# PERFORMANCE EVALUATION OF SOME EXISTING EVAPORATIVE COOLER STORAGE SYSTEMS.

BY

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(PGD /AGRIC. ENG./99/2000/74)

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AUGUST, 2001.

## DECLARATION

I Suleiman Samaila do declare that this project is an original work of mine, and has never been presented elsewhere for any award. Information derived from published and unpublished works of others have been acknowledged in the write up.

Sign:..........................

Date.....17-08-2001.................

## CERTIFICATION

This is to certify that this project work on the "performance evaluation and modification of the existing pot-in-pot evaporative cooler storage system," was presented by Suleiman Samaila of Agricultural Engineering Department, F.U.T Minna in partial fulfillment of the requirement for the award of Post-Graduate Diploma in Agricultural Engineering.

.................................. 08/9/2001 ..............................

**ENGR.P.A. IDAH** **DATE.**
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**ENGR. (DR). M.G. YISA** **DATE.**
**HEAD OF DEPARTMENT.**

## DEDICATION

This project is dedicated to my late Mother, my wife Aisha and my children Salima and Abduljalall.

## ACKNOWLEDGEMENT

I hereby express my profound gratitude to Allah for giving me the wealth and health to carry out this project work.

My sincere thanks goes to my supervisor Engr. P.A. IDAH, who was always ready to read, criticize and offer alternative solutions at every stage of this project work.

My thanks also go to the Head of department Engr. (DR). M.G.Yisa,
Engr. (DR). D.Adgidzi, all academic and non-academic staff, and students of Agricultural Engineering Department for their academic and moral support throughout my stay in the university.

I would also thank my brothers mal Sa'ad Buba and Dr Samaila A.A.for their moral and financial support during the cause of this program.

Finally, I want to thank my class mates especially Mr P.V Kwaya and Alhaja Risikat. O.Yusuf, for their encouragement's and suggestions.

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## ABSTRACT

Fruits and vegetables, though known to be major source of vitamins in our diet, are highly perishable. After harvest, they undergo chemical changes and spoilage by bacteria, yeast, and fungi, leading to gross reduction or total loss of nutrients. These, tend to be the major cause of wastage in fruits and vegetables during time of glut, resulting in very low selling price for farmers and also responsible for its inability to be preserved against off-season, resulting to extremely high price for users (consumers). Several storage systems have been designed and are being used for storage of these fruits and vegetables. The evaporative cooler is one of the storage systems used to store fruits and vegetables. The pot-in-pot and the metal-in-pot models of evaporative coolers were chosen for the purpose of this project. The problem however, is what happens to the quality parameters of these fruits and vegetables, during this period of storage .Of considerable importance, among these parameters are those that have to do with the appearance or physical qualities. Storage trials for mango and tomato were carried out for a period of ten (10) days per replication. Temperature inside the storage chamber and ambient condition was taken at mid day (12:00 noon). An eight point Hedonic scoring questionnaire was used to assess the color and texture changes in both the pot-in-pot and metal-in-pot evaporative cooler by ten (10) panelist. The result obtained was analyzed using Chi-square. The result shows that tomato shows no significant change in both color and texture in both cases (pot-in-pot and metal-in-pot E.C.S). While mango shows significant difference in both texture and color in the pot-in-pot structure, and only significant change in texture in the metal-in-pot structure.

# CHAPTER ONE
# INTRODUCTION

## 1.0 . WHAT ARE FRUITS AND VEGETABLES.

FRUITS: -Is defined botanically as a matured ovary of a plant with or without seeds. Some fruits however, are formed from other flower parts or from the receptacle. Example is. pineapple. Fruits that are formed from inferior ovaries have their enlarged floral tube still present in them. In some cases, these accessory structures may-become a prominent part of the fruits, as in apples.

Further more, a fruits may consist of several natural ovaries remaining together as a unit and may include the matured ovaries of an entire inflorescence. (Hill 1982). Fruits can also be classified into true for those derived from the corpel(s). True fruits may be fleshy or dry. Fleshy fruits include drupes such as plums and cherries as well as tomatoes, gooseberries and currents. Dry fruits are numerous and varied, and include the caryopsis of greases, the product of pees. False fruits are those containing parts of other organs which include apples and strawberries, the flesh of which are actually swollen receptacles, (Clayton, 1986)

VEGETABLES: - Generally refers to plants other than fruits that are cultivated for human consumption or for stock-feeding, for example potatoes, carrots, cabbages. Some fruits such as tomatoes, cucumbers, okra, and pepper and some seeds such as pears, beans are also considered as vegetables. Most vegetables contain useful amount of vitamin C and minerals. Root vegetables are rich in protein. (Clayton, 1986).

Most vegetables are leaves, or steams of herbiscouse plants, although flowers, calyces, immature seeds or fruits may also be consumed as vegetables. Tomatoes and peppers are vegetables belonging to the same plant family (sola naceae) but like the other fruits. (Sydenhem, 1985).

## 1.2. PERISHABILTY OF FRUITS AND VEGETABLES

Fruits and vegetables widely grown in Nigeria like tomato, mango, pepper e.t.c, are very valuable and useful agricultural crops. Unfortunately, they are not only seasonal crops, but they are highly perishable and deteriorates few days after harvest, loosing almost all their required quality attributes and some may likely results to total waste. At high temperature and low relative humidity, as obtained in the northern part of Nigeria where these fruits and vegetables are mostly grown, it is difficult to preserve perishable products (fruits and vegetables) because deterioration sets in fast. Weight loss suffered by the commodities due to low humidity often becomes so high that shriveling and skin wrinkling leads to economic loss. (Robertson, and Creech, 1984).

## 1.3. PRESERVATION AND STORAGE OF FRUITS AND VEGETABLES

Several storage systems have been designed and are been used for the storage of some of the se fruits and vegetables. The problem however is what happens to the quality parameters of these fruits and vegetables, during this period of storage of considerable importance among these parameters are those that have to do with the appearance or physical qualities. Prices of these fruits and vegetables sometimes depend mostly on their physical appearance. (Grace.o.o, 2000).

In Nigeria, because of the initial running and maintenance cost, sophisticated cold storage facilities often supposed for fruits and vegetables storage are in most cases, not affordable and hence not available for most rural dwellers due to cost, the advanced technology they entail. They are also inappropriate to be used in many developing countries, particularly in the tropics because of the operating temperature, as most of these crops are prone to chilling injuries.

Chilling injuries causes death of small group of epidermal and associated cell, which dries up and become useless. As a result of excessive moisture loss, accumulation of toxins and mycotoxins occurs in the fruits, leading to disorderliness at low temperature in the structure of the crops, thus, loss of freshness and flavor of fruits and vegetables occurs when stored in refrigerators.

## 1.4. STATEMENT OF PROBLEM.

Fruits and vegetables are highly perishable in their fresh form, after harvest particularly under hot tropical condition. During harvest, products in excess of immediate consumption are sold, processed or stored. Products such as fruits and vegetables needs low temperature and high relative humidity for ideal storage. (Babarinsa and Nwangwa, 1986). The relevance of low temperature and high relative humidity to preservation of fruits and vegetables has been well established. (Robertson and creech, 1984). At high temperature and high relative humidity as obtained in the northern part of Nigeria, it is difficult to preserve perishable product. The initial, running and maintenance cost of sophisticated cold storage facilities often supposed for fruits and vegetables storage, are in most cases not affordable, due to high cost. The high technology they entail also makes them inappropriate to be used in developing countries.

Considering the socio-economic circumstances of most farmers and traders in fruits and vegetables, it was stressed that the least expensive method for both short and long term storage should be sought, (Ojehumon et al, 1975). To this regard, the evaporative cooler storage system has been developed to provide a suitable cooling chamber for storage of perishable products under reduced temperature and high relative humidity atmosphere, (Babarinsa and Nwangwa, 1988).

This project is undertaken to modify and evaluate the performance of the existing pot-in-pot evaporative coolant storage structure.

## 1.5 JUSTIFICATION OF THE PROJECT.

During harvest, product (Fruits and vegetables) in excess of immediate consumption are either sold, processed or stored. The initial, running and maintenance cost of sophisticated cold storage facilities often supposed for fruits and vegetables storage are in most cases not affordable. Hence, not available in most rural homes, due to cost of the advanced technology involved.

