Cooling Systems

Most fruits and vegetables have a very limited life after harvest if held at normal harvesting temperature. Post harvest cooling rapidly removes field heat, allowing longer storage period. In addition to helping maintain quality, post harvest cooling also provides marketing flexibility and allowing the grower to sell produce at the most appropriate time. Having cooling and storage facilities makes it necessary to market the produce immediately after harvest. This can be an advantage to growers who supply restaurants and grocery stores or to small growers who wants to assemble truckload lots for shipment. Post harvest cooling is essential to delivering produce of the highest possible quality to the consumer.

## 1.5 Objectives of the Study

The objectives of the work reported herein are:

(1) To design and develop a cold storage system for perishable crops.

(2) To carry out the performance evaluation (sensory Analysis) of selected fruits and vegetables stored in various packaging materials inside the system under a prevailing temperature and relative humidity.

(3) Determination of the decay, weight and vitamin C content of the fruits inside various packaging materials.

## 1.6 Justification of the Study

A perishable cold storage system cannot be regarded as a substitute for the ordinary refrigerator but it will be found extremely useful by those who do not possess this appliance, since it will provides a means of storing perishable crops such as fruits and vegetables at a temperature below that of the surrounding atmosphere.

# CHAPTER TWO

# LITERATURE REVIEW

In cold regions, the low temperature prevailing there helps to prolong the keeping quality of perishable food. Fresh fruits and vegetables have a short storage under normal ambient conditions of temperature and relative humidity. Being of highly perishable nature, they soon lose their freshness and become subject to mould and bacteria and bacteria attack and consequently decay and become useless as articles of human food. Since biochemical and microbial changes are slow at low temperature, fresh food and vegetables can be stored for comparatively long period under refrigeration storage.

## 2.1 Economic Importance of Fruits and Vegetables

Daughty (1995) made an important distinction between fruits and vegetables on the usage basis. Those plants item that are generally eaten with the main course of a meal are considered to be vegetables while those that are commonly eaten as desert is considered fruits. Osagie and Eka (1998) reported that fruits are seed, containing organs found in the ripened ovary of a flower. They are the parts of plants that produce seeds. Majority of fruits are fleshy or juicy. Also there are botanically dry fruits which include cereals, grains, nuts and legumes pods. All these form about 4% of the world's food supply and form integral parts of African diet. These are consumed as relishes and snacks and found to be rich in vitamins, especially vitamin C, fats and sugars.

Despite this, fruits have not been given a pride of place in the diet of Nigerians. The main reason for neglect is ignorance of the nutritive values of most of fruits which abound in our environment. Other reasons include the rising cost of fruits, problems of storage of perishable commonly and that of distribution. The estimation of the nutritional values and economic importance of fruits and vegetables in Africa generally and West Africa in particular was reported by Osagie and Eka (1998). They reported that most fresh fruits and vegetables are high in water content at maturity, fresh fruits have 80–90% of water while moisture content of green leafy vegetables ranges from 72% in cassava leaves to 92% in Indian spinach and waterleaf.

Fruits when consumed in good qualities could supply about 9% of calories in the diet; provide about 92% of vitamin C, 49% of vitamin A and 30% of vitamin B6. The carbohydrate content ranges between 5.1 and 23g/100g dry matter. The main sugars in fruits are glucose, fructose and sucrose. For example, banana (*Musa sapientum*) contains 5.82g%, 3.78g% and 6.58g% for glucose, fructose and sucrose respectively. Also, protein (total nitrogen X 6.25) varies from approximately 0.4 – 0.6g% in water melon, pawpaw, grape fruits to more than 1% in avocado–pear, tomatoes and banana. High value of fat between 17g% to 20g% for such only fruits such as avocado pear is reported and mineral rich fruits include strawberries, cherries, peaches and raspberries. Important quantities of potassium (K) give a high dietetic value to fruits and to their processed products.

On the account of low carbohydrate and consequently low calorific value. fruits are usually recommended for weight reducing formulas as well as providing energy for convalescing patients who most often lack appetite during the period of ill health. These researchers concluded that green leafy vegetables constitutes an indispensable constituent oh human diet in Africa generally and West Africa in particular. Generally, they are consumed as cooked complements to the major staples like cassava, cocoyam, guinea corn e.t.c. Indeed, most of the meals based on these staples are considered incomplete without a generous serving of cooked green leaves. The variety of green leafy vegetables so utilize are as diverse as both the staples with which they are consumed and the localities. It has for example been estimated that per harps over sixty species of green leafy daily consumption of fresh vegetables in Nigerian is 360g. Fresh leafy vegetables are very good sources of dietary energy, have crude protein ranging from 1.5% to 1.7%, 75% of total nitrogen in most vegetables is protein, they are very low in sulphur amino acids, and are well known to be poor sources of fat, low in sodium, relatively high in potassium and sulphur.

Daughty (1995) reported vegetables to be richer in mineral substance as compared with fruits. This mineral substance content is normally between 0.60% and 1.80% and more than 60 elements are present in vegetables such as spinach. carrots, cabbage and tomatoes. Green leafy vegetables are good sources of vitamin C. The major antinutritional factors commonly found in green leafy vegetables are phytic acid and oxalic acid, which are significant consequences on the nutritive value of the materials. Daughty (1995) estimated the percentage composition of edible portion of some fruits and vegetables (Table 2. 1).

## 2.2 Nutritional Value of Fruits and Vegetables

Though tropical fruits are generally poor source of proteins and lipids, they provide notable amounts of amino acids (tryptophan, methionine, lysine), ascorbic acid (and other organic acids such as malic and tartaric acid), carotenes and peptic substances, as well as more complex polymers such as lignin). Tropical fruits with high starch content such as plantains and breadfruit comprise an entirely different dietary niche.

Vegetables have little or no calorie value, they are very important as a supplementary nutrition in addition to the main food. The latter which usually consist of cereals and tuber furnish 70% or more of the total calories and the major nutrient requirement. These are poor in vitamins and mineral elements which are readily supplied by fruits and vegetables (Macrae *et al*, 1997).

## 2.3 Effect of Storage Condition on Fruits and Vegetables

Mitra (1997) reported that harvested fruits are living organs; they continue to respire and lose water as if they suffer detrimental changes after harvest. These changes include the utilization of energy reserves through respiration; changes in biochemical composition; changes in texture associated with both water loss and biochemical changes; and the increase ethylene production associated with the ripening of climacteric fruit.

**Table 2.1: Composition of Edible Portion of Some Fruits and Vegetables**

| | Carbohydrates | Protein | Fat | Fibre | Ash | Vit.C | Water |
|---|---|---|---|---|---|---|---|
| **Vegetables: -** | | | | | | | |
| Carrots | 9.1 | 1.1 | 0.2 | 1.20 | 1.0 | 0.8 | 88.6 |
| Tomatoes | 2.50 | 0.60 | 0.10 | 1.50 | 0.40 | 0.20 | 95.90 |
| Radishes | 4.2 | 1.1 | 0.1 | 0.70 | 0.9 | 0.16 | 93.7 |
| Garden egg | 12.90 | 0.73 | 0.10 | 0.69 | 0.40 | 0.17 | 85.0 |
| Asparagus | 4.1 | 2.1 | 0.2 | 0.20 | 0.7 | 0.56 | 92.7 |
| Beans, snap | 7.6 | 2.4 | 0.2 | 1.00 | 0.7 | 0.15 | 89.1 |
| Green peas | 17.0 | 6.7 | 0.4 | 0.90 | 0.9 | 1.00 | 75.0 |
| Fresh lettuces | 2.8 | 1.3 | 0.2 | 0.50 | 0.9 | 0.30 | 94.9 |
| **Earth Vegetable: -** | | | | | | | |
| Potatoes white | 18.9 | 2.0 | 0.1 | 1.10 | 1.0 | 0.10 | 78 |
| Sweet potatoes | 27.3 | 1.3 | 0.4 | 1.20 | 1.0 | 0.09 | 70 |
| **Fruits: -** | | | | | | | |
| Banana | 29.0 | 1.35 | 0.15 | 0.48 | 1.00 | 0.05 | 70.15 |
| Orange | | 11.3 | 0.9 | | 0.2 | 0.60 | 87.1 |
| Apple | 8.0 | 15.0 | 0.3 | 0.70 | 0.4 | 1.30 | 84.0 |
| Strawberries | | 8.3 | 0.8 | | 0.5 | | 89.9 |

*All values are expressed in percentage except Vitamin C which is in mg/100ml*

Source: Daughty (1995)

Osagie and Eka (1998) reported that the vegetables begins to decline as soon as they are harvested, the rate repenting partly on their introits storage potential and partly on environmental conditions. The most characteristics aspect of senescence in vegetables is the loss of chlorophyll and resultant yellowing of tissue. The presence of ethylene whether from the vegetable itself or from an external source hastens storage on the leafy vegetable (*Telgaria occidentalis* and *Prenocarpus soyauxii*) at ambient (30 –35$^{o}$C) and temperature 10$^{o}$C are reported. There were decreases in the chlorophyll, protein and ascorbic acid contents in the stressed leaves.

Under the effect of storage conditions on fruits and vegetables, there is another criterion to be considered in achieving the quality of the produce. Stuart (1997) reported that qualities of fruits and vegetable is a function of many attributes which involved flavour, aroma, texture, firmness, size, shape and appearance. Croshy (1981) ascertain that the method of package is a factor that needed to be considered on the quality of stored fruits and vegetables. This determines some of the function attributed together to achieve the quality of fruits and vegetables in storage.

## 2.4 Brief Descriptions of Some Fruits and Vegetables

### 2.4.1 Garden Egg (*Solanum Sp.)*

There are two varieties of garden eggs namely *Solanum incantum L* and *Solanum melongena L*. However, for the purpose of this experiment the former, which is the locally grown in Minna, was used.

**(a) Common names**

The common names include local garden eggs, bitter tomatoe (English). Jakatoo, Egbe, Igbo, Ikam (West Africa).

**(b) Cultivars**

This species is often referred to as a wild form of the cultivated garden eggs. *Solanum meleongena L.* Two main cultivars are grown in West Africa: one has a sweet taste and the other a bitter taste. It is native to West Africa where it is grown as a local form of garden egg or aubergine.

**(c) Storage condition**

Garden egg cannot be expected to keep satisfactorily in storage for more than about 10 days. The optimum storage temperature is 10°C or slightly lower and it requires a relative humidity of between 85 and 90% for proper storage. Chilling injury has been noted at temperature of 4°C or lower in 4 – 8 days (Pantastico, 1975).

### 2.4.2 Tomatoes (*Lycopersicon esculentum*)

**(a) Common names**

Its common names include Tomato, Love apple (English), Tomate (French), Tomate (Spanish) and Tomati (Yoruba) among others.

**(b) Varieties and cultivars**

Common varieties include Cerasiforme (Dun) Alef (cherry tomato), grandifolium, and pyriforme Alef (pear tomato). However, the variety used in this experiment is the cherry tomato.

Cultivars may be determinate or indeterminate in growth, variable in size, colour, shape, flavour, vitamin content, and degree of resistance to leaf and root diseases (Tindal, 1983).

### (c) Areas of cultivation

Tomato is cultivated in Tropical Asia (India, Malaysia, Indonesia, The Philippines), Central, East and West Africa, Tropical America, The Caribbean (Haiti, Trinidad, Puerto Rico; and throughout the tropics (Tindal, 1983).

### (d) Storage condition

Tomatoes are usually harvested when green (mature green) or partly coloured. The objective in storage after harvest is to control the rate of ripening. Temperature below 10°C in the field or in storage may result in damage caused by chilling injury. At 10°C the rate of colour change and the development of such effects as uneven colouring, pitting, break down and poor flavour are much reduced (Pantastico, 1975).

A storage temperature of 13°C is recommended for slow ripening. At this temperature most cultivars can be kept in good condition for 2–6 weeks and change colour very slowly. At 15°C the rate of colour change increases quite sharply, and above 21°C the rate of maturation and other changes are increased. Temperatures of 21°C or higher induce rapid ripening and bring about changes in colour, softening, and flavour. When tomatoes are fully ripe, the holding time can be increased by reducing the temperature to 10°C. Some experiments have shown that the ripe tomatoes can be held satisfactorily at 0–4°C. It is generally considered hazardous to hold ripe tomatoes in storage for more than a few days. It also requires a relative humidity of between 85 and 90% for proper storage (Pantastico, 1975).

### 2.4.3 Banana (*Musa sp.*)

Banana is a staple food of several African tribes in Tanzania, Nigeria, Uganda among others; and it occurs in many varieties. The family comprises about thirty species of wild and cultivated types. The following are the commonest cultivated type in West Africa.

**(a) *Musa sapientum***

It grows to height of 5 to 6 metres. It is characterized by the compactness of the branch. It is the variety used in this experiment.

**(b) *Musa cavendishi***

These dwarf bananas grow to a height of 150 – 240cm. The fruit has thinner skin than *M. sapientum* and fingers often stand at right angles to the peduncle.

## 2.5 Quality of Fruits and Vegetables

The criterion used by consumers to judge the acceptability of a food is the quality of the food. Quality is a complex function of many attributes of food. For fruit or vegetable, it will typically involve flavour and aroma, texture and firmness, size, shape and appearance. Because of the difficulty of specified quality, the concept of a "quality indicator" is often used. This is the application of one or more attributes of a product to indicate storage changes.

The use of quality indicators is not satisfactory in that it does not give a real assessment of quality but it is necessary in experimental work to utilize some objectives and reproductive measurements rather than the nebulous and subjective concept of overall quality. Nevertheless, direct measurement of quality usually by sensory analysis can give valuable practical data provided its limitations are realized (Stuart, 1997).

## 2.6 Classification of Quality Attributes of Fruits and Vegetables.

Quality attributes can be classified as either sensory or hidden attributes.

### 2.6.1 Sensory Attributes

Sensory attributes are those attributes that can be detected with human senses. They are:

#### (a) Appearance

This includes colour, glassiness, size and shape defects. It is often on its appearance a product is accepted or rejected. Therefore good appearance is very important. Colour is an appearance property attributed to the spectral distribution of light while glassiness and transparency are the geometric manner in which the light is reflected and transmitted. Colour and glassiness can be measured by both subjected and objective ways. Having uniform size and shape will give a suitable appearance, facilitate packaging and increase potential. Defects are usually evaluated by the consumer's eye. Many products of light quality in all other respects may be downgraded because of defects (Owuye, 1988).

**(b) Texture**

Texture deals with the sense of feel, that is finger or mouth feel. For finger feel, the main sensory characteristics are fineness, softness and juiciness. For mouth feel, the main sensory characteristics are stickiness and oiliness. Texture is assessed by test paneling (Owuye, 1988).

**(c) Flavour**

This deals with the sense of taste and smell. Flavour is assessed by test paneling (Owuye, 1988).

**(d) Nutritive value**

This is not usually considered in the marketing place. It is usually guided by mandatory regulations (Owuye, 1988).

**(e) Adulterants and Toxicity**

The excessive use of additives in foodstuff can be harmful. Standards provide legal limits for dosage. The classification of undesirable changes that can occur in foods is as shown in Table 2.2.

### 2.6.2 Hidden attributes

Hidden attributes are attributes that cannot be evaluated with human sense but are important to our health.

**Table 2.2: Classification of Undesirable Changes in Foods**

| Attributes | | Undesirable changes |
|---|---|---|
| Texture | a. | Loss of solubility |
| | b. | Loss of water holding capacity. |
| | c. | Toughness |
| | d. | Softening |
| Flavour | a. | Development of rancidity. |
| | b. | Development of cooked flavour. |
| | c. | Development of other off–flavour |
| Colour | a. | Darkening |
| | b. | Bleaching |
| | c. | Development of other off – colour |
| Appearance | a. | Increase in particle size. |
| | b. | Decrease in particle size. |
| | c. | Non–uniformity of particle size. |

Source: Fennena *et al.* (1985).

## 2.8 Concept of Sensory Evaluation

Sensory evaluation/analysis is an important aspect of quality assessment and should be carried out correctly. Sensory analysis/evaluation is used in quality control, evaluation of new products as well as formulation and introduction of new products.

## 2.9 Types of Tests Used in Sensory Evaluation

The followings are the types of tests used in sensory evaluation.

### 2.9.1 Difference Test

Difference test arises where an assessors is assumed if the sample is different from a given control sample or if there are differences between given samples.

### 2.9.2 Preference Test

Preference test occurs where assessors mostly untrained assessors say which of the two given sample or which of a large numbers of sample they prefer.

### 2.9.3 Ranking Test

Sometimes it is necessary to compare several samples at once. In this case, the assessors rank the samples in order of preference of sweetness or strength or whatever the criteria.

### 2.9.4 Scoring Test

Scoring tests require that assessors have had some training. In these tests he assessors score along some kind of scale which is highlighted as follows:

| | |
|---|---|
| Very poor | 1 – 2 |
| Poor | 3 – 4 |
| Fair | 5 – 6 |
| Good | 7 – 8 |
| Very good | 9 – 10 |

## 2.10 Package

Food packaging is an area of specialization on itself and it has many functions. Four of the most important considerations of packaging are the protection of the food, the economy of the package, the convenience of the package and the appearance. According to Croshy (1981), the method of package has very great influences on the quality of produce stored. Most fresh foods need to "breathe" hence the packaging material used for these products must allow ingress of oxygen and respiration of carbon dioxide. Where the material chosen does not permit sufficient gas transfer, the problem can often be solved by incorporation of a few holes punched into the firm. The major packaging materials available in the food industries are textiles and wood, perforated plastic containers, sacks glass, metals, paper and board and flexible films.