Considering the technical and economic position of most farmers and traders in fruits and vegetables, there is the need for least expensive methods for both long and short-term storage for these products. In this regard, the evaporative cooler storage system has been developed to provide a suitable cooling chamber for storage of perishables (fruits and vegetables) under reduced temperature and high relative humidity. The effect of temperature and humidity on the quality parameters namely color and texture on the stored products, which are the determining factor for the price acceptability and of the product are examined for the period of the trial storage.

## 1.6 SCOPE OF THE PROJECT

The project work is limited only to the pot-in-pot and metal-in-pot evaporative cooler storage structures. Mango and tomato being widely grown and consumed vegetable and fruits in Nigeria were used for the storage trials. The studies of the effect of low temperature and low relative humidity obtained in the cooling chamber, on the selected fruits and provide a suitable cooling chamber for storage of perishable products under reduced temperature and high relative humidity atmosphere, (Babarinsa and Nwangwa, 1988).

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## 1.7 AIMS AND OBJECTIVES.

1. To monitor the degree of cooling achievable in the cooling chamber.
2. To test the effectiveness of the system for fruits and vegetable storage.
3. To evaluate the changes in color and texture for the specified period of the trial test.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 FRUITS AND VEGETABLES

Fruits can be defined as a structure made up of one or more matured ovaries together with any accessory structure closely associated with them. Also, fruits is the ripened ovary of a flower, either by itself or in combination with other structures that have matured with it as a unit e.g. tomato, mango e.t.c. (Hall, 1982).

Vegetables are the leaves, roots or stems of herbaceous plants that is cultivated for human consumption. It is also referred to as edible plants. The edible portion may be the root, stem leaf, flower structures, fleshy fruits, e.t.c. Examples are carrots, rice, beans, e.t.c. (Owuye, 1998).

## 2.2 FRUITS AND VEGETABLES STORAGE

After harvest, fruits and vegetables remain living organisms with normal life process, absorbing oxygen, releasing $Co_2$ and metabolic heat. But, once they are severed from mother plants, they necessarily draw energy from within, hastening internal oxidation and their own deterioration. Thus, preservation requires slowing those processes through low temperature, and high relative humidity between 85 to 99 percent.

Appropriate refrigeration system faces high capital costs, better suited to long term storage than the mere seasonal pre-cooling. Thus, evaporative cooling is more ideal for removing field heat from any products offering low cost, adequate air flow, and humility, and reasonably adequate low temperature (Kordyles, 1990).

## 2.3 CONDITIONS FOR STORAGE

Harvest crop when matured, but when still in the green state and avoid mechanical injury to the crop while handling and exposure to direct sunlight.

1. Sort out damaged crops from undamaged crops before storage, and stored crops should be washed and cleaned.
2. Clean, smooth and ventilated containers should be used for packaging.

## 2.4 CAUSES OF SPOILAGE IN PERISHABLE PRODUCT (FRUIT AND VEGETABLE).

Fruits and vegetables, unlike durable crops do not undergo dormancy period. They do not keep for longer than seven (7) days after ripening. Apart from physiological problems, bacteria, fungi, insect and mechanical damage also accelerate the spoilage of fruits and vegetables. To extend the storage life of fruits and vegetables, these agents of deterioration must be controlled (NSPRI BREIF, FEB, 1986).

Indication of spoilage is noticed by changes that render definite variation in original characteristics, odor test, physical appearance and chemical behavior. Mechanics of spoilage in fruits and vegetables is as a result of continual chemical activities after harvesting (Tindall, 1986).

Extending the shelve life of perishable products such as fruits and vegetables will be of advantage to rapidly expanding market. This will also help in stabilizing the price and reduce waste (Tindall, 1986). Oluwale, (1993) described some of the cooling procedures as hydrocooling, contact icing, vacuum cooling, and the use of high velocity cold air. Other methods are elimination or drastic reduction of $c_{o2}$from the storage environment in conjunction with cold storage. Midon and Lam, (1980).

## 2.5. STORAGE SYSTEMS AND STRUCTURES FOR FRUITS AND VEGETABLE STORAGE.

## 2.6. VINE STORAGE

Market situation or processing companies sometimes force farmers to practice "vine storage", by limiting the number of creates or boxes they will accept each day.vine storage means that the earlier maturing fruits are left on the vine for several weeks after they reach full color. Rueben, (1980).

## 2.7. COLD STORAGE

This is a method of preserving perishable commodities in their fresh and wholesome state for extended self-life, by providing and controlling proper temperature and humidity conditions within the storage compartment.

Normal atmospheric temperature and relative humidity conditions are seldom at a level conducive to the safe and prolonged storage of perishable foods. It is necessary therefore that artificial means be provided to produce such an environment. Cold storage is recommended because it retards: -

1.Respiration and other metabolic activity.

2.Aging due to ripening, softening, texture and color changes.

3.Moisture lost and wilting.

4.Spoilage due to invasion by bacteria, fungi, and yeast.

5.Undesarable growth, such as potato sprouts. Opadakun, (1987).

Table (I) under appendix (vi) shows the characteristics of products in terms of temperature, relative humidity, storage life, highest freezing point, and water content in each product under cold storage. McCollum, (1980).

## 2.8HISTORY OF EVAPORATIVE COOLER

Table (I) Under Appendix (III) shows the optimum storage temperature and shelf life of fruits under cold storage. Hall, (1973).

Evaporative air-cooling occurs in nature near waterfalls, over lakes and in particular human skin. Most primitive humans probably observed it, and exploitation occurred in many areas and ages. Early development took place in the Near East, where hot arid climates provide both incentive and favorable condition.

Evaporative cooling was known to ancient Egyptians.Fresccoes from about 2500 BC Showed slaves fanning jars of water to cool them. The vessels were porous enough to maintain wet surface to facilitate the process. Dale, (1990).

Leonard DA Vinci probably made the first mechanical air cooler, to cool the boudoir of his patriots wife. It was a hollow water wheel through which air was drawn by rising and falling water in its chambers as they revolved successively into and out of a stream. Water entering the wheel splashed through the air-cooling and cleansing it and forcing it through wooden valves out of the hallow axle and into the boudoir. Dale, (1990).

Also, early attempts at automotive air conditioning consist of evaporative coolers that where hanged from the passengers side window. Water was fed by gravity or capillary action over a filter or screen. Incoming air followed through the screen into the passengers' compartment. The evaporating water absorbs heat from incoming air. Hall, (1979).

However, the disadvantage of this system is that it rises the humidity inside the car. Early Auto air conditioners were hanged from the passengers side window and cooled only while the car is moving.

Such coolers deserve some credit for the rapidly growing wealth and population of western areas. Not only did they provide employment in several cities but also, as the world's first inexpensive air conditioning, they make the hottest towns and farmers comfortably habitable for the first time.

Nevertheless, the most usual cooling market agriculture, to which the cost of referidgerative cooling are prohibitive. It is an ideal market for evaporative cooling.

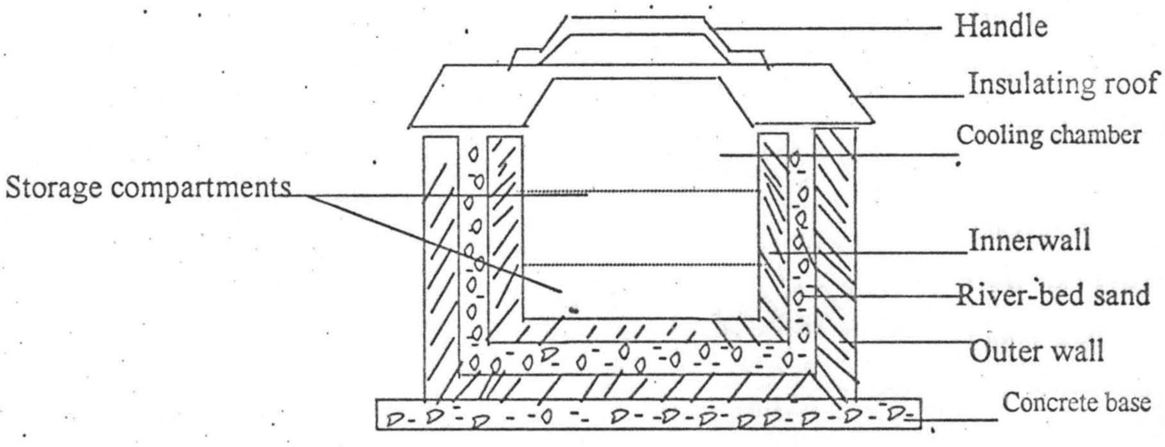
## 2.9 EVAPORATIVE COOLERS.

Evaporative cooler use heat from air to vaporizes water. This, increases the relative humidity, but lowers the air temperature. The lower the relative humidity of incoming air the more effective is the evaporative cooling. Evaporative coolers are therefore useful in dry areas, but also effective in other areas. Humidity drops as air temperature rises, and is usually lowest during the hottest part of the day. ASAE Hand Book (1987). Evaporative cooler works on the principle of cooling resulting from evaporation of water from the surface of the structure. 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 temperature. The atmosphere in the chamber therefore becomes more conducive for fruits and vegetables storage. NSPRI, (1990) .

## 2.10 TYPES OF EVAPORATIVE COOLERS

## 2.11 RECTANGULAR DOUBLE WALLED E.C.S

This structure of evaporative cooling system is composed of burnt brick wall with an insulating roof fig. (1) below. The burnt brick on a solid foundation is used to make a double walled rectangular chamber and carries a heat-insulating roof. Riverbed sand is filled between the double-walled serves as the cooling medium. The storage chamber, which is the inner wall, is divided into compartments for fruits and vegetables storage bed. NSPRI BRIEF, (1986).




(FIG. 1). Doubled walled-rectangular structure evaporative cooling system. Source:- NISPRI BRIEF,(1986).

## 2.12. POT-IN-POT EVAPORATIVE COOLANT STRUCTURE MODEL.

This model consists of two clay pots of different sizes. The smaller pot is placed inside the bigger pot. The space between them was filled with riverbed sand that is periodically kept wet. The smaller pot was coated with cement externally to prevent inside seepage of water. The principle of cooling is based on the wet river bed sand which forms the cooling medium from where heat is also sent out across the outer wall by evaporation of water from the outermost surface of the structure. (NSPRI Brief, 1986).

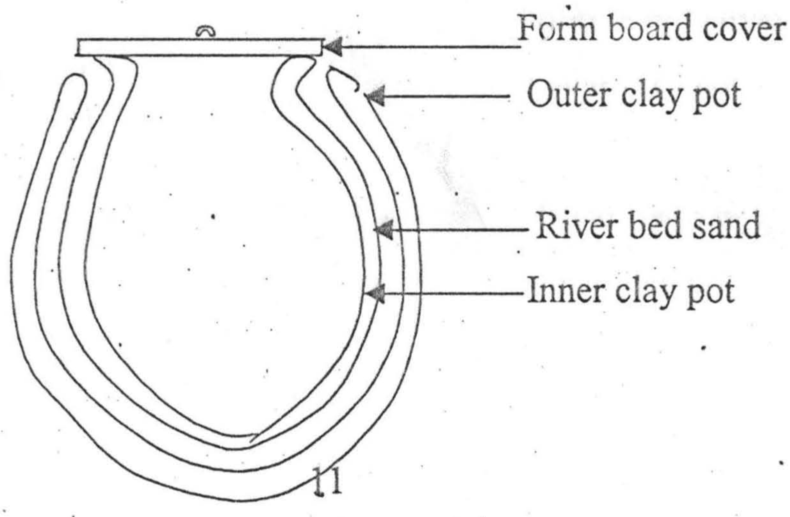


Fig. 2. Shows the pot-in-pot evaporative cooler model.

Source:- NISPRI BRIEF,(1986).

## 2.13METAL-IN-POT EVAPORATIVE COOLER

This model consists of a big clay pot in which a metal tin is placed inside it. The space between the clay pot and the metal tin is filled with riverbed sand, which is constantly kept wet. The metal tin serves as the cooling chamber.

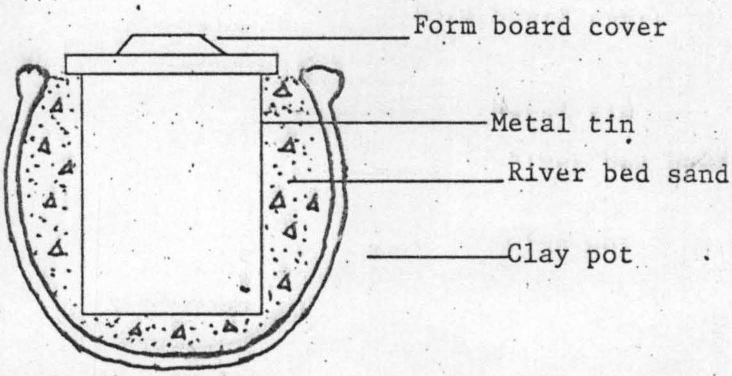



Fig. 4 Metal-in-pot evaporative cooler.

Source:- NISPRI BRIEF,(1986).

## 2.14 LIMITATION OF EVAPORATIVE COOLERS

Evaporative cooling of air closely approximates a constant wet bulb process and lowest possible dry bulb temperature of the air off the cooler (at 100% adiabatic efficiency) as the wet bulb temperature of the ambient air. The area is then one of the important limitation on the evaporative cooler performance.

However, as far as dry bulb temperature is concerned, most people will agree that cooling as desirable in many climate where 32.2 $^0$C is exceeded for several hours of the day over an extended period with wet-bulb temperature not exceeding 23.8 $^0$C. (Stockier, 1958).

Therefore, evaporative cooling is satisfactory only in areas where dry-bulb temperature is in excess of 33.2 $^{0}$C,combined with wet-bulb lower than 23.8 $^{0}$C.

## 2,15. PSYCHOMETRIC COOLING.

Psychometry is a graphical representation of the psychometric properties of air. The term adiabatic means that a process occurs at constant heat. As applied to evaporative cooling, this means that an air-water-vapor mixture as cooled (i.e. it's dry-bulb temperature is lowered) without any gain or loss of heat through the ambient or casing of the cooling mechanism.

However, if an evaporative cooler is to cool air without any heat transfer to or from the outside of the unit, it follows inescapably that some form of heat transfer or exchange must occur within the cooling unit itself. This internal heat exchange involves the evaporation of water, and the heat required to evaporate the water is taken from the sensible heat of air into which the water evaporates.

When the water is injected at a pressure equal to the wet-bulb temperature of the entering air ($t_{wi}$), then the process follows the path of constant wet-bulb temperature line (WTB) as shown in fig.3. below.

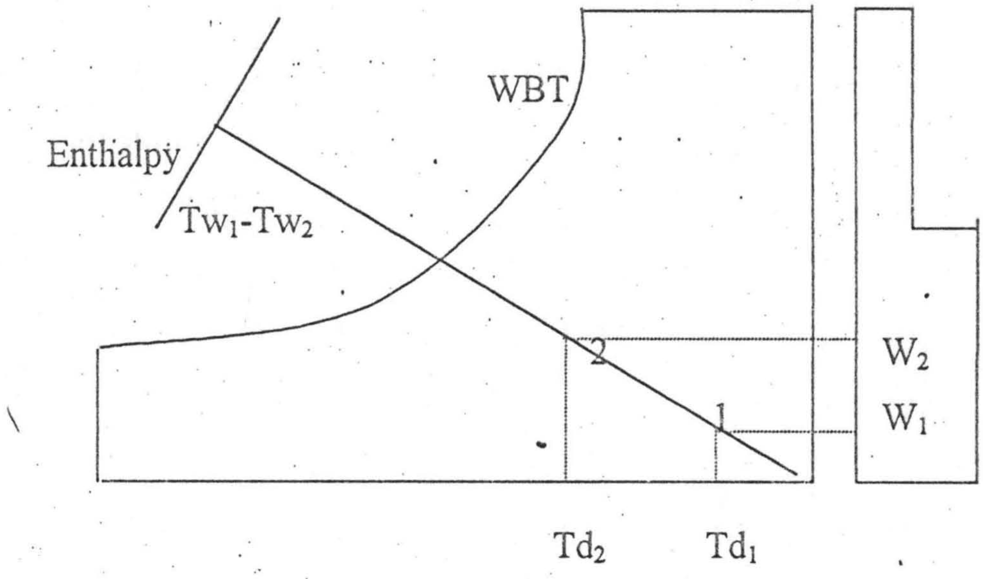


Fig.3 showing psychometric cooling by adiabatic cooling of air by evaporation of water into the air stream.