### 2.10.1 Requirements Needed During Packaging

The followings are the main requirements needed during packaging of Agricultural products:

(i) The package should not influence the products, for example by migration of toxic compounds, by reaction between the pack and the food and by selection of harmful microorganisms in the package food.

(ii) The package should be economical and resistance to breakage.

(iii) The package should retain food in a convenient form

(iv) Ease of loading and unloading

(v) The package should be aesthetically pleasing with functional size and shape.

(vi) The package should meet any legislative requirements concerning labeling of agricultural products.

(vii) Ease of transportation and minimum total cost.

### 2.10.2 Functions of Packaging

(i) To protect the food to a pre–determined degree of the expected shelf life.

(ii) To advertise the food at the point of sale.

## 2.11 Temperature, Relative Humidity, Moisture Content and Their Relationship in Storage Environment

The important features of the environment which influence the longevity of fresh produce and which are amenable to control are temperature, relative humidity and composition of the atmosphere surrounding the produce. Temperature has the greatest effect on storage life and is conveniently the most readily controlled. Humidity is not readily controlled but can have a considerable effect on deterioration. Not only does it regulate the rate of water loss but it has also been implicates in psychological storage such as scald in apples.

According to Richard and Priester (1986), too low humidity in storage cause shrinking or water loss and too high humidity promotes the growth mould possible spoilage of the product. However, the conservation of most fresh produce is enhanced solely by cooling to the most suitable temperature immediately after harvest. This is because low temperature depresses both the physiological activity of vegetable tissues themselves and any microorganism capable of causing spoilage, hence the storage life as then extended. Proper temperature management can be a very effective tool in ensuring that produce remains in a good condition throughout storage and transportation. Table 2.3 shows the recommended storage condition for a range of tropical and subtropical fruits.

Reducing the temperature slow down metabolism (including respiration) and also ethylene production and action, also delaying changes in the produce and reducing the heat produced from respiration, it also shows water loss and development of pathogens. Table 2.4 shows the recommended storage temperature, relative humidity, storage life expectancy, and highest freezing point of fresh vegetables. The lowest safe temperature changes as fruits ripen, with ripe fruits usually more resistant than unripe to chilling injury.

**Table 2.3: Recommended Storage Conditions For a Range of Tropical and Subtropical Fruits**

| Product | Temperature °C | Relative humidity % | Controlled Atmosphere %$O_2$ | %$CO_2$ |
|---|---|---|---|---|
| Avocado | 7 – 13 | 90 – 95 | 2 – 5 | 3 – 10 |
| Banana | 13 – 14 | 90 -95 | 2 – 5 | 2 – 5 |
| Grape fruit | 10 – 15 | 85 – 90 | 3 – 10 | 5 – 10 |
| Lemon | 10 – 13 | 85 – 95 | 5 – 10 | 0 – 10 |
| Mango | 10 – 14 | 85 – 90 | 2 – 5 | 5 – 10 |
| Orange | 1 – 9 | 85 – 90 | 5 – 10 | 0 – 10 |
| Papaya | 7 – 13 | 85 – 90 | 2 – 5 | 5 – 8 |
| Pineapple | 7 – 13 | 85 – 90 | 2 – 5 | 5 – 10 |

Source: Mitra (1997)

**Table 2.4: Recommended Storage Temperature, Relative Humidity, Storage Life Expectancy and Highest Freezing Point of Fresh Vegetables**

| Vegetables | Temperature (°C) | Relative humidity (%) | Approximate length of storage | Highest freezing point (°C) |
|---|---|---|---|---|
| Garlic | 0 | 70 – 75 | 6 – 8 months | - 0.8 |
| Onions (dry) | 0 | 50 – 70 | 5 – 9 months | - 0.3 |
| Onions (green) | 0 | 95 – 100 | 2 weeks | |
| Peas, green | 0 | 95 – 100 | 1 – 2 weeks | - 1.2 |
| Peppers, sweet | 7.0–10.0 | 85 – 90 | 8 – 10 days | - 0.7 |
| Spinach | 0 | 95 – 100 | 10 – 14 days | - 0.3 |
| Squash (summer) | 7.0–10.0 | 70 – 75 | 2 weeks | - 0.5 |
| Squash (winter) | 7.0–10.0 | 70 – 75 | 6 months | - 0.7 |
| Sweet potatoes | 13.0–16.0 | 85 – 90 | 4 – 6 months | - 1.1 |
| Tomatoes (ripe) | 10.0 | 85 – 90 | 3 – 5 days | - 0.5 |
| Tomatoes (Mature green) | 13.0–16.0 | 85 – 90 | 2 – 6 weeks | - 0.8 |
| Salsify | 0 | 95 – 100 | 2 – 4 months | - 0.9 |
| Lettuce (head) | 0 | 95 – 100 | 2 – 3 weeks | - 0.2 |

Source: Mitra (1997)

The effect of chilling injury also depends on the period of exposure and the specific cultivar and cultural conditions. Commonly chilling injury symptoms in fruits are pitting of the peel, discolouration and water soaking. Table 2.5 shows the effect of temperature on chilling sensitive fruits.

## 2.12 Relationship Between Temperature, Relative Humidity and Moisture Content of Stored Food

Many authors have found that equilibrium moisture content and relative humidity is temperature dependent and sorption curves must be found over a wide range of temperature especially when accuracy is desired (Henderson, 1952; Pixton and Warbuton, 1971 and Labuza, 1980).

Rockland and Nishi (1980) stated that agricultural crops and their products are hygroscope in nature and when exposed to the environment, their moisture content will either increase or decrease until they equilibrate with the environment. During storage, moisture content of stored products is altered by prevailing temperature and relative humidity of the environment, water activities ($a_w$) has been of great importance in influencing biological activities which results in bio degradation. Okunola and Igbeka (2000) ascertained that the effect of dynamic process of water movement during the storage of crops or crop products require considerable attention for optimum storage qualities. The high moisture content of plantain and sweet potato coupled with the hygroscopic nature of biological materials when exposed to humid environment establishes the influence of moisture as an important factor in the maintenance of storage stability.

**Table 2.5: Effects of Temperature on Chilling Sensitive Fruits**

| Temperature (°C) | Effect on product |
|---|---|
| 30 – 35 | High temperature injury |
| 15 – 25 | Optimum ripening range |
| 8 – 14 | Optimum for storage and |
| 0 – 14 | Transport |
| < 0 | Chilling injury |
| | Freezing injury |

Source: Mitra (1997)

Water has been a major constituent of agricultural crops and it ranges between 60– 70% for the crops under investigation (FAO, 1981; Okunola, 1991). Water activity has been generally accepted to be more closely related to the physical, chemical, and biological properties of food that is its total moisture content. According to Labuza (1980), specific changes in colour, aroma, flavour, texture, stability and acceptability of raw and processed food products have been associated with relatively narrow water activities range. However, ambient temperature and relative humidity have great influence on crop products during storage, sharp increase in the inherent temperature of crops in storage is an indicator of the extent of the activities of microorganisms and most chemical reaction taking place. Ambient temperature is recognized as the determinant of moisture content of crops during storage, likewise high equilibrium relative humidity (ERH) of environment has significant influence on stored products determination because of the moisture exchange between the product and the environment, hence, the equilibrium relative humidity (ERH) decrease with increase in temperature and vice–versa (Okunola and Igbeka, 2000).

## 2.13 Cold storage

The storage and shelf–life of most vegetables are extended if they are cooled rapidly say within 10 hours to below 5°C and stored just above freezing (Oyeniran, 1988). The bacteria and moulds that can cause spoilage in fruits and vegetables products grow at a slower rate when temperature is low (Oyeniran, 1988).

Cold storage had made fresh fruits and vegetables which are usually available during the growing season to be on sale through most of the year. Most food is stored at a temperature low enough to retard the growth of bacteria and moulds, but high enough to permit the action of enzymes (the chemicals in food that cause fruit and vegetables to ripen) (Owuye, 1998). The perishable cold storage system can be described as a system developed to cool a storage chamber without incorporating mechanical components as associated with conventional refrigeration. This system would be found extremely useful by those who do not possess these appliances since it will provide a means of storing perishable crops like fruits and vegetables at a temperature below that of the surrounding.

## 2.14 Evaporative Cooling

This is a very good economic substitute in most tropical countries where the hot weather condition makes natural evaporation of water an effective method of achieving a cool and humidified environment. This method has been used successfully in foundries and metal shops, poultry houses, textiles mills, green houses e.t.c (Kordylas, 1990). Ilori (1985) reported that the sprinkler evaporative cooling method when used in vine yards during summer resulted in low air temperature and high relative humidity of the air, low plant temperature and good physiological condition of grapes. Ilori (1985) studied the effect of evaporative cooling on apple bud development and frost resistance. He reported that the method could be valued in spreading harvest date. Adegboyega, (1983) reported the used of evaporative cooling method to preserve some leafy vegetables.

tomatoes, and plantain. This was done in the form of wet pad, natural air convection and forced air convection by using fan. He reported that leafy vegetables kept for about 5 days effectively and green tomatoes free from scars stored for 3 weeks. Evaporative cooling systems are quite inexpensive compared to the modern storage methods and their use is widely spread in the preservation of fruits and vegetables in many regions of the world (Owuye, 1998).

## 2.15 General Description of Evaporative Cooler

Evaporative cooler works on the principle of cooling resulting from evaporation of water from the surface. The cooling achieved by this device also results in high relative humidity of the air in the chamber from which the evaporation takes place relative to ambient air. The atmosphere in the chamber therefore becomes more conducive for fruits and vegetables storage (NSPRI, 1990) as reported by (Owuye, 1998). Active evaporative cooler consists of a fan that blows air through a water-saturated pad. It has a reservoir that occasionally must be filled with water and pump that circulates the water in order to keep the pad wet. Under favourable conditions of humidity and temperature and this brings about cooling effect of evaporative cooler. However, this type of evaporative cooler worked on in this project is passive and therefore involve the flow of natural air which cause water to evaporate and in turn having cooling effect on the inner chamber.

## 2.16 Factors Affecting Evaporative Cooling

A substantial amount of work has been reported in the development of appropriate technology for cooling of fruits and vegetables. A more technical approach may involve the use of expensive equipment with sufficient cooling capacity to remove heat from the produce. For crops which have very short post harvest lives, it is essential to remove the field heat rapidly bringing them to their storage temperature as quickly as possible to obtain the maximum period of storage.

Cooling depends on the exposure of the produce to cooling medium with the rate of cooling being dependent on the product size and density as well as the packaging which may reduce contact with the coolant. The produce may be cooled by placing it in a cool room or it may be allowed to cool during transportation. This does not cool highly perishable produce quickly enough, however, circulation and using open stacking also increase the rate of air flow across the fruit can: although this have a detrimental effect of causing a high moisture loss (Mitra, 1997).

Thompson (1988) reported other principal methods of cooling for fruits: these are forced air cooling and hydro-cooling. In forced air cooling, cold air is forced through the containers of packed produce, thereby, coming into direct contact with the produce. The degree or ventilation directions of air flow through the containers are critical for this method. The rate of cooling can be improved by increasing the air circulation through increased fan capacity or increased ventilation through package design. The increased rate of airflow across the fruit can, however, have the detrimental effect of causing a high water loss. Cooling can also be improved by increasing the temperature differential between air and the fruit and reducing the number of stacks of cartons the air is drawn through. A modification is to draw warm dry air through a wet pad. The evaporation of water from the pods cools and humidities the air, after, which it is forced through the packed produce.

Hydro-cooling uses cold water to remove heat from the warmer produce. This method may be used either as a batch or a flow–through process, but is only suitable for produce capable of withstanding wetting. The cooling rate can be increased by reducing the water temperature; increasing the circulation rate and increasing the period of exposure to the water.

The use of controlled and modification atmosphere is becoming more popular. This is particularly true for tropical and subtropical fruit where the benefit of refrigeration is limited because of chilling injury, atmosphere modification through reducing the concentration of oxygen and increasing the concentration of carbon dioxide helps to retard senescence and ripening by reducing respiration and ethylene production.

Bishop (1996) defined controlled atmosphere storage as "a low oxygen and/or high carbon dioxide atmosphere" created by the sequence of measurements and corrections throughout the storage period, he defines modified atmosphere as an atmosphere of the require compositions created by respiration or mixed and flushed into the product enclosure, the mixture is expected to be maintained over the storage life and no further measurement or control takes place.

In summary, controlled atmosphere storage of fruits and vegetables can be described as a system developing for the storage of fresh fruits and vegetables by the means of regulating the carbon dioxide and oxygen levels within gas tight stores a containers when the fruit and vegetables is enclosed which is slowly permeable to the respiratory gases, for the maintenance or improvement of the post harvest quality and the post harvest life of fresh fruits and vegetables.

A charcoal safe or cooler is another technology developed by B.G. Gundry for the storage of perishable foodstuff such as milk, meat, butter, fruits and vegetables, e.t.c. A charcoal safe consists of a rectangular chamber with walls made of small pieces of charcoal held between two layers of wire netting three inches apart, water from a tank overhead is allowed to percolate through the charcoal so that the latter is kept continuously wet. As the water evaporates from the charcoal, it absorbs heat from the surrounding air while passing through the charcoal wall into the interior of the safe should be above 60°F. In Nigeria, the simplest type of storage involves shading away from the direct sunlight in order to prevent undue temperature rise or excessive moisture. Some of the available technologies developed by National Stored Product Research Institute (NSPRI) for the storage of fruits and vegetables in cold region include:

**(a) Vegetable basket**

Vegetable basket is made of cane basket woven into a rectangular shape. It can be of various sizes. The skeleton is covered with just material both inside and outside. The basket is also provided with a lid. The jute material covering is kept sufficiently moist by wetting with potable water. The fresh leaf vegetable to be kept in the basket has their roots cut off. The basket is rewet when dry as the need be and the vegetable inside does not carry free water.

**(b) Pot – in – pot**

The pot – in – pot type consists of two concentric clay pots interspaced with wet river bed sand. One pot (smaller one) is inserted into the second (bigger one) and the inter space filled with wet river bed pervious sand. The sand is constantly kept saturated by sprinkling water as needed depending on the rate of evaporation. The inner space which soon becomes cooler and more humid than the ambient serves as a cooling for stored tomatoes, mangoes, carrots and oranges.

**(c) Tin – in – pot**

The only difference in pot – in – pot and tin – in – pot is replacement of the inner pot with kerosene tin.

**(d) Wall – in – wall**

Wall – in – wall cooler type consists of a double–walled rectangular brick (or cement block) construction with composite walls with the inter space filled with water saturated river–bed previous sand. The interior surfaces of the cooling chamber wall are plastered with cement while the top carries a heat insulating cover of thick particle board. The walls are built on a short plinth of concrete and one-side wall is provided with an access to door of sawn wood. Shelves are provided in the cooler chamber for fruits and vegetables storage

**(e) Metal – in – wall**

The main difference between the design features of the metal–in– wall cooler and that of the wall–in–wall is that the storage chamber is constructed of 16 gauge galvanized iron sheet forming a cube of sides, 122cm long. The outer walls are built of bricks or cement blocks leaving an interspaced cavity 10cm wide. The cavity is filled with riverbed sand which also covers the cabinet top. Both the chamber metal and the outer wall carry doors of metal and wood respectively.

**(f) Cold room Cooler**

Cold room cooler is also a rectangular double walled constructed of cement blocks. It special features are the provision of large storage capacity of 12.3cm and the provision of water receptacle on the top. The receptacle carries a network of piping for uniform flow distribution of water for wetting the interspacing river bed sand. Access into the storage chamber is through two adjacent doors fixed one to each wall on a side.

**(g) Evaporative Cooler Structure (ESC)**

ESC is developed as a model which consists essentially of an open–top cistern which serves as the storage chamber fabricated from 2mm gauges galvanized sheet metal and measures 6 x 8 x 59.6 x 68.8cm. The fruits holder is a wire basket (it could also be of plastic crates) placed in the storage chamber. During operation, the open top of the storage chamber is covered with a metal tray. The tray has four (4) perforations for ventilation. The cistern is placed in another metal tray similar to the one placed on top but without perforations. To operate this (ECS), the storage-chamber is wrapped with jute material externally but dips into the upper and lower trays. The upper tray is filled with water. The water is conducted to the lower tray overtime or jute materials could be wetted and water from the upper tray replenishes it. Evaporation from the jute material results in cooling the storage chamber and increases the humidity sufficient for fruit and vegetables storage.

## 2.17 Functions, Sources and Uses of vitamin C

Vitamin C also known as ascorbic acid is a water-soluble vitamins that is an essential part of life. In its natural state, ascorbic acid appear in the form of a white to yellowish crystal or powder. Because the vitamin C is water-soluble, it must be regularly replenished and is commonly found in fresh fruits, especially in the citrus family that is dominated by oranges, lemons, limes and tangerines. Other sources include green peppers, tomatoes, and brocolli. Vitamin c is also abundant in green leafy vegetables. The body requires vitamin C to form and maintain bones, blood vessels and skin. It also helps build and maintain tissues and strengthening immune system. Vitamin C activity may be helpful in the prevention of some cancers and cardiovascular diseases (Barber & Barber 2002). Vitamin C protect against heart disease by reducing the stiffness of arteries and tendency of platelets to clump together (Barber & Barber 2002). Individuals with high blood levels of vitamin C have significantly reduced risk of stroke. The risk of stroke was inversely related to vitamin C in the blood stream (Khachik *et al.*, 2002). Table 2.6 shows the relative abundance of vitamin C in some plants.