Where: - $T_{d1}$ = Dry-bulb Temperature of entering air.

$T_{d2}$ = Dry-bulb Temperature of leaving air.

$T_{W1}$ = Wet-bulb Temperature of entering air.

$T_{w2}$ = Wet-bulb Temperature of leaving air.

$W_1$ = Specific humidity of entering air.

$W_2$ = Specific humidity of leaving air.

## 2.16. MECHANICAL REFRIGERATED STORAGE.

Mechanical refrigeration is a process of lowering temperature of a substance below that of its surrounding. Refrigeration is firmly rooted in two basic principles known as first and second laws of thermodynamics. The first law states that energy may neither be created nor destroyed. . The second law states that no system can receive heat at a given temperature without receiving work from surroundings. Heat always flows from the warmer to the cooler body. Through, a consideration of this law, the ideal refrigeration cycle would be the reversed carnot cycle.

## 2.17 QUALITY EVALUATION.

Quality of foodstuff is said to be assessed on the basis of balancing specific characteristic each of, which has significance in determining the acceptability of the product, thus determining overall gravity. Drecrosier, (1997) declared the each of there characteristics should be measured and controlled adequately.

Quality is said to be commonly thought of as degree of excellence. Drecrosier, (1977) also noted that it may be considered as a specific action or set of specifications which are to be meet, within a given tolerance or limit. Therefore, the level of excellence of the product may be considered as the average or mean level of quality required in the market place, and not necessarily the highest quality that is obtainable regardless of cost.
The uniformity of the product may be described in terms of minimum limits or a tolerance between upper and lower control limits.

An important aspect of quality control is said to be the utilization of reliable method of measurement in establishing standards or specifications of quality and grading procedure, to control the quality of raw materials as well as the processing operation and finished products. (Williams, 1982).

## 2.18 OBJECTIVE AND SUBJECTIVE METHODS.

Subjective or sensory evaluation is said to be made up by human judgement, using human senses. It has been noticed by Williams (1982) that sensory evaluation suffers from being influence by environmental conditions, mood and health of the individual, lack of an absolute reference point, tendency for cooperative rather than absolute evaluations and above all personal bias which may enter the evaluation consciously or subconsciously.

Objective evaluation is said to refer to use of calibrated instruments, to measure physical or chemical components, which is less dependent on human element. However, Williams (1982) that unless correctly conducted, it can lead have noted it to greater error than subjective evaluation. It has also been noted by Williams (1982) that human evaluation is the ultimate criterion of the accuracy of any objective method, hence if a subjective evaluation is possible, it is generally used in preference to an objective evaluation, With all products destined for consumption. Williams (1982) has noted that the only way to judge their success or failure is to have them examined by human assessors

## 2.19 QUALITY ATTRIBUTES

Quality attributes are said to be classified as either sensory or hidden. Sensory characteristics are those which can be detected with human sense including sense of sight, touch, taste, and smell, whereas hidden characteristics are said to be those which cannot be evaluated with sense but are of importance to health. Williams et al, (1977).

Appearance-Factors of quality included in appearance is said to be those evaluated with the eye and hence the first noticed by the consumer. It has been noted by Williams et al, (1977) that it is often on its appearance that product is accepted or rejected, and therefore good appearance is most important.

Colour-is said to be an appearance property attributable to the spectral distribution of light.

The most complex and experience instrument used for Colour measurement is the spectrophotometer which measurement the amount of light reflected from the surface of an object at each wave length in the range of approximately 380 to770 um.

A quicker and cheaper method is the munsell system—which uses 3 or 4 Colour disc, each of which is calibrated in term of live (red, green), value (lighting and darkness), chroma (strength of Colour) each of these is expressed on a scale. The discs are developed so that the proportion of each disc, which is exposed, may be adjusted until blend of colors obtained by spinning the disc, match the object whose Colour is being measured. The percentage of each disc exposed, and the disc notations are converted to munsell notions, using tables and charts.

The main Colour evaluation instrument is the Hunter Colour difference meter. It is less expensive than the spetrophometer, but more costly than the munsell system. It measures the value, the amount of redness or greenness and the amount of yellowness or blueness, that is Hunter value, which can be converted to munsell notation.

Some important properties are said to be determined by instruments or by chemical analysis, but Williams, et al (1977) noted that such measurements must be related to consumers preference by sensory evaluation, hence direct sensory evaluation is often the only acceptable method, especially when the combined effect of several different properties is concerned.

## 2.20SENSORY EVALUATION

In sensory evaluation the reactions of a selected group of people testing the product under controlled conditions are used to predict the ultimate acceptability of the product. Useful information are obtained only if the right questions are asked of the right people.

To choose satisfactory test procedure, depending on the type of product being tested, different assessors are required.

**1.Expert assessors**: - Experts assessors are said to be those who know a great deal about the production, use, and marketing of a commodity. Thy are said to be able to describe all the attributes of a sample in detail and can usually indicate the causes of any defects. Their training is a long and expensive process and they are usually found working in production and development departments of food manufacturing companies or consultancy, and specialist commodity dealers. They are full-time assessors. Dresrosier, (1977).

**2.Eperienced assessors:** -These is said to be people selected for their ability to recognize, describe and qualify basic characteristics of food and to detect small differences between samples. They may or may not specialize in one commodity. Experienced assessors usually employed to spend only part of their time as assessors. They work in panel of 10 to 15 members. Most quality control and product development work is done with assessors of this type. Dresrosier, (1977).

**3. Untrained assessors:** -are said to be selected as typical as possible of the consumers of the product concern. They work in panels of 10 to 30, usually assessing acceptability and preference before consumer trails are begun. Dresrosier, (1977).

4. **Consumer panels:** -Consumer panels are said to be of large untrained groups of at least 100 members, they are selected at random from the section of the population whom the product is aimed and usually concerned with preference and acceptability, in which case they must be willing and able to take part in as many test as is necessary.

5. They are also selected for interest purpose, in which case, they must be interested in the product and in taking part in the test. They should normally be consuming similar product themselves. This group is for consistency therefore they must be consistent in their assessment. If they are presented with the same preference in a significant proportion of these test. Drosrosier, (1977).

It has been noted by Drosrosier, (1977) that experienced assessors would be able to: -

A.paired comparison:

This test is more efficient when R is always the control sample. This method should not be used when there are more than two treatments. Statistical tables can be used to determine the significance of results. Drosrosier, (1977).

B. Ranking.

The panelists are asked to rank several coded samples according to the intensity of some particular characteristics. The ranking method is said to be generally used for screening one of the best samples from a group of samples rather than to test all samples thoroughly.

This method is rapid and allows for testing of several samples, but no more than six samples of any product should be ranked at a time. Ranking gives no more indication of the amount of difference between the samples since samples are evaluated only in relation to each other; results from one set of ranks cannot be compared directly with the results. Dresrosier, (1977).

# CHAPTER THREE

# MATERIALS AND METHOD

## 3.1. MATERIALS

- Two big burnt clay pot
- One small burnt clay pot
- One cylindrical metal pot with cover
- River bed sand
- Mango (magnifere indica)
- Tomato(Lycopersium esculentum)
- Wet and Dry bulb Thermometer
- Colour and Texture scouring Questionnaire.

## 3.2 EVALUATION OF THE EXISTING POT-IN-POT EVAPORATIVE COOLER STRUCTURE.

Storage trial using Mango (Magnifere indica) and Tomato (lycopersium esculentum) were conducted using the existing pot-in-pot evaporative cooler. The temperature drop and relative humidity inside the storage chamber were recorded daily for a period of thirty days. A test panel was constituted among Lecturers, Laboratory Technicians and Students of Federal University of Technology Minna, to obtain the variation in Color and Texture, using the eight point Hedonic score as described by Desrosier(1977).

## 3.3 EVALUATION OF THE METAL-IN-POT (E.C.S).

Storage trails were conducted in the modified system with mango (magnifera indica) and tomato (lycopersium esculentum). A similar procedure was followed as discussed in 3.2 above.

## 3.4 DETERMINATION OF COLOR AND TEXTURE(QUALITY PARAMETERS).

### SENSORY EVALUATION METHOD.

The color and texture qualities of the fruits stored in evaporative cooler were determined, using sensory evaluation method. Sensory evaluation is used in studies involving product development, product improvement, quality maintenance as well as in acceptability studies of newly formed product. Omojiba, (2000).

The test essentially employs senses of sight, feel or touch to ascertain the quality of the product. This method is important, as it makes research into consumers preference of organolephic quality (such as that of color and texture in this particular research work) thereby, ascertain the product acceptability.

A ten-panel chosen from Lecturers, Laboratory Technicians, and Students were used to evaluate the color and texture qualities of the stored fruit and vegetable, using eight-point Hedonic scoring scale method. Dresrosier, (1977).

Coded samples were evaluated for specific characteristics (color and texture), by the panelist, who records their evaluation on a descriptive graduated scale shown in Appendix 1,2,3 and 4. Scoring gives an indication of the size and direction of the differences or variation from standard sample, which are the fresh fruit and vegetable. The samples were evaluated at an interval of two days from the beginning of the storage.

## 3.5 CHI-SQUARE TEST

The data collected was then transformed and analyzed using chi-square method (for analyzing enumerated data) using the formula below.

$$\chi^2 = \Sigma \frac{(o - E)^2}{E}$$

Where, o =The observed value of each sample

E = Corresponding expected value (Kwan chi et al, 1984, Thomas et al, 1978, Murry, 1992).

To evaluate this expression, the expected value is first determined, according to our hypothesis. The expected value is then subtracted from the observed value, the resulting difference is then squared and then divided by the expected value. These quotients are summed over all the samples. The sum is then compared with values in a chi-square Table at the appropriate degree of freedom (df).

The chi-square test is the classical method of analyzing frequencies. The test involves comparing a test statistics, which is compared with a chi-square ($\chi^2$) distribution at a given degree of freedom (df) called the value at the significance, level we are interested in, that is p=0.05and 0.01 (5%and 1%lvels) each are commonly employed. Murry, (1992).

A measure of the discrepancies existing between the observed and expected frequencies is supplied by the statistic

$\chi^2$(chi-square) which is given by Murry (1992).

$$\chi^2 = \frac{(0_1 - E_1)^2}{E_1} + \frac{(0_2 - E_2)^2}{E_2} + \ldots\ldots\ldots\ldots\ldots\ldots \frac{(0_k - E_k)^2}{E_K}$$

$$= \sum_{j=1}^{K} \frac{(0_j - E_j)^2}{}$$

Where the total frequency is N

$\sum_{Oj} = \sum_{Ej} = N$

$$\chi_2 = \frac{\sum O_j - N}{E_j}$$

If $\chi_2 = 0$, the observed and expected frequencies agree exactly, while if $\chi_2 > 0$, they do not agree exactly. The larger the value of $\chi_2$, the greater is the discrepancy between the observed and expected frequencies.

In practice (Murry, 1992) frequencies are computed on the basis of a hypothesis $H_o$: If under this hypothesis, the computed value $\chi_2$ is given by equation ($x_2 = \frac{\sum_{oj} - N}{E_j}$) or $\{x_2 = \sum_{j=1}^{k} \frac{(o_j - E_j)^2}{E_j}\}$ is greater than some critical Value (such as $x_2 = 95$ or $x_2 = 99$), which would conclude that the observed frequencies differ significantly from the expected frequencies and would reject $H_o$: at the corresponding level of significance, otherwise we accept it (or at least not reject it).

CAPTER FOUR

RESULT AND DISCUSSION

## 4.1 EVALUATION OF THE POT-IN-POT EVAPORATIVE COOLER

TEMPERITURE AND RELATIVE HUMIDITY OBSERVED IN THE PO-IN-POT E.C.S.

Reading of wet and dry-bulb temperatures and relative humidity inside the pot-in-pot evaporative cooler storage structure were taken at mid-day (12:00 Noon), for the thirty days storage trials. The results are shown in table 1 below.

**Table 1** Wet and dry-bulb temperature, and relative humidity in the pot-in-pot structure, for the thirty days storage period.

| | POT-IN-POT E. C. S | | | | AMBEINT TEMPERATURE | | | |
|---|---|---|---|---|---|---|---|---|
| DAYS | Wet-bulb ($^0$C) | Dry-bulb ($^0$C) | Wet-bulb depression($^0$C) | R .H (%) | Wet-bulb ($^0$C) | Dry-bulb ($^0$C) | Wet-bulb depression($^0$C) | R .H (%) |
| 1 | 24 | 28 | 4 | 70 | 25 | 36 | 11 | 38 |
| 2 | 24.1 | 27.6 | 3.5 | 75 | 24 | 38 | 14 | 28 |
| 3 | 25 | 30 | 5 | 65 | 26 | 33 | 7 | 56 |
| 4 | 26 | 27 | 1 | 92 | 26 | 35 | 9 | 48 |
| 5 | 20 | 23 | 3 | 75 | 20 | 28 | 8 | 45 |
| 6 | 21 | 27 | 6 | 56 | 26 | 34 | 8 | 51 |
| 7 | 20 | 25 | 5 | 61 | 20 | 34 | 14 | 23 |
| 8 | 20 | 22 | 2 | 82 | 21 | 35 | 14 | 23 |
| 9 | 20 | 24 | 4 | 68 | 20 | 34 | 14 | 23 |
| 10 | 26 | 29 | 3 | 78 | 26 | 34 | 8 | 51 |
| 11 | 24 | 25 | 1 | 84 | 21 | 36 | 15 | 22 |
| 12 | 25 | 29 | 3 | 78 | 24 | 36 | 12 | 34 |
| 13 | 25 | 29 | 4 | 71 | 23 | 37 | 14 | 26 |
| 14 | 22 | 25.5 | 3.5 | 73 | 26 | 38 | 12 | 36 |
| 15 | 24. | 25 | 1 | 92 | 25 | 38 | 13 | 32 |
| 16 | 25 | 27 | 2 | 84 | 26 | 39 | 13 | 34 |
| 17 | 25 | 27 | 2 | 84 | 25 | 40 | 15 | 27 |
| 18 | 23 | 25 | 2 | 84 | 26 | 30 | 4 | 72 |
| 19 | 26 | 28 | 2 | 85 | 29 | 36 | 7 | 58 |
| 20 | 25 | 28 | 3 | 77 | 27 | 34 | 7 | 56 |
| 21 | 27 | 30 | 3 | 79 | 27 | 34 | 7 | 56 |
| 22 | 25 | 29 | 4 | 71 | 26 | 37 | 11 | 40 |
| 23 | 26 | 30 | 4 | 72 | 28 | 38 | 10 | 45 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 24 | 25 | 29 | 4 | 71 | 26 | 37.5 | 11.5 | 40 |
| 25 | 25 | 30 | 5 | 65 | 27 | 38 | 11 | 40 |
| 26 | 23 | 25 | 2 | 84 | 23 | 27 | 4 | 70 |
| 27 | 25 | 28 | 3 | 77 | 30 | 36 | 6 | 63 |
| 28 | 26 | 30 | 4 | 72 | 29 | 35 | 6 | 63 |
| 29 | 27 | 30 | 33 | 78 | 29 | 38 | 9 | 50 |
| 30 | 26 | 30 | 4 | 72 | 30 | 35 | 5 | 69 |

Table 4and 5 shows the Hygrograph and multiple bar chart for the above data

## 4:2 COLOR SENSORY EVALUATION OF THE STORED FRUITS AND VEGETABLES (MANGO AND TOMATO) IN THE POT-IN-POT STRUCTURE.

During the storage period, each of the fruits and vegetable samples were evaluated for change in physical quality parameters by the use of questionnaires shown in Appendix 1,2,3 and 4..

The results of the observed panelist scores for color and texture for the two products (mango and tomato) are shown in Tables 2 and 3.

## 4:3 COLOR EVALUATION OF STORED MANGO IN THE POT-IN-POT EVAPORATIVE COOLER STRUCTURE.

To determine whether the observed color scores differs significantly from the expected or original color of the mango, the observed panelists scores were statistically analyzed. For mango, the data is as shown in table 2.

A statistical hypothesis is then set up about the sample population. It is hypothesed that there is no significant difference between the color quality of the fresh and the stored mango at the end of the ten- (10) day's storage.