## 2.18 Dosage, Deficiencies and Side Effects of Vitamin C

The recommended dietary allowance (RDA) for vitamin C in nonsmoking adults is 75mg per day for women and 90mg per day for men. For smokers, the RDAs are 110mg per day for women and 125mg per day for men. Increased intakes of vitamin C are required to maintain normal plasma levels under acute emotional or environmental stress such as fever, infection or elevated environmental temperatures. Full blood and tissue saturation is achieved with daily intakes of 200–500mg per day (Steinmetz, *et al.*, 1996). Ascorbic acid is a relatively fragile molecule and it may be lost from foods during preparation, cooking and/or storage. Although the vitamin occurs in small amounts in animal tissues, it is usually destroyed either by exposure to air or by processing before it reaches the table for consumption. Deficiency symptoms of vitamin C include general weakness, depression, anemia, increased susceptibility to infections, male infertility, scurvy, bleeding gums, rash on the legs, joint and muscle ache (Steimetz *et al.*, 1996). The high doses of vitamin C (more than 2,000mg daily) can cause diarrhea, stomach upset, nausea e.t.c. (Khachik *et al.*, 2002).

**Table 2.6 Relative Abundance of Vitamin C in Some Plants**

| Plant source | Amount |
|---|---|
| Baobab | 400 |
| Red pepper | 190 |
| Guava | 100 |
| Orange | 50 |
| Lemon | 40 |
| Melon | 40 |
| Grapefruit | 30 |
| Tangerine | 30 |
| Spinach | 30 |
| Cabbage raw green | 30 |
| Potato | 20 |
| Mango | 16 |
| Tomato | 10 |
| Pineapple | 10 |
| Pawpaw | 10 |
| Watermelon | 10 |
| Banana | 9 |
| Carrot | 9 |
| Apple | 6 |
| Pear | 4 |
| Lettuce | 4 |
| Cucumber | 3 |
| Eggplant | 2 |

The amount is given in milligrams per 100g of fruits and vegetables.

Source: Kalt *et al.* (1999)

## 2.19 Changes of Vitamin C Content of Some Fruits and Vegetables During Post–Harvest Storage

Several important changes occur in the structure of tomatoes during ripening, such as synthesis of pigments, production of flavour and aroma compounds (Grierson and Kader, 1986). Abushita *et al.* (1997) and Giovanelli *et al.* (1999) reported an increase in ascorbic acid content of tomatoes during their ripening.

The metabolism of tomatoes continues even after their detachments from the plant, when fruits have reached their red stage. They continue to ripen and finally deteriorate to appoint where they become valueless (Yanuriatti *et al.*, 1999). To extend the shelf life of fruits and vegetables, their respiratory metabolism is slowed by low–temperature storage or storage in high carbon dioxide atmosphere (Kalt *et al.*, 1999). Storage of tomatoes and other products of tropical or subtropical origin, at below critical temperatures, predisposes them to chilling injury (Grierson and Kader, 1986; Yanuriatti *et al.*, 1999). Storage of tomatoes at temperatures below 13°C has been reported to have a significant effect on tomato flavour, even before any visual symptoms are seen (Machiex *et al.*, 1990).

Maul *et al.* (2000) observed that, when the light–red tomatoes were stored below 13°C, they were significantly ($p \leq 0.05$) lower in ripe aroma and tomato flavour, and higher in off–flavour compared to tomatoes stored at 20°C. A slightly accumulation of ascorbic acid was observed during storage of tomatoes (Kalt *et* *al.*, 1999). He also observed that no loses in ascorbic acid content during post–harvest storage of strawberries and blueberries. Tomato is a highly acidic fruit and it showed a relatively stable ascorbic content during post–harvest storage (Mapson, 1970). The presence of flavonoids in tomato cells may have helped to maintain the ascorbic acid content (Miller and Rice Evans, 1997). Toor and Savage (2005) also reported that during storage, a slight increase in the level of ascorbic acid occurred in the tomatoes and their possible synergistic interactions may have been responsible for the slight increase. Ramandeep and Geoffrey (2006) also reported that the post–harvest storage of light–red tomatoes does not have any deleterious effect on the total ascorbic acid content of tomatoes.

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.0.0 General

The effect of packaging methods on the storage of fruits and vegetables in a passive evaporative cooler was investigated. A passive evaporative cooler was designed, constructed and its performance evaluated by determining its adiabatic efficiency under no – load and load conditions. The following soil properties were determined for the soil used in the evaporative cooler: moisture content, sieve analysis and coefficient of soil permeability. Garden egg, banana and tomato were packaged in perforated plastic container (PPC), sisal sack (SS) and stored in the evaporative cooler for 8, 14 and 12 days respectively according to the recommended storage period for fruits and vegetables by NSPRI. The perforated plastic container and the sisal sack were chosen because of their ease of loading and unloading, ease of transportation and resistance to breakage and moisture. The control (C) contains the fruits stored in the evaporative cooler without any form of packaging. Mature fresh green banana, garden egg and tomato were harvested from a farm located at Chanchanga area, Minna, Nigeria. Seventy pieces of each of the three fruits were used in the study. The decay, weight and vitamin c content of the fruits were also determined. Sensory evaluation of the stored products was also undertaken. The garden egg, banana and tomato were chosen for the experiment because they are the fruits that are in the season during the September/October period when this experiment was conducted. The temperature and relative humidity in the storage chamber of the cooler were measured daily at 0800H, 1200H and 1700H. The moisture content of the stored products was measured once daily at 0800H. The experiment design was a 3 x 3 factorial in a complete randomized design of 3 replicates. The effect of PPC, SS and C on decay, moisture content and vitamin c of the stored fruits was analyzed using ANOVA at $p \leq 0.05$ and the significant effects further evaluated by the use of F–LSD at $p \leq 0.05$.

### 3.1.0 Evaporative Cooler

Evaporative cooler are generally classified into two: active evaporative cooler and passive evaporative cooler. Active evaporative cooler are those that depend on forced air convection by using fan for evaporation while the passive evaporative coolers are those ones that depend on natural air flow pattern for evaporation. However, this project is based on passive evaporative cooler.

### 3.1.1 Description of Evaporative Cooler

The structure consists of a rectangular box (opened at the top) fabricated from 2mm gauges galvanized sheet metal and measures (1,754 x 0.688 x 0.59) m. This galvanized sheet metal is further enclosed with plywood and measures (1.760 x 0.720 x 0.60) m. The plywood housing is necessary so as to reduce the rays of the sun from acting directly on the galvanized sheet since plywood is a poor conductor of heat. Inside this housing are three box–like structures fabricated from galvanized sheet and inter spaced with loamy sand (0.1m). These box–like structures are the cooling chambers. The floor of the galvanized sheet housing is also under laid with loamy sand as well, which is also 0.01m thick. The fruits were packed inside a perforated plastic container, a sisal sack and stored inside the cooler.

During operation, the open top of the storage chambers is covered with the same material (galvanized sheet) which are further covered with jute sacks to be wetted very often so as to provide a cool atmosphere for the fruits and vegetables. Evaporation from the jute materials result in cooling the storage chambers and this increases the humidity sufficient for fruits and vegetables storage. Its special feature is the provision of large storage tank and connected to this is a network of perforated plastic pipes laid on top of the structure for uniform flow and distribution of water for wetting the interspacing loamy sand. Table 3.1 shows the materials employed in the construction of the evaporative cooling system.

### 3.1.2 Design Analysis of Evaporative Cooler

#### 3.1.2.1 Calculation for Flow Rate/Discharge Through the Pipe

The velocity of flow is calculated from the relation,

$$V = \sqrt{2gh} \qquad \text{equation 3.1}$$

Where g = acceleration due to gravity, $9.8 m/s^2$

h = differential height of water in the pipe 0.30m

Substituting these values in equation 3.1,

$$v = 2.426 m/s$$

**Table 3.1: List of Material Used in the Fabrication of the Evaporative Cooling System**

| S/N | Materials | Dimensions | Quantity | Uses |
|---|---|---|---|---|
| 1. | Galvanized Sheet (guage 22) | 183cm x 122cm | 3 | for the storage chambers and the internal housing |
| 2. | Angle Iron | 2 X 2 | 1 length | stand for the housing |
| 3. | Square pipe | 2 X 2 | 1 length | stand for storage tank |
| 4. | Gate valve | - | 1 | controls flow of water |
| 5. | Elbow joint | ½" | 5 | connects the plastic pipes |
| 6. | T – joint | ½" | 4 | connects the plastic pipes |
| 7. | Plywood | 1" | 2 | for the external housing |
| 8. | Electrode | - | 1 pack | welding the galvanized sheet |
| 9. | Plastic pipe | ½" | 1 length | channels for flow of water |
| 10. | Union connector | - | 4 | connects the plastic pipes |
| 11. | Plastic bucket | - | 1 | storage tank |

Area of the pipe is also calculated from the relation,

$$\text{Area} = \frac{\pi}{4d^2} \qquad \text{equation 3.2}$$

Where d = diameter of the pipe (0.0127m)

$$\text{Therefore, Area} = \frac{\pi}{4(0.0127)^2} = 0.0001267\text{m}^2$$

The discharge Q when the valve is half opened is calculated from the expression

$$\text{Discharge} \quad Q = \frac{\text{Total volume in the tank (cm3)}}{\text{Elapse time (seconds)}} \qquad \text{equation 3.3}$$

$$= \frac{40000}{132} = 303.03\text{cm}^3/\text{secs} = 3.0303\text{m}^3/\text{s}$$

### 3.1.2.2 Calculation for the Quantity Rate of Flow From the Outlet Perforated Section

To obtain the discharge water through the perforated pipes, the following formula can be used,

$$qd = \frac{Q_d}{n} \qquad \text{equation 3.4}$$

Where; n = number of perforations on the pipe = 26

Substituting these values in equation 3.4,

$$qd = \frac{303.03}{26} = 11.6550\text{cm}^3/\text{s} = 0.11650\text{m}^3/\text{s}$$

### 3.1.2.3 Calculation of Pressure or Friction Loss in Pipes

Pressure loss or loss of head may be caused by friction between the moving particles of a fluid and the interior surfaces of a pipe. When a pressure loss occurs in a straight pipe, it is usually classed simply as friction loss. Friction or pressure loss in pipes can be calculated from Weisbach D'arcy equation:

Pressure loss, $$P_f = \frac{4fV^2L}{2D}$$ equation 3.5

Where

| | | |
|---|---|---|
| $P_f$ | = | pressure loss |
| D | = | diameter of the pipe (m), 0.0127m |
| L | = | total length of the pipes (6.12m) |
| V | = | velocity of flow in the pipes (4.011m/s) |

It is important to determine the pattern of flow in the pipe, i.e whether turbulent or laminar flow pattern depending on the Reynolds Number (Re) value which could be obtained from the expression;

$$Re = \frac{DV\rho}{\mu}$$ equation 3.6

Where;

| | | |
|---|---|---|
| D | = | diameter of the pipe, 0.0127m |
| V | = | velocity of flow in the pipe (2.426m/s) |
| ρ | = | density of water, $1000kg/m^3$ |
| μ | = | Viscosity at 0°C ($0.00179NS/m^2$) |

Substituting these values in equation 3.8

$$Re = \frac{0.0127 \times 1000 \times 2.426}{0.00179} = 7212.40$$

This is greater than 4,000, so the flow pattern in the pipe is turbulent. In this condition, the friction coefficient $f$, in the head loss formula can be calculated from the relation,

$$f = \frac{0.136}{4xR_e^{-0.25}} \qquad \text{equation 3.7}$$

$$f = 0.316/4 \text{ X } (17212.40)^{-0.25}$$

$$f = 0.0006$$

Putting this value into the D'arcy–Weisbach equation in equation 3.5, we have

$$P_f = \frac{4\,(0.0006 \text{ X } 6.12 \text{ X } (2.426)^2}{2\,(0.0127)}$$

$$P_f = 3.403\text{J}$$

### 3.1.2.4 Friction Loss in Fittings

A greater pressure loss, per unit of pipe length, may be caused by the excessive friction between particles in the eddy currents following special fittings in which case the term shock loss is usually used. Four types of fittings were used in this application and these are the elbow joint (90° Standard), the tee joint, union connector and the gate valve. Each of them has its own friction loss factor, Ks factor, which are standard for a particular fitting. The Ks factor for the Tee joint, elbow joint, gate valve and union connector are 1.5, 0.74, 0.13 and 0.5 respectively.

Friction loss in fittings can be calculated from the relation

$$Fr = \frac{K_s V^2}{2} \qquad \text{equation 3.8}$$

The total number of Tee joints used in this application is 6,

Therefore, the Ks factor = $6 \text{ X } 1.5 = 9$

Friction loss $F_f$ in Tee joint = $\frac{9 \text{ X } (2.426)^2}{2}$

= 26.48J

The total number of elbow joints used in this application is 4,

Therefore, the Ks factor = $4 \text{ X } 0.74 = 2.96$

Friction loss $F_f$ in elbow joint = $\frac{2.96 \text{ X } (2.426)^2}{2}$

= 8.711J

The total number of gate valve used in this application is 1,

Therefore, the Ks factor = $1 \text{ X } 0.13 = 0.13$

Friction loss $F_f$ in gate valve = $\frac{0.13 \text{ X } (2.426)^2}{2}$

= 0.383J

The total numbers of connector (union) used in this application is 4,

Therefore, the Ks factor = $4 \text{ x } 0.5 = 2$

Friction loss $F_f$ in connector = $\frac{2 \text{ x } (2.426)^2}{2}$

= 5.885J

Total pressure loss in fittings = (26.48 + 8.711 + 0.383 + 5.885)J = 41.459J

The energy required to move 1kg of water against the head of 0.30m is given by:

$$E_p = Zg \qquad \text{equation 3.9}$$

$$= 0.30 \text{ X } 9.81 = 2.943\text{J}$$

Now, the total energy requirement per kg for flow of water in the entire cooling system = Friction loss in pipes + Friction loss in fittings + Energy to move 1kg of water against a head of 0.82m

= (3.403 + 41. 459+ 2.943) J = 47.81J

### 3.1.2.5 Capacity of the Main Cooling Chamber

Each cooling chamber has a length of 0.45m, breadth of 0.45m and height of 0.40m. The volume of each cooling chamber is calculated from the relation:

Volume = length x breadth x height equation 3.10

= 0.45 X 0.45 X 0.40 = $0.81\text{m}^3$

Total capacity of the three cooling chambers = 0.81 X 3= $0.243\text{m}^3$

### 3.1.2.6 Determination of Amount of Water Used

At condition (A) = 0.0078kg/kg of dry air ($W_1$)

At condition (C) = 0.0120kg/kg of dry air ($W_2$)

The amount of water used is given by;

$$= \frac{Q \text{ X } (W_2 - W_1)}{\text{Specific volume}} \qquad \text{equation 3.11}$$

Substituting the values o f W1, $W_2$, Q and specific volume in equation 3.11

$$= \frac{0.47194 \ X (0.0120 - 0.0078)}{0.870}$$

$= 0.002278kg/s \quad = \quad 0.13668kg/min \quad = \quad 8.2008kg/hr$

The above expression signifies that after 1 hour; about 8 litres of water should be added to the water reservoir to ensure continuity of operation of the cooler.

But, 1 gallon = 3.782kg

Therefore, 8kg = 8/ 3.782 = 2.1153gal/hr

For this project work, the design is 10 gallon of water that means;

$$\frac{10}{2.1153} = 4.73 \qquad \text{(Approximately 5 hours)}$$

This implies that when 10 gallons of water is poured into the reservoir, it will take at least 5 hours before more water will be added.

But 4 litres = 1 gallon

40 litres = 10 gallons = $40000cm^3$

The amount of water collected after the stated period of about one hour (3600 seconds) can be calculated from the Darcy's equation.

$$K = \frac{QL}{thA} \qquad \text{equation 3.12}$$

Where;

Q = Total quantity of water collected after passing through soil $m^3$

H = Head difference = 1.091 – 0.30 = 0.791m

L = Length of soil sample, 0.1m

A = Cross sectional area of soil sample, $m^2$

= Cross–sectional area of the Housing – Cross–sectional area of the cooling chambers

= (1.76 X 0.72) – (0.45 X 0.45)3 = $0.6597m^2$

K is the coefficient for permeability of the sandy soil which is $0.245m^{-1}s^{-1}{}^{o}C^{-1}$.

The quantity of water collected after one hour of passing through the soil can be calculated from equation 3.12

$$Q = \frac{tKhA}{L}$$

Substituting the values

$$Q = \frac{3600 \text{ X } 0.245 \text{ X } 0.791 \text{ X } 0.6597}{0.1} = 4602.8cm^3$$

Amount retained in the soil = 8000 – 4602.8 = $3397.2cm^3$

This implies that out of the 8 litres ($8,000cm^3$) added to the soil every hour (3600seconds) about $3397.2cm^3$ is retained in the soil. For a total period of five hours (18000seconds), the quantity of water collected after passing through the soil is given as;

Q = 18000 X 0.245 X 0.791 X 0.6597/ 0.1 = $23012.38cm^3$

Amount retained in the soil = 40000 – 23012.38 = $16987.62cm^3$

This implies that out of the 40 litres ($40000cm^3$) added to the soil every five hours (18000 seconds) about $16987.62cm^3$ is retained in the soil.