$H : \mu = 8$

$H : \mu < 8$

TABLE 2 RESULT OF COLOUR SENSORY EVALUAITION OF STORED MANGO IN THE POT-IN-POT STRUCTURE.

| Sample. | Y1(replication) Panelist:- 1 2 3 4 5 6 7 8 9 10 | x̄ | Y2(replication) Panelists:- 1 2 3 4 5 6 7 8 9 10 | x̄ | Y3(replication) Panelist:- 1 2 3 4 5 6 7 8 9 10 | x̄ |
|---|---|---|---|---|---|---|
| A11 | 8 8 8 8 8 8 8 7 8 8 | 7.9 | 8 8 8 8 8 8 8 8 8 8 | 8.0 | 8 7 8 8 7 8 8 8 8 8 | 7.9 |
| A11 | 8 8 7 8 7 8 7 6 7 7 | 7.3 | 8 6 7 8 7 7 8 7 8 7 | 7.3 | 7 7 8 7 7 7 7 8 7 7 | 7.2 |
| A11 | 7 6 6 7 7 7 6 5 6 6 | 6.3 | 7 6 5 7 5 6 7 6 6 6 | 6.1 | 5 6 7 6 6 6 6 7 6 6 | 6.1 |
| A11 | 5 3 6 4 6 6 5 4 5 5 | 4.9 | 2 2 3 5 4 4 6 5 4 3 | 3.8 | 3 5 5 4 6 5 4 6 5 4 | 4.7 |
| A11 | 3 2 4 3 4 4 3 3 3 4 | 3.3 | 1 1 2 2 4 3 4 3 3 2 | 2.5 | 2 3 4 3 5 4 3 4 4 2 | 3.4 |
| | ..Y | 5.94 | ..Y | 5.5 | ..Y | 5.86 |
| | | | | 4 | | |
| A12 | 8 8 8 7 8 8 7 7 7 7 | 7.5 | 7 8 7 8 7 8 8 7 8 8 | 7.6 | 8 7 8 7 7 8 7 8 8 8 | 7.6 |
| A12 | 7 7 8 7 8 7 6 7 6 6 | 6.9 | 7 6 6 7 6 6 7 6 8 7 | 6.8 | 7 7 7 6 6 7 6 6 7 7 | 6.6 |
| A12 | 6 5 7 6 6 5 5 7 4 5 | 5.6 | 5 7 4 5 5 5 6 4 6 4 | | 4 6 6 5 5 7 5 5 5 4 | 5.2 |
| A12 | 4 2 6 6 5 5 4 5 4 3 | 4.4 | 2 2 4 3 3 3 5 4 3 2 | 5.1 | 2 4 4 3 5 6 3 5 4 3 | 3.9 |
| A12 | 2 1 6 4 3 3 2 4 2 2 | 2.9 | 1 1 3 3 2 2 3 2 2 1 | 3.1 | 1 2 3 2 4 3 2 3 3 1 | 2.4 |
| | ..Y | 5.46 | ..Y | | ..Y | 5.14 |
| | | | | 2.0 | | |
| A13 | 8 8 8 8 8 6 7 7 7 6 | 7.3 | 8 8 8 7 7 8 7 7 8 7 | | 7 7 7 7 6 8 7 7 7 7 | 7.0 |
| A13 | 7 7 8 8 7 6 6 7 6 5 | 6.7 | 8 7 6 7 6 7 6 5 7 6 | 4.9 | 6 6 7 6 6 5 5 6 6 6 | 5.9 |
| A13 | 5 5 7 6 7 4 4 6 4 4 | 5.2 | 5 7 4 6 5 5 5 5 5 4 | 2 | 4 5 5 5 5 4 6 4 4 | 4.7 |
| A13 | 3 2 7 6 6 3 3 6 3 2 | 4.1 | 1 1 3 4 3 2 4 4 3 2 | | 2 4 3 4 5 4 3 4 3 3 | 3.5 |
| A13 | 1 1 5 4 3 2 2 4 2 1 | 2.5 | 1 1 1 2 3 2 2 2 2 1 | 7.5 | 1 1 2 1 3 2 2 1 2 1 | 1.6 |
| | ..Y | 5.16 | ..Y | 6.5 | ..Y | 4.54 |
| | | | | 5.1 | | |
| | | | | 2.7 | | |
| | | | | 1.7 | | |
| | | | | 4.7 | | |

Where:- A11, A12,& A13 = Samples of mango stored.

Y1 , Y2 ,& Y3 = Storage replication after ten (10) days.

..Y = mean color scores at the end of ten (10) days Storage period.

To determine whether the observed frequencies (obtained from 4.14 above), differs significantly from the expected frequencies, a measure of discrepancy existing between the observed and the expected frequencies is supplied by the statistic chi-square.

Given by $\chi^2 = \frac{(O_1-E_1)}{E_1} + \frac{(O_2-E_2)}{E_2} \ldots\ldots\ldots + \frac{(O_K-E_K)}{E_K}$

$$= \sum_{j=1}^{K} \frac{(O_j-E_j)^2}{E_j}$$

## 4.4 COLOR EVALUATION FOR TOMATO STORED IN THE POT-IN-POT E.C.S.

TABLE 4 RESULT OF COLOR SENSORY EVALUATION OF STORED TOMATO IN THE POT-IN-POT E.C.S

| SAMPLE | Y1(replication) Panellist 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ | Y2(replication) Panellist 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ | Y3(replication) Panellist 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ |
|---|---|---|---|---|---|---|
| B11 | 8 8 8 8 8 8 8 8 8 8 | 8.0 | 7 7 8 8 7 8 8 8 8 8 | 7.7 | 8 7 8 8 7 8 8 8 8 8 | 7.8 |
| B11 | 8 8 8 8 8 8 8 8 8 7 | 7.9 | 7 5 7 8 7 8 8 8 8 8 | 7.4 | 7 7 7 8 7 8 8 8 8 8 | 7.6 |
| B11 | 7 8 8 7 7 7 8 8 7 7 | 7.4 | 7 8 7 7 7 8 8 8 8 7 | 7.5 | 7 7 7 7 6 7 7 7 8 8 | 7.1 |
| B11 | 7 8 7 7 7 6 7 7 7 6 | 6.9 | 4 5 7 6 4 8 7 7 7 8 | 6.3 | 7 7 7 7 7 7 8 7 7 8 | 6.9 |
| B11 | 6 8 7 7 6 6 6 7 6 6 | 6.5 | 4 5 6 6 3 7 6 6 6 7 | 5.6 | 7 7 6 7 6 6 6 6 7 7 | 6.5 |
| | ..Y | 7.34 | ..Y | 6.9 | ..Y | 7.1[illegible] |
| B12 | 8 8 8 8 8 8 8 8 8 8 | 8.0 | 7 6 8 8 7 8 8 8 8 8 | 7.8 | 8 7 8 8 7 8 8 8 8 8 | 7.8 |
| B12 | 7 8 7 7 7 8 7 8 8 7 | 7.4 | 6 7 8 8 7 8 8 8 8 8 | 7.6 | 7 7 7 7 6 7 8 8 8 8 | 7.3 |
| B12 | 6 7 7 7 6 8 7 8 8 7 | 7.1 | 7 8 7 8 8 7 7 7 8 8 | 7.5 | 7 7 6 7 6 6 8 8 7 7 | 6.9 |
| B12 | 6 7 7 6 6 7 6 7 8 7 | 6.7 | 7 5 6 7 4 7 6 6 7 6 | 6.1 | 7 7 6 6 7 5 8 8 7 6 | 6.7 |
| B12 | 6 7 6 6 5 7 5 7 7 7 | 6.3 | 7 5 6 7 3 5 6 5 6 5 | 5.5 | 6 7 5 6 7 4 7 7 6 6 | 6.1 |
| | ..Y | 7.1 | ..Y | 6.9 | ..Y | 6.9[illegible] |
| B13B | 8 7 7 8 8 8 8 8 8 8 | 7.8 | 7 6 8 8 6 8 8 8 8 7 | 7.4 | 8 7 8 8 7 8 8 8 8 8 | 7.8 |
| 13 | 8 7 8 8 7 8 7 7 8 8 | 7.6 | 7 4 7 8 6 8 7 8 8 7 | 7.0 | 8 6 8 8 6 8 8 8 8 7 | 7.5 |
| B13 | 7 7 7 7 6 7 7 7 7 8 | 7.0 | 7 7 6 8 8 7 7 7 8 6 | 7.1 | 8 6 7 8 6 8 8 8 7 6 | 7.2 |
| B13 | 6 7 7 7 6 7 6 6 7 6 | 6.5 | 7 4 6 8 3 7 7 6 8 7 | 6.3 | 6 6 7 8 7 7 7 8 7 5 | 6.8 |
| B13 | 5 6 7 6 6 6 6 5 6 7 | 6.0 | 7 4 5 7 2 5 7 5 7 6 | 5.5 | 6 6 5 7 7 7 7 7 6 5 | 6.3 |
| | ..Y | 6.98 | ..Y | 6.66 | ..Y | 7.1[illegible] |

To determine weather the observed frequencies (obtained. from table 4) differ significantly from the expected frequencies, a measure of the discrepancy existing between the observed and the expected frequencies is supplied by the statistic chi-square. Using the mean values obtained in table to calculate the chi-square value as shown below.

$$\chi^2 = \Sigma\frac{(O-E)^2}{E}$$

$$= (7.34-8)^2 + (7.1-8)^2 + (6.98-8)^2 + (6.9-8)^2 + (6.9-8)^2 \ldots\ldots.(7.12-8)^2$$

$$=1.12.$$

Checking the calculated value of 1.12 opposite one degree of freedom shows that the probability of obtaining the result by chance is greater than 5%.

Applying the results to discrete data to determine its goodness of fit using Yates correction factor, to further check the discrepancy the validity of the previous result obtained.

$$\chi^2\,(\text{corrected}) = \frac{\{(O_1 - E_1) - 0.5\}^2}{E_2} + \frac{\{(O_2 - E_2) - 0.5\}^2}{E_2} + \text{--------}$$

$$+ \frac{\{(O_k - E_k) - 0.5\}^2}{E_k}$$

$$\chi^2\,(\text{corrected}) = \frac{\{(7\text{-}34 - 8) - 0.5\}^2}{8} + \frac{\{(7\text{-}1\text{-}8) - 0.5\}^2}{8} + \text{---------}$$

$$+ \frac{\{(7.12 - 8) - 0.5\}^2}{8} = 2.65$$

Referring to the chi- square table under 1 degree of freedom, we would expect a value greater than 3.84 at 5% level and not less than 1.325 at 1% level.since the calculated chi – squared value of 2.65 is less than 2.71 the hypothesis is accepted at with 5% level of error.

**4.5 TEXTURE EVALUATION FOR MANGO STORAGE IN THE POT-IN-POT E. C. S**

TABLE 5 RESULTS OF TEXTURE SENSORY EVALUATION OF STORED MANGO IN THE POT-IN-POT E.C.S

| SAMPLE | Y1(replication) Panelist 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ | Y2(replication) Panelist 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ | Y3(replication Panelist 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ |
|---|---|---|---|---|---|---|
| A11 | 8 8 8 8 8 8 8 8 8 8 | 8.0 | 7 3 8 8 8 8 7 8 8 8 | 7.8 | 8 7 8 8 7 8 8 8 8 8 | 7.8 |
| A11 | 8 7 8 6 8 7 7 8 7 7 | 7.3 | 7 3 7 7 7 7 7 7 8 7 | 6.7 | 7 6 7 6 6 7 7 7 7 6 | 6.6 |
| A11 | 7 6 7 4 7 6 6 7 5 6 | 6.1 | 7 3 5 6 6 6 6 7 7 6 | 5.9 | 7 4 5 5 6 6 6 6 5 5 | 5.5 |
| A11 | 4 4 6 3 4 6 5 5 4 4 | 4.5 | 2 3 2 5 4 3 3 5 4 4 | 4.2 | 1 3 4 4 5 5 4 5 4 3 | 3.8 |
| A11 | 2 3 4 2 4 3 3 3 3 3 | 3.0 | 1 2 1 3 4 3 3 5 4 4 | 3.0 | 1 2 3 3 3 4 3 3 4 2 | 3.1 |
| | ..Y | **5.78** | ..Y | **5.52** | ..Y | **5.36** |
| A12 | 8 8 8 7 8 7 7 7 7 8 | 7.5 | 7 4 7 8 7 7 7 7 7 8 | 6.9 | 7 7 7 7 6 6 7 7 7 8 | 6.9 |
| A12 | 8 8 8 5 7 7 6 7 6 7 | 6.9 | 7 2 5 7 6 6 7 5 6 7 | 5.8 | 7 6 5 5 6 5 6 6 6 6 | 5.8 |
| A12 | 5 7 7 4 6 5 5 6 6 5 | 5.9 | 7 2 3 5 5 5 5 5 6 6 | 4.9 | 6 3 4 4 5 4 4 5 4 4 | 4.3 |
| A12 | 3 5 5 2 5 3 4 4 5 3 | 3.9 | 3 2 3 3 3 3 4 4 5 5 | 3.5 | 1 3 2 3 4 3 3 4 3 2 | 3.3 |
| A12 | 1 2 3 1 3 1 2 2 4 2 | 2.1 | 1 2 2 1 3 2 2 3 3 3 | 2.2 | 1 1 1 1 3 2 2 2 3 1 | 1.9 |
| | ..Y | **5.26** | ..Y | **4.66** | ..Y | **4.44** |
| A13 | 8 8 7 6 7 7 7 7 7 7 | 7.1 | 7 4 7 7 7 7 8 8 7 6 | 6.8 | 8 7 7 8 6 7 6 7 7 7 | 7.0 |
| A13 | 8 7 6 4 7 6 6 6 7 6 | 5.6 | 7 3 4 6 5 5 8 7 7 8 | 6.0 | 6 5 5 7 6 6 5 6 6 5 | 5.7 |
| A13 | 5 5 5 3 6 5 6 5 5 4 | 4.9 | 7 1 3 4 5 4 7 7 6 7 | 5.1 | 5 3 3 6 5 5 3 5 4 4 | 4.3 |
| A13 | 2 4 4 1 5 3 4 4 4 4 | 3.5 | 2 2 2 2 3 2 6 6 4 6 | 3.5 | 1 2 3 4 5 4 2 4 3 2 | 3.0 |
| A13 | 1 2 1 1 3 1 2 2 3 3 | 1.9 | 1 1 1 1 2 1 4 4 2 2 | 1.9 | 1 1 1 2 2 2 4 1 2 2 | 2.0 |
| | ..Y | **4.6** | ..Y | **4.66** | ..Y | **4.4** |

To determine weather the observed frequencies (obtained from table 5) differ significantly from the expected frequencies, as a measure of the discrepancy existing between the observed and the statistic chi –squared.. Using the mean values obtained in table 5 as follows.

$$\chi^2 = \Sigma \frac{(O-E)^2}{E}$$

$$= \frac{(5.78-8)^2}{8} + \frac{(5.25-)^2}{8} + \frac{(4.6-8)^2}{8} +$$

$$\frac{(5.36-8)^2}{8} + \frac{(4.66-8)^2}{8} + \frac{(4.66-8)^2}{8}$$

$$+ \frac{(5.36-8)^2}{8} + \frac{(4.44-8)^2}{8} + \frac{(4.4-8)^2}{8}$$

$$= 0.62 + 0.95 + 1.45 + 0.76 + 1.39 + 1.39 + 0.87 + 1.58 + 1.6 = 10.63$$

Checking the value of 10.63, opposite 1 degree of freedom shows that the probability of obtaining the observed result by chance is about 1%. Since the observed chi- squared is close to 10.828 found at 1% point.