#### 3.1.2.7 Heat Transfer Calculations

The rate of heat transfer from the plywood to the soil and finally to the cooling chamber can be calculated from the relation;

$$Q = KA\frac{dT}{dr}$$

equation 3.13

Where; Q = rate of heat transfer, w

K = thermal conductivity, $m^{-1}\ s^{-1}\ {}^{o}C^{-1}$

dT = Temperature difference between the inside and the outside = $33 - 24 = 9^{o}C$

dr = thickness ,m

The length, breadth and height of the cooling chamber are 0.45m, 0.45m and 0.40m respectively (Figure 2).

**(a) Heat Transfer Through the Plywood**

**For Face A**

$$Q = KA\frac{dT}{dr}$$

Thickness for the plywood , dr = 0.015m

Thermal conductivity for plywood, K = $0.28m^{-1}s^{-1}\ {}^{o}C^{-1}$

Area, A = $0.45 \times 0.40 = 0.18m^2$

Substituting the values in equation 3.13;

$$Q = \frac{0.28 \times 0.18 \times 9}{0.015} = 30.24W$$

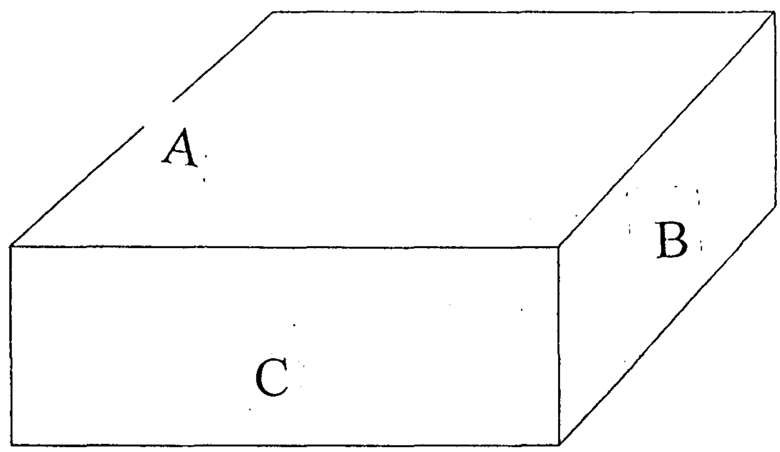



Figure 2: Heat transfer through the faces of evaporative cooler

**For Face B**

$$Q = \frac{0.28 \times 0.18 \times 9}{0.015} = 30.24W$$

**For Face C**

Area = 0.45 x 0.45 = $0.2025m^2$

Therefore,

$$Q = \frac{0.28 \times 0.2025 \times 9}{0.015} = 34.02W$$

## (b) Heat Transfer Through the Galvanized Sheet

The thickness for the galvanized sheet = 0.001m

The thermal conductivity for galvanized sheet = $45Jm^{-1}s^{-1}\,{}^{o}C^{-1}$

dT = 33°C – 24°C = 9°C

**For Face A**

$$Q = \frac{45 \times 0.18 \times 9}{0.001} = 72.900W$$

**For Face B**

$$Q = \frac{45 \times 0.18 \times 9}{0.001} = 72.900W$$

**For Face C**

$$Q = \frac{45 \times 0.2025 \times 9}{0.00} = 82.0125W$$

## (c) Heat Transfer Through the Lagging Material (Loamy Sand)

Thickness of the soil is 0.1m

Permeability K of the soil = $0.245cm^{-1}s^{-1}\,{}^{o}C^{-1}$ = $0.00245\ m^{-1}s^{-1}\,{}^{o}C^{-1}$

**For face A**

Area = 0.45 X 0.40 = $0.18m^2$

$Q = KA\frac{dT}{dr}$ = 0.00245 x 0.18 X 9 / 0.1 = 0.03969w

**For face B**

$Q = KA\frac{dT}{dr}$ = 0.00245 X 0.18 X 9/0.1 = 0.03969w

**For face C**

$Q = KA\frac{dT}{dr}$ Area = 0.45 X 0.45 = $0.2025m^2$

Q = 0.00245 X 0.2025 X 9/ 0.1 = 0.04465w

Total heat transferred =

3(30.24 + 72.900 + 0.03969 + (30.24 + 72.900 + 0.03969 + (34.02 + 82.0125 + 0.04465) w

= 3 (103.1797 + 103.1797 + 116.077) = 967.309w

**3.1.2.1 Construction of Evaporative Cooler:** This is as shown in the engineering drawings attached to this project.

### 3.1.3 Determination of Soil Properties of Evaporative Cooler

### 3.1.3.1 Moisture Content Determination (Initial and Final)

A dry clean can was weighed ($W_1$) and known weight of the soil sample was placed in the can and weighed ($W_2$). The sample with the can was then dried in an oven at 110°C for about 48 hours during which a constant weight is obtained ($W_3$). The percentage moisture content in the soil sample is calculated as follows:

Percentage moisture content $= \frac{W2 - W3}{W2 - W1} x100$ equation 3.14

### 3.1.3.2 Sieve Analysis

About 700g of the soil sample was weighed into an aluminium pan using a balance after which it was poured in the upper test sieve which is fixed to the mechanical shaker to shake it for a minimum of 10 minutes. Finally, the weight of the soil sample in each of the sieve is obtained.

### 3.1.3.4 Determination of Coefficient of Soil Permeability (k) Using Constant–Head Permeameter

The test is generally used to determine the coefficient of permeability values of coarse–grained soils (gravel, sand and coarse silt). The soil is packed into the permeameter and water under a fixed pressure head is passed through the sample. When steady flow has been obtained a quantity of water Q is collected from the outlet in time t. The cross–sectional area of the sample A is known and the hydraulic gradient is measured across a length of sample L using manometer tubes to record the loss of head "h". The calculation of the coefficient of permeability is then obtained by direct use of Darcy's law

$$K = \frac{QL}{Aht}$$ equation 3.15

Where;

Q = total quantity collected in time t

L = distance between tapping points

A = cross – sectional area of the sample

H = difference in level of two standpipes tapped into container

The experiment was repeated three times and their average was taken as the coefficient of permeability of the loamy sand (k).

The constant – head permeameter is shown in Appendix A.

#### 3.1.3.5 Determination of Soil Type

About 250g of soil from horizon A was dried in an oven set at 90°C. The soil crumbs were lightly crushed using a pestle and mortar. The soil was then placed in the top compartment of a set of soil sieves and shake vigorously for several times while the sieves are in the vertical position. The soils left in each compartment were weighed and the percentage of each fraction was calculated using the formula below:

$$\text{Percentage of clay} = \frac{\text{Weight of particles in base}}{\text{Total weight of soil sample}} \times 100$$

$$\text{Percentage of silt} = \frac{\text{Weight of particle at the middle}}{\text{Total weight of soil sample}} \times 100$$

Percentage of sand = 100% - % of clay - % of silt

(See Appendix C)

### 3.1.4 Performance Evaluation of Evaporative Cooler

The efficiency of the cooler is given by Norman (1983) as follows:

$$\text{Percentage efficiency adiabatic} = \frac{DBon - DBoff}{DBon - WBon} x100 \quad \text{equation 3.16}$$

Where; DBon = dry bulb temperature of air entering the cooler

DBoff = dry bulb temperature of air leaving the cooler

WBon = wet bulb temperature of air entering the cooler

The data obtained from the School Meteorological Station for so many years can be used for the design. These are dry bulb, DB = 28 – 34°C,wet bulb, WB = 18 – 19°C and relative humidity = 73%

For the purpose of this design, dry bulb temperature of 30°C and wet bulb temperature of 18°C shall be used.

Efficiency adiabatic = 80% = 0.8 (Norman, 1983)

DBon = 30°C

and WBoff = 18°C

Substituting the values obtained into equation 3.16

$$0.8 = \frac{30 - DBoff}{30 - 18}$$

$$0.8\,(12) = 30 - DBoff$$

$$DBoff = 20.4^{\circ}C \text{ and wet bulb } 18^{\circ}C$$

#### 3.1.4.1 Testing the Performance of the Evaporative Cooling System

After the design and construction of the Evaporative Cooler, it was tested to evaluate the degree to which the cooler could achieve cooling by evaluating the On–load and Off–load efficiencies of the cooler. These efficiencies were obtained by using the digital thermometer to measure the temperature of the air leaving the cooler and the temperature of the thermometer. The performance of the evaporative cooling system can be evaluated using equation 3.16;

$$\text{Efficiency (Adiabatic)} = \frac{DBon - DBoff}{DBon - WBon} x100$$

Where; DBon = dry bulb temperature of air entering the cooler = 33°C

DBoff = dry bulb temperature of air leaving the cooler = 24.5°C

WBon = wet bulb temperature of air entering the cooler = 20°C

Note that these data were obtained during off – load;

Substituting these in the equation;

$$\text{Efficiency adiabatic} = \frac{13-24}{30-20} x100$$

$$= 69.23\%$$

For the on–load efficiency, the following were data obtained;

DBon = dry bulb temperature of air entering the cooler = 33°C

DBoff = dry bulb temperature of air leaving the cooler = 25°C

WBon = wet bulb temperature of air entering the cooler = 21°C

Therefore, on load efficiency $= \frac{33-25}{33-21} x100$
$= 66.7\%$

With the help of Psychrometric Chart analysis of the system air, sensible heat absorbed by the evaporative cooled air is as shown in Figure 3. The diagram explained the heat absorbed in a system with time specification. If 24.5°C of dry bulb temperature is adopted as the system temperature;

Sensible heat absorbed by cooler, HB = 50kJ/kg (At 30°CDB, 18°CWB)

Sensible heat entering the cooler, HC = 55.5kJ/kg (At 27°CDB, 20.4°CWB)

The Total heat removed from the system by the air per kg of cool air HS is calculated as:

HS = HC – HB  equation 3.17

HS = (55.5 – 50) kJ/kg = 5.5kJ/kg

The amount of heat per hour which 1000cfm (0.47194$m^3$/s) of air through the cooler can absorb under the design condition is calculated as follows:

$$H = \frac{Q}{\text{Specific volume}} x \text{ Sensible heat}$$ equation 3:18

$$H = \frac{0.47194}{0.870} x \text{ Sensible heat}$$

$m^3$kg (at condition A)

H = 2.9835kJ/s = 179.01kJ/min = 10740.6kJ/hr.

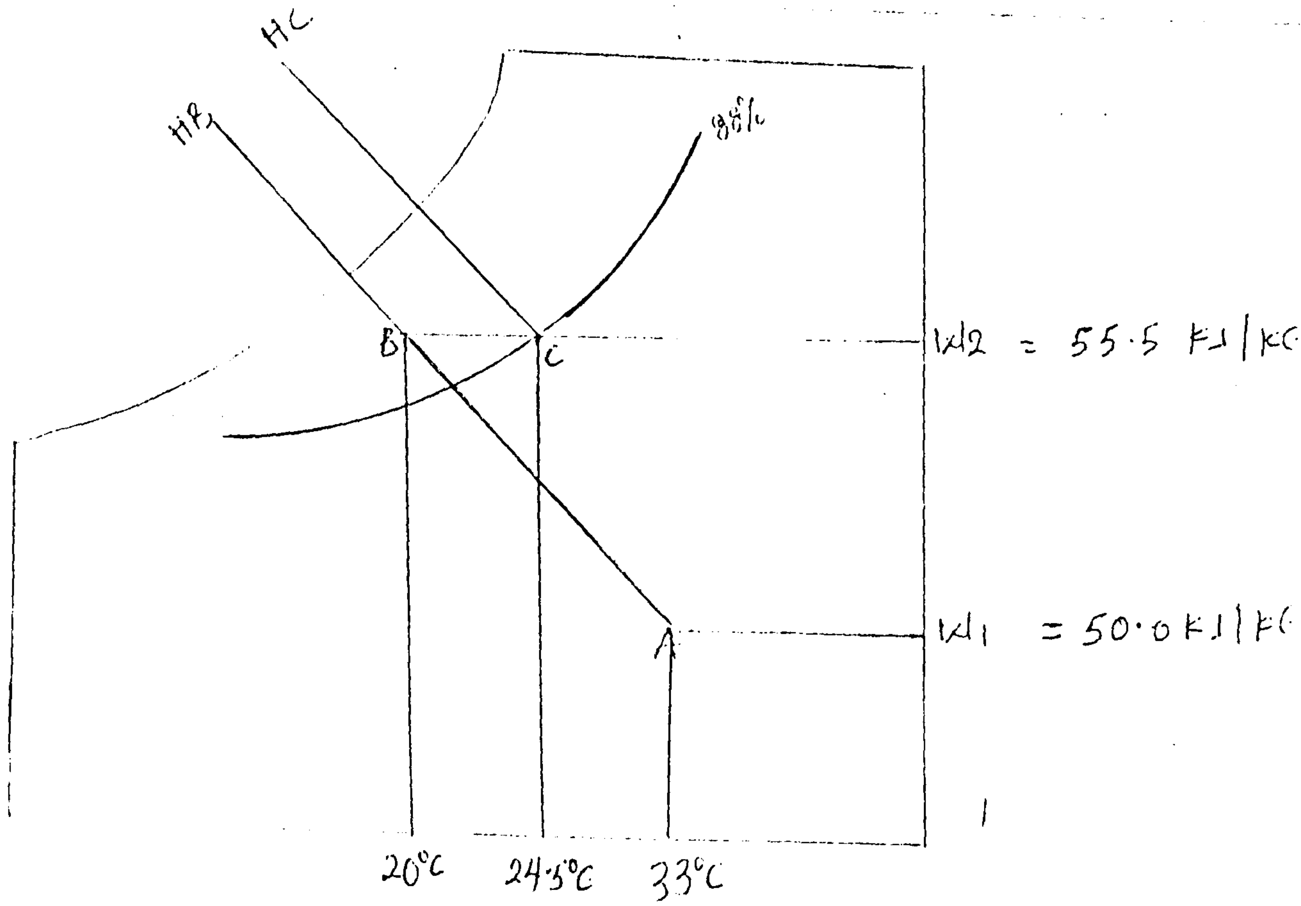



Figure 3: Change in sensible heat absorbed by the system

### 3.2.0 Experimental

The effect of packaging methods on the storage of fruits and vegetables in a passive evaporative cooler was investigated. A passive evaporative cooler was designed, constructed and its performance evaluated by determining its adiabatic efficiency under no–load and load conditions.

Seventy pieces of garden eggs, seventy pieces of tomatoes and seventy pieces of green bananas were put inside the system using perforated plastic container and sisal sac as the packaging materials. The ordinary storage (without a packaging material) was taken as the control. This experiment was carried out in the month of September and October, 2005.

### 3.2.1 Temperature and Relative Humidity Measurements

The temperature and relatively are taken three times a day by 8.00am, 12 noon and 5.00pm (Appendix F).

### 3.2.2 Measurement of Weight

The weight was taken with a weighing balance. The fruits and vegetable were weighed at intervals of two days from the beginning to the end of the storage period. Eight pieces of garden eggs and tomatoes were randomly selected and weighed while two pieces of bananas were randomly selected and weighed.

### 3.2.3 Determination of Decay

The fruits and vegetable in all the storage systems were observed at intervals (at the beginning, middle and the end of storage) for any decay.

Whenever any of the samples was suspected to have got rotten, it would be removed from the rest, cut into two or more pieces to know whether rotting process has really set in (Appendix E).

### 3.2.4 Determination of Moisture Content

The moisture contents of the stored produce were taken also taken daily.

#### (a) Procedure

A dry clean crucible was placed in an oven at 80°C for about 30 minutes, cooled in a dessicator and weighed ($W_1$), known weight of the sample was placed in the crucible and weighed ($W_2$). The sample with the crucible was then dried in an oven at 70°C to a constant weight. The procedure is repeated, drying for about one hour for each subsequent drying till constant weight ($W_3$) was obtained

#### (b) Calculation

$$\text{Percentage moisture content} = \frac{\text{Loss in weight due to drying}}{\text{Weight of sample taken}} \times 100$$

$$= \frac{W2 - W3}{W2 - W1} x100 \qquad \text{equation 3.19}$$

### 3.2.5 Determination of Vitamin C Content

The vitamin C content was also determined on a daily basis (Appendix H).

#### (a) Procedure

Glacial acetic acid (2ml) and 1ml chloroform were added into 5ml of the sample and the resulting solution was titrated with a solution of 2,6 – D in the burette until a permanent faint pink colour was obtained. The time, T was then recorded. The titration was repeated with 5ml distilled water for the blank (B) and 5ml of standard ascorbic acid solution (S).

**(b) Calculation**

The Vitamin C content of the sample (mg/100ml) was calculated as follows:

$$\text{Vitamin C content} = \frac{T - B}{S - B} x \text{ n dilution} \qquad \text{equation 3.20}$$

Where: T = Titre value of sample

B = Blank S = Standard

### 3.2.6 Sensory Analysis

The daily sensory analyses carried out on the produce are the colour, flavour, taste, defect and general appearance based on the following grades:

5 – Very desirable
4 – Desirable
3 – Acceptable
2 – Fairly acceptable
1 – Very undesirable

The grades, which apply to all the factors (except colour), are as follows:

| For banana | For tomato | For garden egg |
|---|---|---|
| 5 – Very green | 5 – Slightly orange | 5 – Very green |
| 4 – Green | 4 – Orange | 4 – Slightly green |
| 3 – Moderately green | 3 – Slightly red | 3 – Slightly orange |
| 2 – Yellow | 2 – Red | 2 - Orange |
| 1 – Very yellow | 1 – Very red | 1 – Very orange |

The sensory evaluation was assessed daily by myself, some postgraduate students and my Project Supervisor using grades mentioned above to represent the qualities of the stored produce (Appendix 1).

### 3.3.0 Analysis

The experimental design was a 3 x 3 factorial in a complete randomized design of 3 replicates. The effects of perforated plastic container (PPC), sisal sack (SS) and control (C) on decay, moisture content and vitamin C of the stored fruits was analyzed using ANOVA at $p \leq 0.05$ and the significant effects further evaluated by use of F – LSD at $p \leq 0.05$.

# CHAPTER FOUR

# RESULTS AND DISCUSSION

## 4.1 Soil Parameters

The initial and final moisture content of the soil sample used were 21.8% and 87.1% respectively and the soil type was loamy sand. The average value of the coefficient of permeability of the soil (k) obtained from three runs was 0.245cm/sec. The result is as summarized in Table 4.1.

## 4.2 Percentage Decay of Stored Produce

The summary of the percentage decay of stored produce at the end of storage period is as presented in Table 4.2. The incidence of decay was observed as spot rotting and the main cause of termination of shelf life of the stored produce in the system. The produce stored inside the perforated plastic container showed the least number of decay, followed by those inside the control and the highest decay was noticed inside the produce stored in the sisal sack. This observation may be attributed to the relatively high temperature recorded in the sisal sack compared to others. The perforated plastic container minimizes decay while maintaining good appearance for all stored produce than the produce inside the sisal sack and the control system. This may be due to the very low temperature recorded in the perforated plastic container. Low temperature reduces respiration and keeps moisture loss low.

**Table 4.1: Summary of Measured Soil Parameters of the Evaporative Cooler**

| **Parameters** | **value** |
|---|---|
| Soil type | (80% sand, 12% silt, 8% clay Loamy sand) |
| Soil moisture content | |
| Before | 21.8% |
| After | 87.1% |
| Permeability | 0.245cm/s |

Table 4.2: **Summary of the Percentage Decay, Moisture Content and Vitamin C Content Changes of Stored Produce Inside the Evaporative Cooler**

| | Packaging Material | Crop | Factor B | | |
|---|---|---|---|---|---|
| | | | Vit. C | Decay | M.C |
| | **PPC** | Garden egg | 0.168 | 1.25 | 85.38 |
| | | Banana | 0.056 | 0.00 | 69.99 |
| | | Tomato | 0.170 | 5.00 | 95.07 |
| | | Mean | 0.131 | 2.08 | 83.48 |
| **Factor A** | **Sisal sack** | Garden egg | 0.159 | 6.25 | 87.59 |
| | | Banana | 0.049 | 21.40 | 74.05 |
| | | Tomato | 0.142 | 17.50 | 95.30 |
| | | Mean | 0.117 | 15.05 | 85.65 |
| | **Control** | Garden egg | 0.165 | 1.25 | 87.34 |
| | | Banana | 0.051 | 14.20 | 72.45 |
| | | Tomato | 0.158 | 12.50 | 95.20 |
| | | Mean | 0.125 | 9.32 | 85.13 |

PPC = Perforated Plastic Container

## 4.3 Assessment of the Moisture Content and the Vitamin C Content of Stored Produce

The summary of the result of the moisture content determination of the stored produce is as presented in Tables 4.2. The difference in the moisture content of the system could be attributed to the differences in relative humidity and temperature of the storage environment. The produce either lost or gained moisture in relation to either increase or decrease in temperature and relative humidity. The relative humidity of the system was very high and the temperature was low, this accounted for the gain in moisture by the fruits stored in this system. The low moisture content in some fruits and vegetables in the system indicates higher respiration rate because as they continue to respire under storage, they tend to lose more water. The low moisture content in the perforated plastic container indicate higher respiration rate.

The summary of the results of the vitamin C content determination is presented in table 4.2. The higher percentage of vitamin C content of fruits and vegetables stored inside the perforated plastic container is as a result of the lower temperature in the perforated plastic container which tend to slow down the metabolism (including respiration) which eventually reduce the extent of microorganisms activities and chemical reaction taking place inside the system.

## 4.4 Temperature and Relative Humidity of Stored Produce

The temperature and relative humidity of stored produce inside the system were taken three times a day at 8.00am, 12 noon and 5.00pm using digital thermometer and relative humidity measuring instrument and their averages calculated. The summary of the results is as presented in Table 4.3.

The effect of temperature on various storage conditions in the storage system is as presented in Figures 4, 5 and 6 while that of relative humidity is as presented in Figures 7,8 and 9.

The effectiveness of the various packaging material inside the ECS for storing perishables is expected to be proportional to both temperature drop and relative humidity rise achieved in their respective storage chamber. The three systems recorded lower temperature and higher relative humidity values as compared with those of the ambient. This could be attributed to the cooling effect of the evaporative cooler. The wetting of the jute pads and the evaporation of water in the soil also helped in reducing the temperature. The produce inside the perforated plastic container gave the least temperature. This is because the plastic material is a poor conductor of heat and so it reduces the amount of heat that is supposed to have a direct contact with the produce. The produce inside the sisal sack gave the highest temperature due to the heat generated in the sack followed by those stored in the control. The temperature of the stored produce inside the control system is high because of the direct contact (reaction) of the produce with the galvanized sheet which has a very high conducting property.

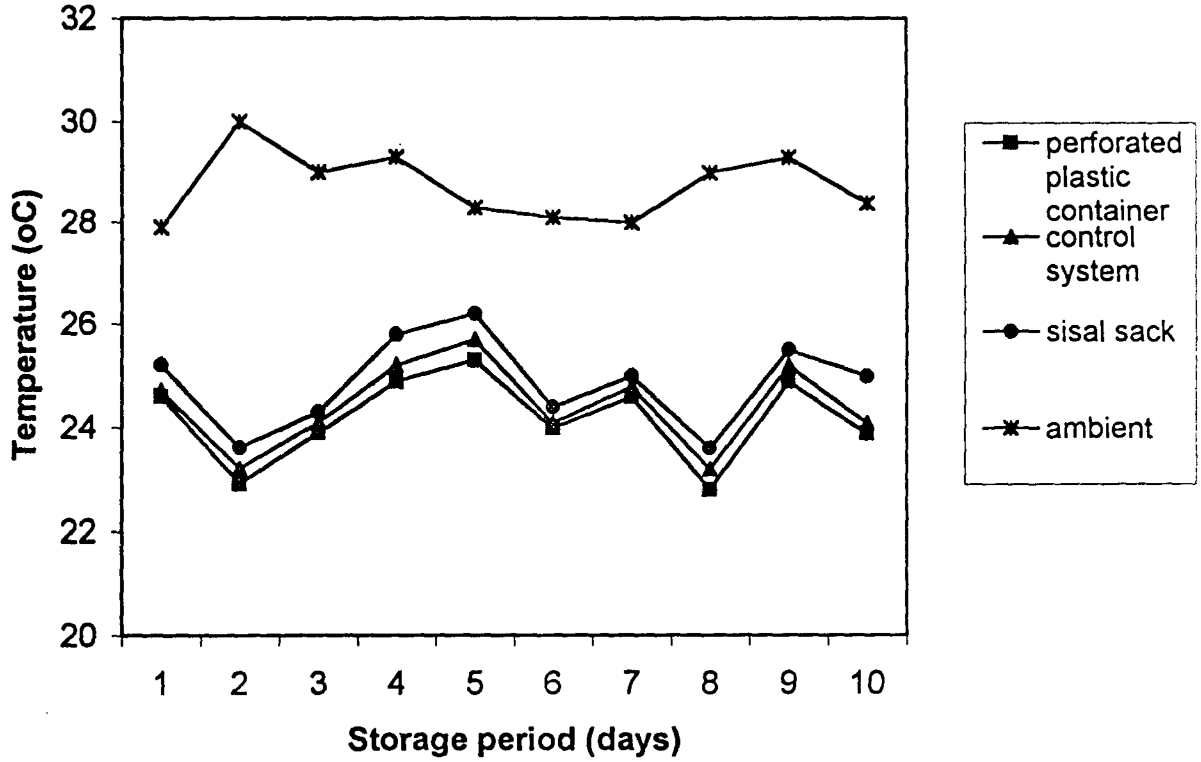



**Figure 4: The effect of temperature on stored garden egg inside the system.**

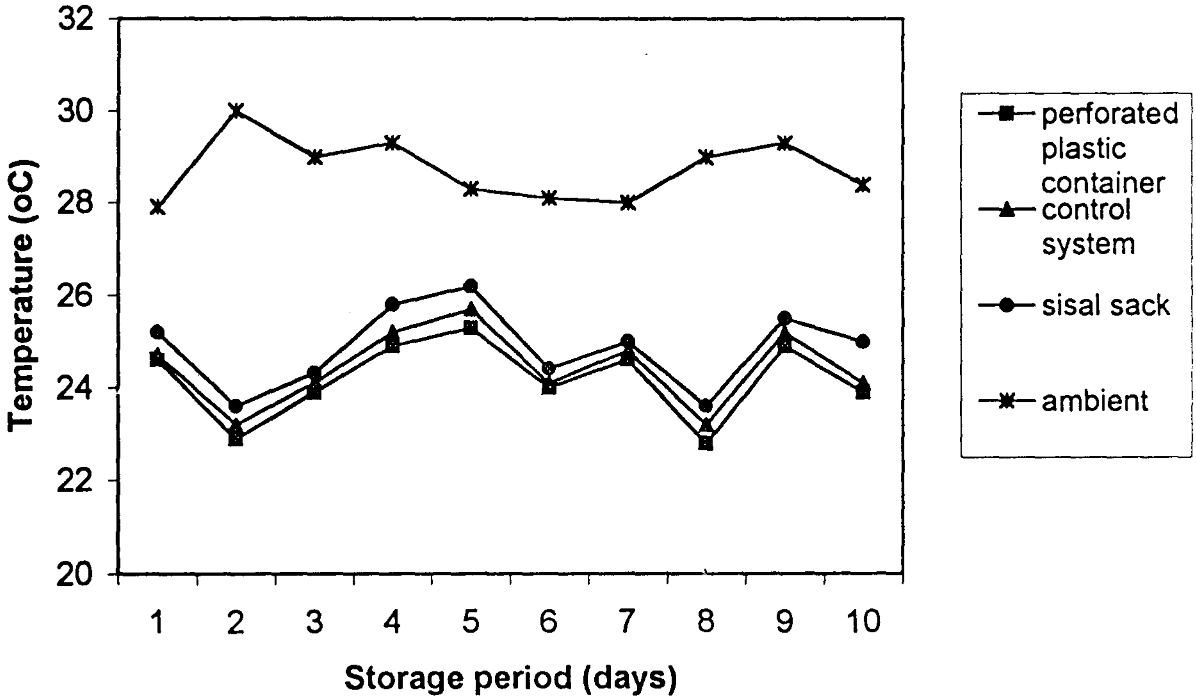



**Figure 5: The effect of temperature on stored garden egg inside the system.**

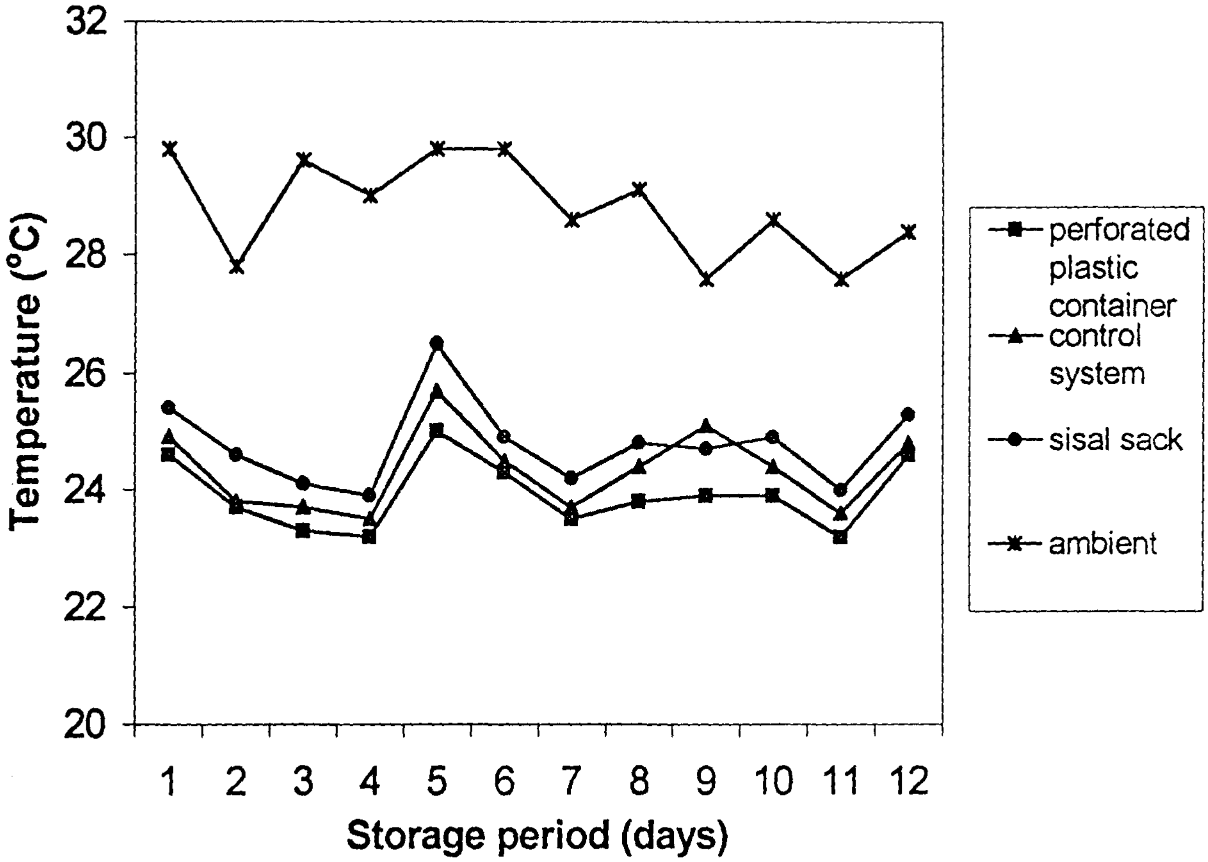



**Figure 6: The effect of temperature on stored tomato inside the system.**

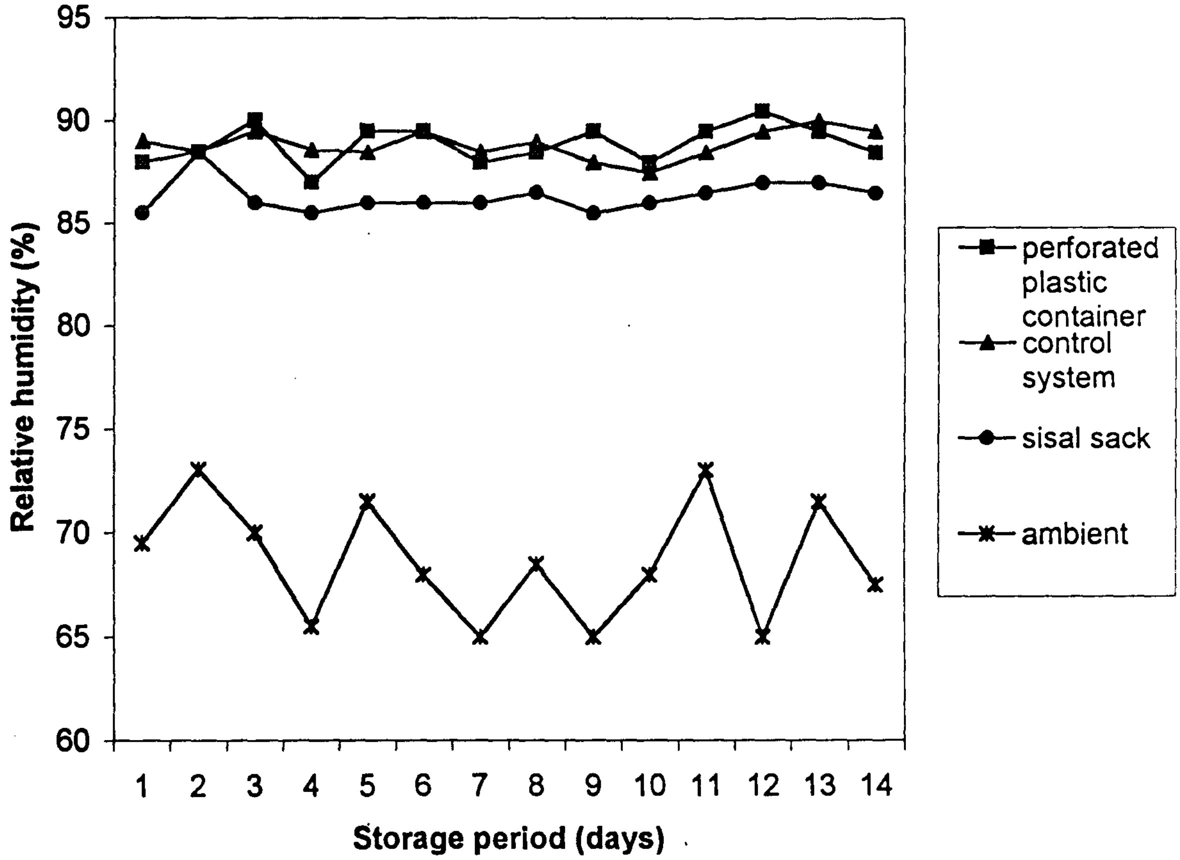



**Figure 7: The effect of relative humidity on stored banana inside the system**

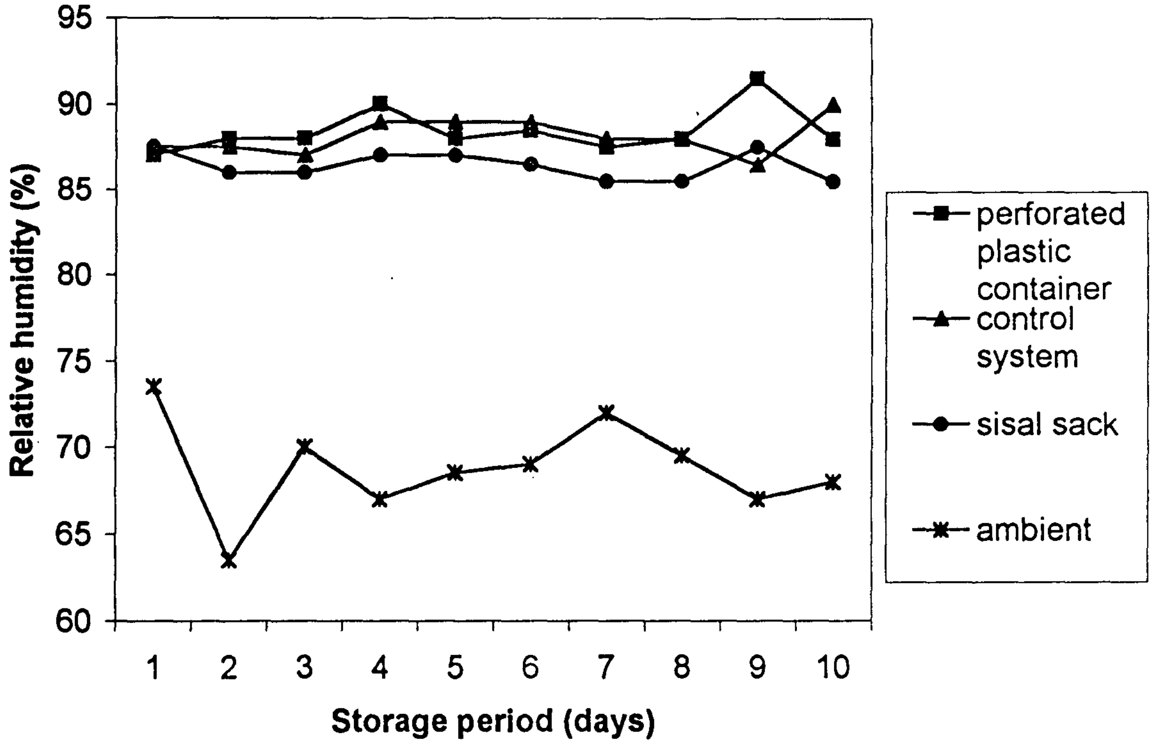



**Figure 8: The effect of relative humidity on stored garden egg inside the system**

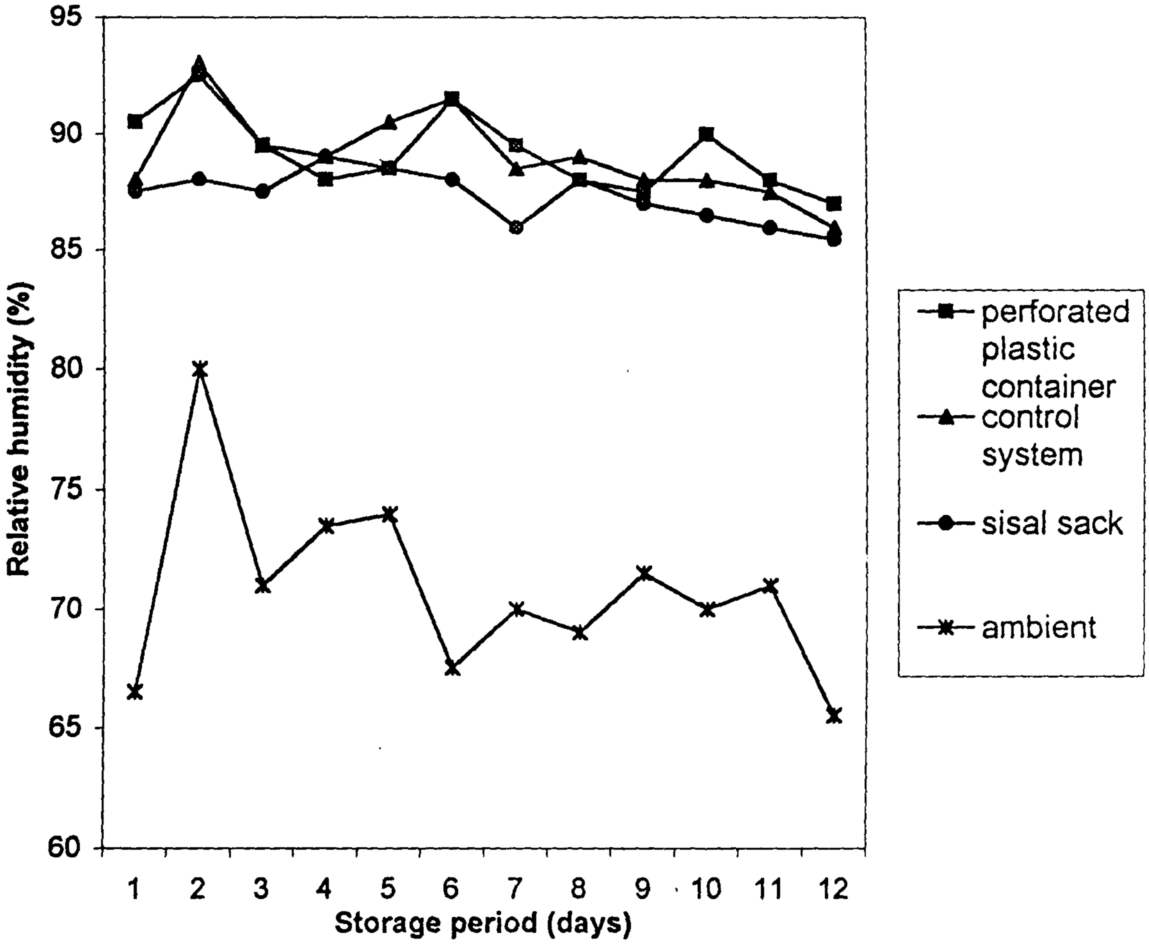



**Figure 9: The effect of relative humidity on stored tomato inside the system**

**Table 4.3: Summary of Measured Temperature and Relative Humidity**

| Packaging material | Fruits | Temp. (°C) | | RH (%) | |
|---|---|---|---|---|---|
| | | Ambient | Cooler | Ambient | Cooler |
| Perforated plastic | Garden egg | 28.71 | 24.20 | 68.80 | 88.45 |
| | Banana | 28.96 | 23.90 | 68.64 | 88.96 |
| | Tomato | 28.81 | 23.90 | 70.79 | 89.21 |
| | Mean | 28.82 | 24.00 | 69.41 | 88.87 |
| Sisal Sack | Garden egg | 28.71 | 24.86 | 68.80 | 86.40 |
| | Banana | 28.95 | 24.74 | 68.64 | 86.32 |
| | Tomato | 28.81 | 24.81 | 70.79 | 87.29 |
| | Mean | 28.82 | 24.80 | 69.41 | 86.67 |
| Control | Garden egg | 28.71 | 24.43 | 68.80 | 88.15 |
| | Banana | 28.95 | 24.27 | 68.64 | 88.86 |
| | Tomato | 28.81 | 24.34 | 70.79 | 89.04 |
| | Mean | 28.82 | 24.35 | 69.41 | 88.68 |

## 4.5 Assessment of the Sensory Characteristics of the Stored Produce

The summary of the results of the sensory analyses comprising colour, taste, texture, flavour, defects and general appearance are presented in table 4.4. It was noticed that banana stored inside the perforated plastic container were still fresh, have a good taste, very firm and also maintaining their initial good appearance until after 11$^{th}$ day of storage (Appendix I). There was no sign of deterioration and the samples were still green in colour. First ripening was noticed after the 11$^{th}$ day of storage. None of the samples got deteriorated and they still have normal banana flavour at the end of storage period.

In the case of banana stored inside the sisal sac, the samples were still fresh after one week of storage. Ripening occurred at a faster rate and the first ripening was observed 6$^{th}$ day of storage and none of the samples retained their initial green colour. Ripening continued until the end of storage period. Their texture and appearance are still very good until after the 10$^{th}$ day of storage when their texture was reduced. Only three samples got deteriorated at the end of storage period. The initial good taste has reduced drastically but they still have normal banana flavour. For the samples stored inside the control system, first ripening was noticed after 7$^{th}$ day of storage. The texture, taste, freshness are still very good. This condition was maintained until after 12$^{th}$ day of storage when the samples are becoming softer in texture and the initial good appearance is no longer visible but some samples are still green.

**Table 4.4: Summary of Sensory Analysis of the Stored Fruits and Vegetables Throughout the Storage Periods**

| | Fruits | Appearance | Color | Flavour | Firmness | Taste | Defects |
|---|---|---|---|---|---|---|---|
| | Garden egg | 4.60 | 4.00 | 4.50 | 4.40 | 4.60 | 4.60 |
| PP | Banana | 4.36 | 4.43 | 4.71 | 4.36 | 4.86 | 4.57 |
| | Tomato | 4.33 | 3.67 | 4.42 | 4.17 | 4.42 | 4.08 |
| | Mean | 4.43 | 4.03 | 4.54 | 4.31 | 4.63 | 4.42 |
| | Garden egg | 4.10 | 3.30 | 3.50 | 3.50 | 3.90 | 3.70 |
| SS | Banana | 3.86 | 3.71 | 3.93 | 3.86 | 4.00 | 3.86 |
| | Tomato | 3.67 | 3.25 | 3.08 | 3.50 | 3.67 | 3.58 |
| | Mean | 3.88 | 3.42 | 3.50 | 3.62 | 3.86 | 3.71 |
| | Garden egg | 4.30 | 3.60 | 3.90 | 4.10 | 4.30 | 4.20 |
| CC | Banana | 4.00 | 4.07 | 4.21 | 4.07 | 4.50 | 4.29 |
| | Tomato | 3.83 | 3.58 | 4.00 | 3.92 | 4.08 | 3.75 |
| | Mean | 4.04 | 3.75 | 4.04 | 4.03 | 4.29 | 4.08 |

PP – perforated plastic, SS – sisal sack, CC – control

The taste of the bananas in this system is slightly better than those stored inside the sisal sac. Only two samples got deteriorated at the end of the storage period but they still have their normal banana flavour.

In the case of the garden eggs, the results after one week showed that the samples stored inside the perforated plastic container were still fresh and firm with ripening taking place very slowly as most of them are still green. The samples were still smooth and very attractive and they still retain the normal taste of garden egg. There was no sign of deterioration. This condition was maintained up to the $10^{th}$ day of storage after which the freshness was reduced and they appear a little bit soft. First ripening was noticed after the $11^{th}$ day of storage and only one samples got bad at the end of the storage period but they still have the normal garden egg flavour. Only one sample got bad at the end of the storage period.

The result obtained for sisal sack showed that the samples were still fresh after one week but ripening take place very rapid. First ripening was noticed after the $8^{th}$ day of storage and the larger percentage of the samples changed from green to orange colour and this continues until the end of storage period. The samples are softer than those inside the perforated plastic container. Their appearances are not too attractive and the normal garden egg flavour has reduced. Five samples got deteriorated at the end of the storage period.

In the case of the samples stored inside the control system, ripening occur after $9^{th}$ day of storage although the samples are still fresh and firm. Ripening occurs more slowly than in the perforated plastic container as some of the samples still retain their green colour. The appearance is still good at the end of the storage period. Only two samples got bad at the end of the storage period and the normal garden egg flavour is better than that inside the sisal sack.

In the case of the tomatoes, the results after 6th day of storage showed that the samples stored inside the perforated plastic container were still smooth, firm and very attractive. Ripening as usual took place very slowly and this condition was maintained until 11th day of storage when the samples became softer and not looking very attractive. About four samples got deteriorated at the end of the storage period; however, they still have their normal tomato flavour.

For the tomatoes stored inside the sisal sack, the ripening was very rapid and about four days of storage in this condition, the firmness has reduced and also they are not very attractive. This was maintained till the end of the storage period. About 14 samples got deteriorated at the end of the storage period.

Ripening occurred in the control faster than those stored inside the perforated plastic container but not as fast as that inside the sisal sack. After 5 days of storage, the samples are still fresh and firm and also maintain their good appearance but there was a colour change from slightly orange to red. This condition was maintained until the 9th day of storage after which the samples became softer and no more attractive. About 10 samples got deteriorated at the end of the storage period.

## 4.6 Statistical Analysis of Data

The experimental design was a 3 x 3 factorial in a complete randomized design of 3 replicates. The effect of perforated plastic container (PPC), sisal sack (SS) and control CC) on decay, moisture content and vitamin c of the stored fruits was analyzed using ANOVA at $p \leq 0.05$ and the significant effects further evaluated by use of F–LSD at $p \leq 0.05$. Table 4.5 shows the 3 x 3 randomized complete block design for the experiment.

The analysis of variance for the 3 x 3 randomized block design is shown in Table 4.6. Using α – level of 0.05, the critical value of F,-i.e $f_{0.05,2,26} = 3.37$. Since $f_o$ , $f_{tab}$, we conclude that the packaging materials have no significant effect on the storage parameters. This means that from the results of our observations, there is no significant difference on the effect of the packaging materials on the storage parameters. Although the results obtained form the perforated plastic container are a bit favorable due to the low temperature and high relative humidity experienced in the system. The packaging materials (Factor A) and the interactions (Factor A and B) show high level of their insignificant effect since their mean square value is high relative to the error.

The analysis of variance table for the LSD method is as shown in Table 4.7 and it could be seen from the table that all of the averages are not significantly different from others in all the produce stored inside the system because the mean difference computed is less than the LSD values at 0.05% level of significance in all cases.

**Table 4.5: Randomized Complete Block Design for the Experiment**

| | Packaging Material | Crop | Factor B | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Vit. C | | Decay | | M.C | | yi.. |
| | | Garden egg | 0.168 | | 0.013 | | 0.854 | | |
| | PPC | Banana | 0.056 | **0.131** | 0.000 | **0.021** | 0.699 | **0.835** | 0.987 |
| | | Tomato | 0.170 | | 0.050 | | 0.951 | | |
| | | Garden egg | 0.159 | | 0.063 | | 0.876 | | |
| Factor A | SS | Banana | 0.049 | **0.117** | 0.021 | **0.086** | 0.741 | **0.857** | 1.060 |
| | | Tomato | 0.142 | | 0.175 | | 0.953 | | |
| | | Garden egg | 0.165 | | 0.013 | | 0.873 | | |
| | CC | Banana | 0.051 | **0.125** | 0.142 | **0.093** | 0.725 | **0.850** | 1.068 |
| | | Tomato | 0.158 | | 0.125 | | 0.952 | | |
| | y.i. | | | 0.373 | | 0.200 | | 2.542 | 3.115 |

PPC Perforated Plastic Container SS = Sisal Sack CC Control

**Table 4.6: Analysis of Variance Table for the 3x3 Factorial Randomized Complete Design**

| Sources of variation | Degree of Freedom | Sum of Squares | Mean Squares | Fo |
|---|---|---|---|---|
| Packaging Materials (Factor A) | 2 | $4.45508922 \times 10^{-4}$ | $2.227544611 \times 10^{-4}$ | $6.635295494 \times 10^{-4}$* |
| Storage Parameters (Factor B) | 2 | $3.754051669 \times 10^{-1}$ | $1.892025835 \times 10^{-1}$ | $5.635869394 \times 10^{-1}$* |
| Interaction (A & B) | 4 | $7.298842113 \times 10^{-4}$ | $1.824710528 \times 10^{-4}$ | $5.435354014 \times 10^{-4}$* |
| Error | 18 | 6.042805937 | $3.357114409 \times 10^{-1}$ | |
| Total | 26 | 6.422386497 | $2.470148653 \times 10^{-1}$ | |

* not significant

**Table 4.6: Analysis of Variance Table for the 3x3 Factorial Randomized Complete Design**

| Sources of variation | Degree of Freedom | Sum of Squares | Mean Squares | Fo |
|---|---|---|---|---|
| Packaging Materials (Factor A) | 2 | $4.45508922 \times 10^{-4}$ | $2.227544611 \times 10^{-4}$ | $6.635295494 \times 10^{-4}$* |
| Storage Parameters (Factor B) | 2 | $3.754051669 \times 10^{-1}$ | $1.892025835 \times 10^{-1}$ | $5.635869394 \times 10^{-1}$* |
| Interaction (A & B) | 4 | $7.298842113 \times 10^{-4}$ | $1.824710528 \times 10^{-4}$ | $5.435354014 \times 10^{-4}$* |
| Error | 18 | 6.042805937 | $3.357114409 \times 10^{-1}$ | |
| Total | 26 | 6.422386497 | $2.470148653 \times 10^{-1}$ | |

* not significant

**Table 4.7: Analysis of Variance Table for the Experiment Using F – LSD Method**

| Sources of Variation | Sum of Squares | Degree of Freedom | Mean Differences | LSD Values at 0.05% level | Remarks |
|---|---|---|---|---|---|
| Between PPC and CC | $7.576637333 \times 10^{-1}$ | 2 | 0.0270667 | $3.017371392 \times 10^{-2}$ | ns |
| Between CC And SS | $7.47311555 \times 10^{-1}$ | 2 | $2.6333337 \times 10^{-3}$ | $5.168553428 \times 10^{-3}$ | ns |
| Between PPC and SS | $7.7183969 \times 10^{-1}$ | 2 | $2.44333 \times 10^{-2}$ | $2.86765 \times 10^{-2}$ | ns |

PPC = Perforated Plastic Container SS = Sisal Sack CC = Control ns = not significant

# CHAPTER FIVE

# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

This project focused on the effect of packaging materials/methods on the storage of fruits and vegetables in a passive evaporative cooler. This was done to compare their results so as to know the best conditions to store the fruits and vegetables for them to lose very little of their qualities. The shelf life and qualities of the stored produce in the perforated plastic container were much longer and higher than the produce in the control and sisal sack. This is because the produce inside the perforated plastic container recorded the least temperature ($24^0$C ) and the highest relative humidity (88.87% ) throughout the storage period compared to the control and sisal sack (24.35$^0$C, 88.68% and 24.80$^0$C, 86.67% respectively).

The packaging of produce in the perforated plastic container also minimizes decay (2.1%) for all stored produce that the control and the sisal sack ( 9.32% and 8.63% respectively). Also the packaging of produce inside the perforated plastic container retained the highest amount of vitamin c content (13.19%) for all stored produce than the control and the sisal sack (12.5% and 11.7% respectively).

In conclusion the low cost, simplicity and energy–free nature of the cold storage system for perishables crops make it appropriate for rural and small – scale storage of fruits and vegetables using perforated plastic container as their packaging material.

## 5.2 Recommendations

Based on the construction technique employed in the cold storage system, the following recommendations were suggested:

(i) The use of soil that contains a little proportion of clay which might be able to retain more water and thereby performing the cooling effectively. The use of soil containing a little proportion of clay may also reduce the amount of water to be added to the soil from time to time from the storage tank and so reduce the total amount of water used throughout the experiment.

(ii) Also storage with perforated plastic container inside the evaporative cooling system is recommended for the storage of fruits and vegetables. This is because storage under this condition loses very little of their qualities.

(iii) The use of wooden covers for the cooling chambers and jute sack to lag the inside of the cooling chamber is highly recommended as these may reduce the temperature inside the system

(iv) The use of other packaging materials is also recommended.

# REFERENCES


Abushitta, A.A., Hebshi, E.A., Daood, H.G., and Biacs, P.A. (1997). Determination of antioxidant vitamins in tomatoes. Journal of Food Chemistry. 60: 207 – 212.

Adisa, C. T. (1994). Evaluation of the local and modern methods of storing tomatoes as vegetables A Master Project (Unpublished). University of Ilorin, Ilorin, Nigeria. Page 14.

Barber, N.J. and Barber, J. (2002). Lycopene and prostate cancer. Prostate cancer and prostatic diseases. CRS Press Inc, Florida. Pp5, 6 – 12.

Bishop, D. (1996). Controlled atmosphere storage. In: Dello, C. J.V (ed), Cold and chilled storage technology. Macmillan Publisher, London. Pp 43 - 47

Croshy, N. I. (1981). Food packaging materials. Applied Science Publisher Ltd. London, pp 1 – 11.

Daughty, M. E. (1995). Fruits and vegetables processing. F.A.O Agriculture Service Bulletin 199, pp 7 – 9.

Desrosier, N. W. and Desrosier, J. N. (1977). Technology of Food Preservation. Fourth Edition, C.B.S. Publisher, Indian Pp. 47 - 48.

F.A.O. (1981). Food loss preservation in perishable crops. F.A.O. Agriculture Service Bulletin, 43: 3 – 15, 53 and 78.

·ierson, D. and Kader, A.A. (1986). Fruit ripening and quality. In J. G. Atherton and R. Rudich (Eds). The tomato crop: A scientific basis for improvement. Pp.241 – 280. London. Chapman and Hall.

lenderson, S. M. (1952). A basic concept of equilibrium moisture content. Agricultural Engineering 33 (2): 29 – 32.

Ilori, O. A. (1985). Evaporative cooling for preservation of vegetables (design and construction). B. Sc. Project, University of Ibadan, Ibadan, Nigeria. Pp 31 – 37

Kalt, W., Forney, C.F., Martin, A., and Prior, R.L.(1999). Antioxidant capacity, Vitamin C, phenolics, and anthocyanins after fresh storage of small fruits. Journal of Agriculture and Food Chemistry, 47: 4638 – 4644.

Khachik, F., Carvalho, L., Bernstein, P.S., Muir, G.J., Zhao, D.Y., and Katz, N.B.(2002). Chemistry, distribution, and metabolism of tomato Carotenoids and their impact on human health. Experimental Biology and Medicine Journal. Pp 227, 845 – 851.

Kordylas, J. M. (1990). Processing and preservation of tropical and subtropical food. Macmillan Publishers Ltd. London pp 80 – 101.

Labuza, T. P. (1980). Effect of water activity on reaction kinetics of food deterioration. Food Technology Journal. 34 (4) : 36.

Macheix, J.J., Fleuriet, A. and Billot, J. (1990). Fruit phenolics. Florida. CRS Press. Inc, Florida. Pp 32 – 41.

Macrae, R., Robinson, R. K. and Sadlex, M. J. (1997). Encyclopedia of food science and technology and nutrition. Harcourt. Brace Jovanovich. publishers, London, San Diego, New York, Boston, Sydney, Tokyo. Toronto. Volume 3 Pp 2102 – 2113.

Maul, E., Sergent. S.A., Sims, C.A., Baldwin, E.A., Balaban, M.O. and Hubber. D. J. (2000). Tomato flavour and aroma quality as affected by storage temperature. Journal of Food Science. 65 : 1228 – 1237.

Miller, N.J. and Rice Evans, C.A. (1997). The relative contributions of ascorbic acid and phenolic antioxidants to the total antioxidant activity of orange and apple fruit juices and blackcurrant drink. Food Chemistry Journal. 60: 331–337.

Mitra, A. K. (1997). Post harvest physiological and storage of tropical fruits CAB INTERNATIONAL 1997 pp 10 – 11.

Nigerian Stored Product and Research Institute (NSPRI) (2002). Post harvest news, NSPRI Research News Number 2, April, 2001.

Norman, W. D. (1977). Elements of food technology. AVI Publishing Company Inc. Westpoint Connecticut, Pp 7 – 20, 219 – 246.

Okunola, A. A. (1991). Equilibrium moisture content and relative humidity of some tropical Agricultural crops. A Master Project (Unpublished) University of Ibadan, Ibadan, Nigeria.

Okunola, A. A. and Igbeka, J. C. (2000). Water absorption characteristics of plantain and sweet potatoes. Proceedings of the first international conference and millennium general meeting of the Nigerian institution of Agricultural Engineers, a division of the Nigerian society of engineers, pp.20,vol. 2, 2000.

Osagie, A. U and Eka, O. U. (1988). Nutritional quality of plant food. Published by the post harvest research unit, Department of Biochemistry, University of Benin, Nigeria. pp 84 – 86 and 208 – 215.

Owuye, A. A. (1998). Investigative survey and modification of evaporative cooler. B. Eng. (unpublished) thesis. Federal University of Technology, Minna.

Oyeniran, J. O. (1988). Proceedings of the National workshop on improved packaging and storage system for fruits and vegetables in Nigeria

Pantastico, E. R. B. (1975) (ed): Post Harvest Physiology , Handling and Utilization Tropical and Subtropical Fruits and Vegetables. AVI publishing Co., Inc.

Pixton, S. W. and Warbuton, S. (1971). Moisture content and relative humidity equilibrium of some cereals grains at different temperature, journal of stored product research, Vol. 6, pp 283 – 293.

Richard, C. J. and Priester, G. B. (1986). Refrigeration and air conditioning, second edition.

Rockland, L. B. and Nishi, S. K. (1980). Influence of water activity on food product quality and stability. Food Technology 42, pp 44 – 46 and 59.

, T. (1997). Development in food preservation. Department of food science and nutrition, Queen Elizabeth College, University of London, U.K

npson, A. K. (1998). Controlled atmosphere storage of fruits and vegetables. CAB International Publisher, London. 1998, Pp 11 – 12.

lall, H. D. (1983). Vegetable in the tropics. First edition. Published by Macmillan Education Limited. London. Pp. 360 – 365.

or, R. K. and Savage, G.P. (2005). Antioxidant activities in different fractions of tomato. Food Research International, 38, 487 – 494.

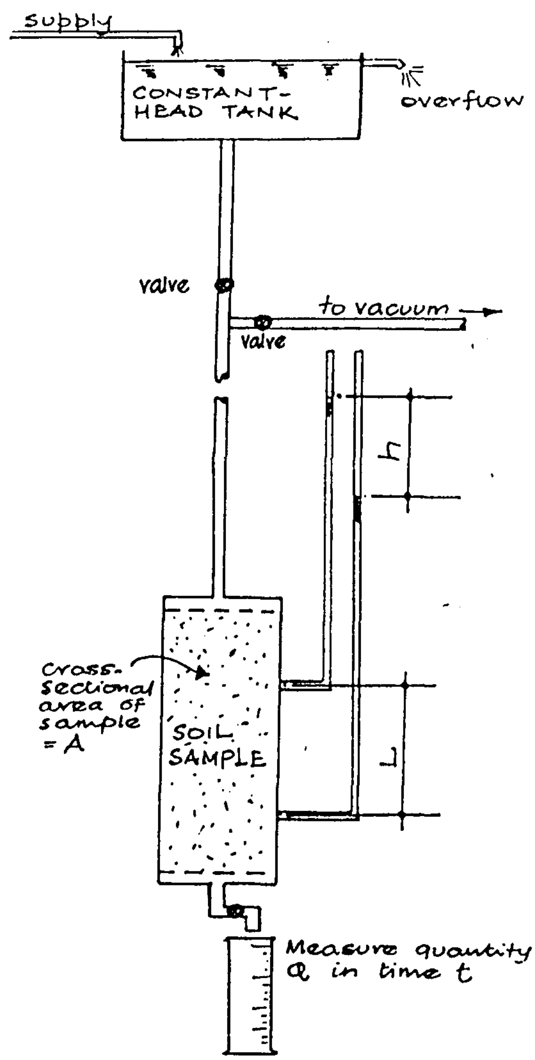
oor, R. K. and Savage, G. P. (2006). Changes in major antioxidant components of tomatoes during post–harvest storage. Food Chemistry 99, 724 – 727.

Valker, D. J. (1992). Food storage manual. World Food Programme. Natural Resources Institute, Central Avenue, Chatham Maritime, Charthan, Kent ME4, 4TB, U.k, pp 23.

Walker, A. and Abernathie, J. W. (1984). Evaporative cooling of green houses. American Orchid. Soc. Bulletin, 33, Pp 377 – 381.

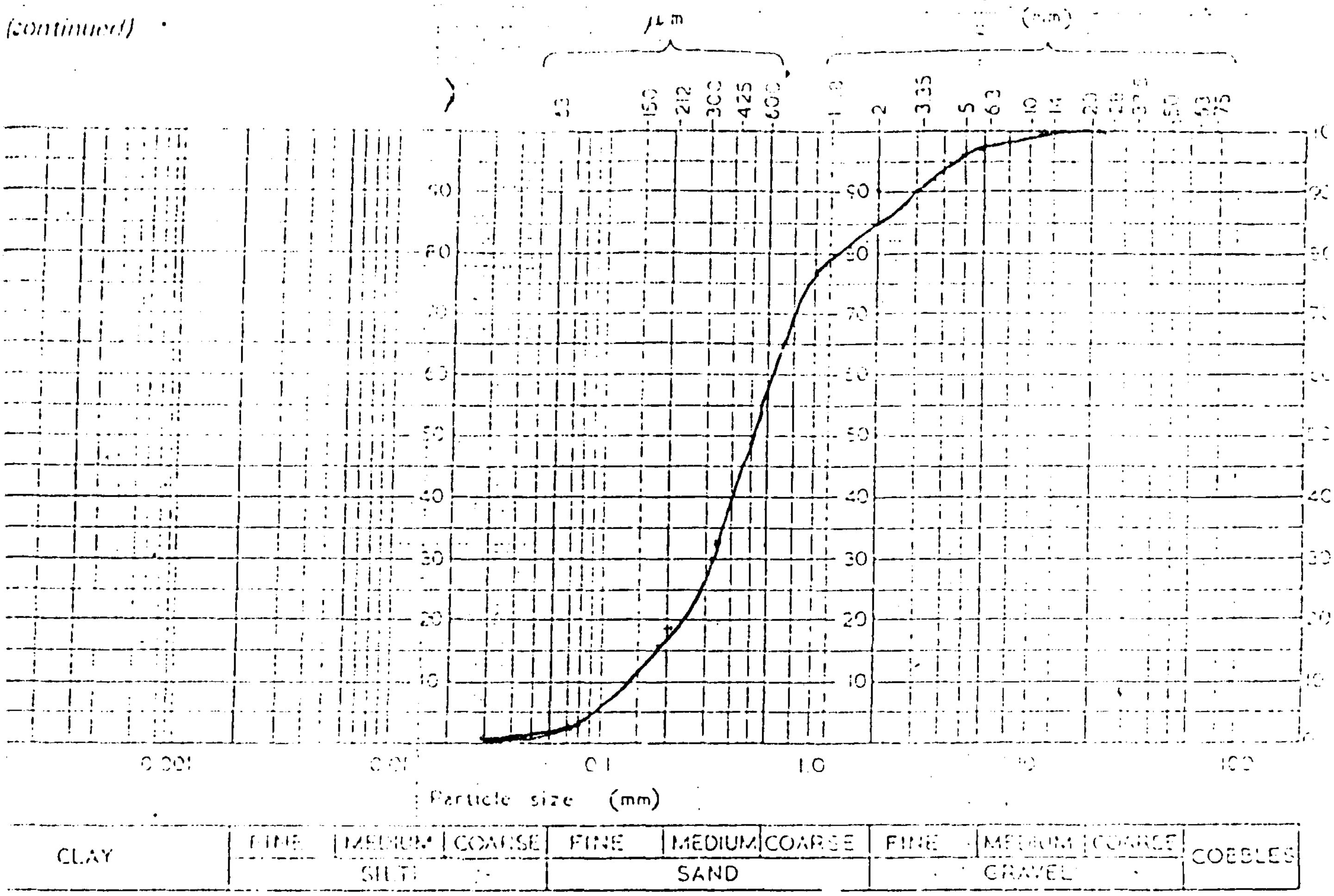
Yanuriatti, A., Savage, G.P., and Rowe, R.N.(1999). The effects of ethanol treatment on the metabolism, shelf life and quality of stored tomatoes at different maturities and temperatures. Journal of science of Food and Agriculture 79, 995– 1002.

## Appendix A: Constant – Head Permeameter set - up



**Appendix B:** **Sieve Analysis Test**

(continued)




Job:

Site:

Borehole No:

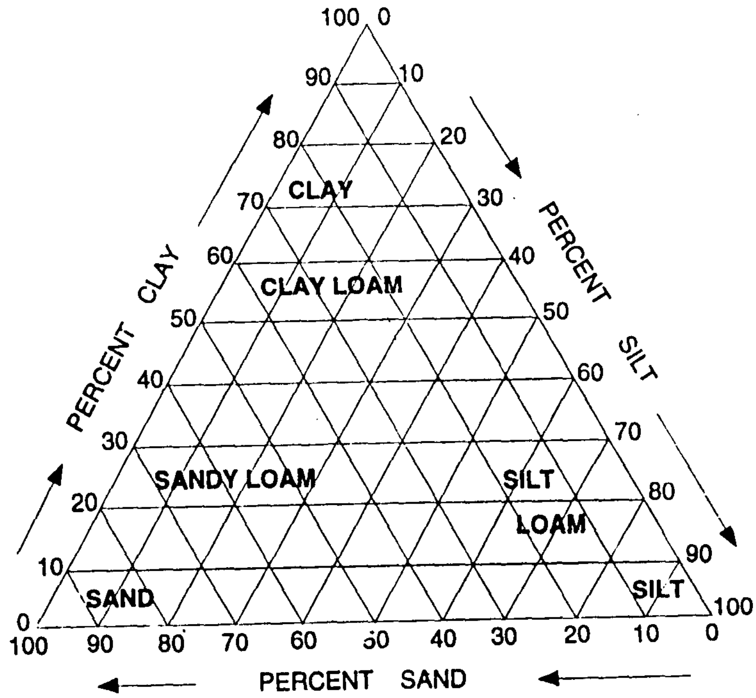
of soil:

Sample No:

Depth of sample

British Standard test sieves

**Appendix C: Soil Class Test**



# Appendix D: Summary of the Results for the Coefficient of Permeability of the Soil.

| Run No | Volume collected V ($cm^3$) | Elapse time (t secs) | Piezometric reading (cm) | Flow rate Q ($cm^3$/secs) | Volume flux q (cm/sec) | Hydraulic head (h/l) | Permeability K (cm/sec) |
|---|---|---|---|---|---|---|---|
| 1 | 194.75 | 15.00 | 2.10 | 15.80 | 12.98 | 0.26 | 0.290 |
| 2 | 178.20 | 17.00 | 1.98 | 14.80 | 10.48 | 0.25 | 0.245 |
| 3 | 164.00 | 20.00 | 1.88 | 9.900 | 8.020 | 0.24 | 0.200 |
| Mean | | | | | | | 0.245 |

**Appendix E: Percentage decay of stored produce at the end of storage period**

| Produce | Packaging materials | No before storage | No after storage | % decay |
|---|---|---|---|---|
| Banana | Perf. Plastic container | 14 | - | 0 |
| | Control system | 14 | 2 | 14.2 |
| | Sisal sack | 14 | 3 | 21.4 |
| Garden Egg | Perf. Plastic container | 80 | 1 | 1.25 |
| | Control system | 80 | 3 | 3.75 |
| | Sisal sack | 80 | 5 | 6.25 |
| Tomatoes | Perf. Plastic container | 80 | 4 | 5.00 |
| | Control system | 80 | 10 | 12.50 |
| | Sisal sack | 80 | 14 | 17.50 |

**Appendix F1: Average daily temperature and relative humidity of stored banana under various storage conditions**

| Storage Period (Days) | PPC Avg. Tp/ .Rh | Stored bananas CS Avg. Tp/Rh | SS Av. Tp/ Rh | AMB Av. Tp/Rh |
|---|---|---|---|---|
| 1 | 24.0/88.0 | 24.2/89.0 | 24.8/85.5 | 28.7/69.5 |
| 2 | 22.5/89.5 | 23.7/88.5 | 24.2/88.5 | 28.7/73.0 |
| 3 | 23.9/90.0 | 24.3/89.5 | 24.9/86.0 | 28.6/70.0 |
| 4 | 24.6/87.0 | 24.9/88.6 | 25.3/85.5 | 28.4/65.5 |
| 5 | 23.3/89.5 | 23.7/88.5 | 24.1/86.0 | 30.1/71.5 |
| 6 | 24.7/89.5 | 24.9/89.5 | 25.4/86.0 | 29.9/68.0 |
| 7 | 23.9/88.0 | 24.1/88.5 | 24.6/86.0 | 29.0/65.0 |
| 8 | 24.0/88.5 | 24.1/89.0 | 24.5/86.5 | 28.5/68.5 |
| 9 | 24.8/89.5 | 25.3/88.0 | 25.8/85.5 | 29.8/65.0 |
| 10 | 23.2/88.0 | 23.5/87.5 | 23.9/86.0 | 27.5/68.0 |
| 11 | 23.5/89.5 | 23.7/88.5 | 24.1/86.5 | 28.5/73.0 |
| 12 | 24.5/90.5 | 24.6/89.5 | 25.0/87.0 | 30.0/65.0 |
| 13 | 23.7/89.5 | 24.0/90.0 | 24.5/87.0 | 29.5/71.5 |
| 14 | 24.3/88.5 | 24.8/89.5 | 25.3/86.5 | 28.1/67.5 |

PPC = perforated plastic container, CS = control system and SS = sisal sack

**Appendix F2: Average daily temperature and relative humidity of stored garden eggs under various storage conditions.**

| | Stored garden eggs | | | |
|---|---|---|---|---|
| | **PPC** | **CS** | **SS** | **AMB** |
| Storage Period (Days) | Avg. Tp/ .Rh | Avg. Tp/Rh | Av. Tp/ Rh | Av. Tp/Rh |
| 1 | 24.6/87.0 | 24.7/87.5 | 25.2/87.5 | 27.7/73.5 |
| 2 | 22.9/88.0 | 23.2/87.5 | 23.6/86.0 | 30.0/63.5 |
| 3 | 23.9/88.0 | 24.1/87.0 | 24.3/86.0 | 29.0/70.0 |
| 4 | 24.9/90.0 | 25.2/89.0 | 25.8/87.0 | 29.3/67.0 |
| 5 | 25.3/88.0 | 25.7/89.0 | 26.2/87.0 | 28.3/68.5 |
| 6 | 24.0/88.5 | 24.1/89.0 | 24.4/86.5 | 28.1/69.0 |
| 7 | 24.6/87.5 | 24.8/88.0 | 25:0/85.5 | 28.0/72.0 |
| 8 | 22.8/88.0 | 23.2/88.0 | 23.6/85.5 | 29.0/69.5 |
| 9 | 24.9/91.5 | 25.2/86.5 | 25.5/87.5 | 29.3/67.0 |
| 10 | 23.9/88.0 | 24.1/90.0 | 25.0/85.5 | 28.4/68.0 |

PPC = perforated plastic container, CS = control system , SS= sisal sack and AMB = ambient

and SS = sisal sack

**Appendix F3: Average daily temperature and relative humidity of stored tomatoes under various storage conditions.**

| | Stored tomatoes | | | |
|---|---|---|---|---|
| | PPC | CS | SS | AMB |
| Storage Period (Days) | Avg. Tp/ .Rh | Avg. Tp/Rh | Av. Tp/ Rh | Av. Tp/Rh |
| 1 | 24.6/90.5 | 24.9/88.0 | 25.4/87.5 | 29.8/66.5 |
| 2 | 23.7/92.5 | 23.8/93.0 | 24.6/88.0 | 27.8/80.0 |
| 3 | 23.3/89.5 | 23.7/89.5 | 24.1/87.5 | 29.6/71.0 |
| 4 | 23.2/88.0 | 23.5/89.0 | 23.9/89.0 | 29.0/73.5 |
| 5 | 25.0/88.5 | 25.7/90.5 | 26.5/88.5 | 29.8/74.0 |
| 6 | 24.3/91.5 | 24.5/91.5 | 24.9/88.0 | 29.8/67.5 |
| 7 | 23.5/89.5 | 23.7/88.5 | 24.2/86.0 | 28.6/70.0 |
| 8 | 23.8/88.0 | 24.4/89.0 | 234.8/88.0 | 29.1/69.0 |
| 9 | 23.9/87.5 | 25.1/88.0 | 25.2/87.0 | 27.6/71.5 |
| 10 | 23.9/90.0 | 24.4/88.0 | 24.9/86.5 | 28.6/70.0 |
| 11 | 23.2/88.0 | 23.6/87.5 | 24.0/86.0 | 27.6/71.0 |
| 12 | 24.6/87.0 | 24.8/86.0 | 25.3/85.5 | 28.4/65.5 |

PPC = perforated plastic container, CS = control system , SS= sisal sack and AMB = ambient

**Appendix G1: Moisture Content of stored garden eggs**

| Storage Period (Days) | Storage systems<br>Perf. plastic container | Control | Sisal sack |
|---|---|---|---|
| 1 | 85.30±0.98 | 85.30±0.98 | 85.30±0.98 |
| 2 | 85.30±0.98 | 85.69±0.98 | 85.72±0.98 |
| 3 | 85.32±0.98 | 86.13±0.98 | 86.17±0.98 |
| 4 | 85.33±0.98 | 86.57±0.98 | 86.69±0.98 |
| 5 | 85.35±0.94 | 86.92±0.89 | 86.95±0.55 |
| 6 | 85.37±0.94 | 87.07±0.89 | 87.37±0.55 |
| 7 | 85.41±0.94 | 88.39±0.89 | 88.47±0.55 |
| 8 | 85.44±0.94 | 88.79±0.89 | 89.02±0.55 |
| 9 | 85.47±1.98 | 89.05±1.89 | 89.87±1.88 |
| 10 | 85.50±1.98 | 89.53±1.89 | 90.29±1.88 |

**Appendix G2: Moisture Content of stored banana**

| Storage Period (Days) | Storage systems<br>Perf. plastic container | Control | Sisal sack |
|---|---|---|---|
| 1 | 69.10±1.09 | 69.10±1.09 | 69.10+1.09 |
| 2 | 68.57±1.09 | 69.93±1.09 | 70.23±1.09 |
| 3 | 68.93±1.09 | 70.23±1.09 | 71.57±1.09 |
| 4 | 69.13±1.09 | 69.89±1.09 | 71.89±1.09 |
| 5 | 69.47±1.09 | 71.23±1.09 | 72.63±1.09 |
| 6 | 69.47±1.09 | 71.23±1.09 | 72.63±1.09 |
| 7 | 69.96±1.09 | 71.97±1.09 | 72.93±1.09 |
| 8 | 70.05±1.04 | 72.21±1.09 | 73.29±1.05 |
| 9 | 70.23±1.04 | 73.19±1.09 | 74.57±1.05 |
| 10 | 70.67±1.04 | 74.59±1.09 | 75.97±1.05 |
| 11 | 70.91±1.04 | 75.01±1.09 | 76.36±1.05 |
| 12 | 71.00±1.04 | 75.01±1.09 | 76.34±1.05 |
| 13 | 71.15±1.04 | 75.35±1.09 | 79.59±1.05 |
| 14 | 71.15±1.04 | 75.35±1.09 | 79.59±1.05 |

**Appendix G3: Moisture Content of stored tomatoes**

| Storage Period (Days) | Storage System Perf. plastic container | Control | Sisal sack |
|---|---|---|---|
| 1 | 95.01±0.91 | 95.01±0.91 | 95.01±0.91 |
| 2 | 95.01±0.91 | 95.05±0.91 | 95.07±0.91 |
| 3 | 95.03±0.91 | 95.10±0.91 | 95.14±0.91 |
| 4 | 95.04±0.91 | 95.13±0.91 | 95.20±0.91 |
| 5 | 95.04±0.91 | 95.17±0.91 | 95.27±0.91 |
| 6 | 95.05±0.91 | 95.21±0.91 | 95.29±0.91 |
| 7 | 95.07±0.91 | 95.23±0.91 | 95.31±0.91 |
| 8 | 95.10±0.84 | 95.26±0.90 | 95.37±0.59 |
| 9 | 95.11±0.84 | 95.28±0.90 | 95.43±0.59 |
| 10 | 95.13±0.84 | 95.31±0.90 | 95.49±0.59 |
| 11 | 95.13±0.84 | 95.32±0.90 | 95.51±0.59 |
| 12 | 95.15±0.84 | 95.33±0.90 | 95.55±0.59 |

**Appendix H1: Vitamin C content of stored produce inside the perforated Plastic container**

| Run Number/ Storage Period(days) | Garden egg (g/100ml) | Banana (g/100ml) | Tomatoes (g/100ml) |
|---|---|---|---|
| 1 | 0.185±0.01 | 0.063±0.01 | 0.200±0.01 |
| 2 | 0.183±0.01 | 0.063±0.01 | 0.185±0.01 |
| 3 | 0.179±0.01 | 0.062±0.01 | 0.185±0.01 |
| 4 | 0.172±0.01 | 0.060±0.01 | 0.179±0.01 |
| 5 | 0.170±0.01 | 0.059±0.01 | 0.174±0.01 |
| 6 | 0.168±0.01 | 0.058±0.01 | 0.170±0.01 |
| 7 | 0.162±0.01 | 0.056±0.01 | 0.166±0.01 |
| 8 | 0.159±0.01 | 0.056±0.01 | 0.164±0.01 |
| 9 | 0.156±0.01 | 0.054±0.01 | 0.160±0.01 |
| 10 | 0.150±0.01 | 0.053±0.01 | 0.157±0.01 |
| 11 | | 0.051±0.01 | 0.154±0.01 |
| 12 | | 0.050±0.01 | 0.150±0.01 |
| 13 | | 0.049±0.01 | |
| 14 | | 0.049±0.01 | |

**Appendix H2: Vitamin C content of stored produce inside the control system**

| Run Number/ Storage Period (days) | Garden egg (g/100ml) | Banana (g/100ml) | Tomatoes (g/100ml) |
|---|---|---|---|
| 1 | 0.185±0.01 | 0.063±0.01 | 0.200±0.01 |
| 2 | 0.182±0.01 | 0.061±0.01 | 0.183±0.01 |
| 3 | 0.178±0.01 | 0.060±0.01 | 0.180±0.01 |
| 4 | 0.170±0.01 | 0.058±0.01 | 0.173±0.01 |
| 5 | 0.168±0.01 | 0.056±0.01 | 0.169±0.01 |
| 6 | 0.166±0.01 | 0.055±0.01 | 0.164±0.01 |
| 7 | 0.156±0.01 | 0.053±0.01 | 0.158±0.01 |
| 8 | 0.153±0.01 | 0.050±0.01 | 0.149±0.01 |
| 9 | 0.150±0.01 | 0.048±0.01 | 0.142±0.01 |
| 10 | 0.140±0.01 | 0.047±0.01 | 0.134±0.01 |
| 11 | | 0.045±0.01 | 0.127±0.01 |
| 12 | | 0.043±0.01 | 0.120±0.01 |
| 13 | | 0.040±0.01 | |
| 14 | | 0.040±0.01 | |

**Appendix H3: Vitamin C content of stored produce inside the Sisal sack**

| Run Number/ Storage Period (days) | Garden egg (g/100ml) | Banana (g/100ml) | Tomatoes (g/100ml) |
|---|---|---|---|
| 1 | 0.185±0.01 | 0.063±0.01 | 0.200±0.01 |
| 2 | 0.180±0.01 | 0.059±0.01 | 0.178±0.01 |
| 3 | 0.176±0.01 | 0.057±0.01 | 0.164±0.01 |
| 4 | 0.168±0.01 | 0.056±0.01 | 0.157±0.01 |
| 5 | 0.164±0.01 | 0.054±0.01 | 0.149±0.01 |
| 6 | 0.158±0.01 | 0.051±0.01 | 0.142±0.01 |
| 7 | 0.148±0.01 | 0.048±0.01 | 0.135±0.01 |
| 8 | 0.143±0.01 | 0.046±0.01 | 0.128±0.01 |
| 9 | 0.140±0.01 | 0.041±0.01 | 0.122±0.01 |
| 10 | 0.130±0.01 | 0.040±0.01 | 0.118±0.01 |
| 11 | | 0.038±0.01 | 0.114±0.01 |
| 12 | | 0.035±0.01 | 0.100±0.01 |
| 13 | | 0.033±0.01 | |
| 14 | | 0.030±0.01 | |

## Appendix I1: Sensory Analysis of Banana Stored Inside Evaporative Cooler

| Characteristics | Storage System | Storage periods (Days) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1. Appearance | Perf. plastic | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 |
| | Control | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 |
| | Sisal sack | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 2 |
| 2. Colour | Perf. plastic | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 2 |
| | Control | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 2 |
| | Sisal sack | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 2 | 2 |
| 3. Flavour | Perf. plastic | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 |
| | Control | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 3 |
| | Sisal sack | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 2 | 2 |
| 4. Firmness/ Texture | Perf. Plastic | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 3 |
| | Control | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 |
| | Sisal sack | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 2 | 2 |
| 5. Taste | Perf plastic | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 |
| | Control | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 |
| | Sisal sack | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 2 |
| 6. Defect | Perf. Plastic | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Control | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 |
| | Sisal sack | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 2 |

## Appendix I2: Sensory Analysis of Tomatoes Stored Inside Evaporative Cooler

| Characteristics | Storage System | Storage periods (Days) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1. Appearance | Perf. plastic | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 3 | 3 | 3 |
| | Control | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 2 |
| | Sisal sack | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 2 | 2 | 2 |
| 2. Colour | Perf plastic | 5 | 5 | 5 | 5 | 4 | 4 | 3 | 3 | 3 | 2 | 2 | 2 |
| | Control | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 3 | 2 | 1 |
| | Sisal sack | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 2 | 2 | 2 | 2 | 1 |
| 3. Flavour | Perf plastic | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 |
| | Control | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 |
| | Sisal sack | 5 | 5 | 5 | 4 | 4 | 3 | 3 | 2 | 2 | 2 | 1 | 1 |
| 4. Firmness/ Texture | Perf. plastic | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 3 |
| | Control | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 2 |
| | Sisal sack | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 3 | 2 | 2 | 2 |
| 5. Taste | Perf. Plastic | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 |
| | Control | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 3 |
| | Sisal sack | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 2 | 2 | 2 |
| 6. Defect | Perf plastic | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 |
| | Control | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 2 | 2 |
| | Sisal sack | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 2 | 2 | 2 |

## Appendix I3: Sensory Analysis of Garden egg Stored Inside Evaporative Cooler

| Characteristics | | Storage System | Storage periods (Days) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1. | Appearance | Perf. plastic | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 |
| | | Control | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 |
| | | Sisal sac | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 |
| 2. | Colour | Perf plastic | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 2 |
| | | Control | 5 | 5 | 5 | 5 | 4 | 4 | 3 | 2 | 2 | 1 |
| | | Sisal sack | 5 | 5 | 5 | 4 | 4 | 3 | 3 | 2 | 1 | 1 |
| 3. | Flavour | Perf plastic | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 3 |
| | | Control | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 3 | 3 |
| | | Sisal sack | 5 | 5 | 5 | 4 | 4 | 3 | 3 | 2 | 2 | 2 |
| 4. | Firmness/ Texture | Perf plastic | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 3 | 3 |
| | | Control | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 |
| | | Sisal sack | 5 | 5 | 5 | 4 | 3 | 3 | 3 | 3 | 2 | 2 |
| 5. | Taste | Perf plastic | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 |
| | | Control | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 |
| | | Sisal sack | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 3 | 3 |
| 6. | Decay | Perf plastic | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 |
| | | Control | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 3 | 3 | 3 |
| | | Sisal sack | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 2 | 2 |