Applying the result of the discrete data to determine its goodness of fit using Yates correction factor, to further check the discrepancy and the validity of the previous result obtained.

$$\chi^2 \text{ (corrected)} = \frac{\{(O_2 - E_2) - 0.5\}^2}{E_2} + \frac{\{(O_2 - E_2) - 0.5\}^2}{E_2} + \text{-------}$$

$$\frac{\{(O_k - E_k) - 0.5\}^2}{E_k}$$

$$\chi^2 \text{ (corrected)} = \frac{\{(5.78-8) - 0.5\}^2}{8} + \frac{\{(5.25-8) - 0.5\}^2}{8} + \frac{\{(4.6-8) - 0.5\}^2}{8} + \frac{\{(5.52-8) - 0.5\}^2}{8} + \frac{\{(4.66-8) - 0.5\}^2}{8} + \frac{\{(4.66-8) - 0.5\}^2}{8}$$

$$+ \frac{\{(5.36-8) - 0.5\}^2}{8} + \frac{\{(4.44-8) - 0.5\}^2}{8} + \frac{\{(4.4-8) - 0.5\}^2}{8}$$

$$= 0.92 + 1.32 + 1.90 + 1.11 + 1.84 + 1.84 + 1,23 + 2.06 + 2.10$$

$$= 14.32$$

Referring to the chi-square table under 1 degree of freedom, we would expect a value not greater than 10.82 at 1%, but 14.32 is greater than at 1%. Hence, we reject the hypothesis at 1% level of significance.

## 4.6 TEXTURE EVALUATION FOR TOMATO STORED IN THE POT-IN-POT E. C. S.

TABLE 6 RESULT OF TEXTURE SENSORY EVALUATIION OF STORED TOMATO IN THE POT-IN-POT E.C.S.

| SAMPLE | Y1(replication) Panelists 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ | Y1(replication) Panelists 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ | Y1(replication) Panelists 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ |
|---|---|---|---|---|---|---|
| A11 | 8 8 8 8 8 8 8 8 8 8 | 8.0 | 8 6 8 8 8 8 8 8 8 8 | 7.8 | 8 7 8 8 7 8 8 8 8 8 | 7.8 |
| A11 | 8 7 7 8 8 8 8 8 8 8 | 7.8 | 8 7 7 8 8 8 8 8 8 8 | 7.8 | 8 7 8 8 6 8 8 8 8 7 | 7.6 |
| A11 | 7 7 7 8 7 8 8 8 8 7 | 7.5 | 7 7 7 8 7 7 8 8 8 8 | 7.5 | 8 7 8 8 6 8 8 7 8 6 | 7.4 |
| A11 | 6 7 6 8 7 7 8 8 7 7 | 7.1 | 4 7 7 7 4 7 8 7 7 7 | 6.5 | 6 6 7 7 6 8 7 7 7 6 | 6.7 |
| A11 | 5 7 6 8 7 7 7 7 6 7 | 6.7 | 3 7 7 7 3 7 7 7 7 7 | 6.2 | 5 6 7 7 5 7 7 7 7 5 | 6.3 |
| | ..Y | **7.42** | ..Y | **7.16** | ..Y | **7.1[illegible]** |
| A12 | 8 8 8 8 8 8 8 8 8 8 | 8.0 | 8 6 8 8 8 8 8 8 7 7 | 7.6 | 8 6 8 8 7 8 8 8 8 8 | 7.7 |
| A12 | 8 8 8 8 7 8 8 8 8 7 | 7.8 | 8 7 7 8 8 8 8 7 6 7 | 7.4 | 7 6 7 7 6 8 8 8 7 8 | 7.2 |
| A12 | 6 7 7 7 6 8 8 8 8 7 | 7.2 | 7 5 7 8 8 7 8 7 6 6 | 6.9 | 7 6 6 7 5 8 7 7 7 7 | 6.7 |
| A12 | 5 6 7 7 6 6 7 7 8 6 | 6.5 | 7 6 7 8 3 7 7 6 5 6 | 6.2 | 5 5 6 6 5 8 6 7 6 7 | 6.1 |
| A12 | 4 7 6 7 6 6 6 6 7 8 | 6.3 | 5 5 6 6 3 6 6 6 4 6 | 5.3 | 4 5 5 5 6 7 6 6 6 7 | 5.7 |
| | ..Y | **7.16** | ..Y | **6.68** | ..Y | **6.6[illegible]** |
| A13 | 8 8 7 8 8 8 8 8 8 8 | 7.9 | 8 6 7 8 8 8 8 7 8 8 | 7.6 | 8 6 8 8 6 8 8 7 8 8 | 7.5 |
| A13 | 8 8 6 8 7 8 8 7 8 8 | 7.6 | 8 7 6 7 7 6 8 7 8 8 | 7.2 | 7 6 8 8 6 8 7 7 7 8 | 7.2 |
| A13 | 6 6 5 8 7 7 7 7 8 8 | 6.9 | 8 6 6 7 7 5 7 7 8 8 | 6.9 | 6 7 7 8 5 7 7 6 7 7 | 6.7 |
| A13 | 4 8 5 7 7 5 7 6 8 8 | 6.5 | 7 7 6 7 2 4 7 6 7 7 | 6.0 | 6 6 7 8 5 6 6 6 5 7 | 6.2 |
| A13 | 3 8 7 7 6 5 7 5 7 7 | 6.0 | 6 6 6 7 2 3 6 5 7 7 | 5.5 | 4 6 6 7 5 5 5 5 5 6 | 5.4 |
| | ..Y | **6.98** | ..Y | **6.64** | ..Y | **6.6** |

To determine weather the observed frequencies (obtained from table 6) differs significantly from the expected frequencies, as a measure of the discrepancy existing between the observed and expected frequencies is supplied by the statistic chi-square. Using the mean values obtained in table 6 to calculate the chi-square as follows.

$$\chi^2 = \frac{\sum(O-E)^2}{E}$$

$$=\frac{(7.42-8)^2}{8}+\frac{(7.16-8)^2}{8}+\frac{(6.98-8)^2}{8}+\frac{(7.16-8)}{8}\ldots\ldots\frac{(6.6-8)^2}{8}$$

$=0.042+0.088+0.130+0.088+0.218+0.231+0.088+0.218+0.245$

$=1.35$

Checking the value of 1.35 opposite 1 degree of freedom shows that the probability of obtaining the result by chance alone is greater than 5%.

Using Yates correction factor, to further check the result,

$$\chi^2(\text{corrected})=\frac{\{(O_1E_1)-0.5\}^2}{E_1}+\frac{\{(O_2-E_2)-0.5\}^2}{E_2}+\ldots\ldots\ldots\ldots\frac{\{(O_K-E_K)-0.5\}^2}{E_K}$$

$$=\{(7.42-8)-0.5\}^2+\{(7.16-8)-0.5\}^2+\ldots\ldots\ldots\ldots\{(6.6-8)-0.5\}^2$$

$=0.146+0.224+0.320+0.2245+0.414+0.432+0.224+0.414+0.451$

$=2.85.$

Referring to the chi-square table, under 1 degree of freedom, we would expect a value not greater than 6.6349 at 1% level.

## 4.7 EVALUATION OF THE METAL-IN-POT E.C.S TEMPERATURE AND RELATIVE HUMIDITY OBSEVATION IN THE METAL-IN-POT E.C.S.

**TABLE 7** showing the wet and dry-bulb temperature and relative humidity readings in the metal-in-pot structure for the thirty days storage period.

| METAL-IN-POT E.C.S | | | | AMBIENT CONDITION | | | |
|---|---|---|---|---|---|---|---|
| WB($^0$C) | DB($^0$C) | WB-dep($^0$C) | R.H(%) | WB($^0$C) | DB($^0$C) | WB-dep($^0$C) | R.H(%) |
| 24 | 27 | 3 | 77 | 25 | 37 | 12 | 35 |
| 24 | 26 | 2 | 84 | 25 | 38 | 13 | 32 |
| 25 | 28 | 3 | 77 | 26 | 33 | 7 | 56 |
| 26 | 27 | 1 | 92 | 26 | 35 | 9 | 48 |
| 22 | 26 | 4 | 69 | 20 | 28 | 8 | 45 |
| 21 | 25 | 4 | 68 | 26 | 35 | 9 | 46 |
| 20 | 24 | 4 | 68 | 20 | 34 | 14 | 23 |
| 20 | 21 | 1 | 91 | 21 | 35 | 14 | 23 |
| 20 | 23 | 3 | 75 | 20 | 34 | 14 | 51 |
| 24 | 26 | 2 | 84 | 26 | 34 | 8 | 22 |
| 21 | 23 | 2 | 83 | 21 | 36 | 15 | 34 |
| 23 | 28 | 5 | 64 | 24 | 36 | 12 | 28 |
| 23 | 27 | 4 | 70 | 23 | 37 | 14 | 36 |
| 22 | 25.5 | 3.5 | 76 | 26 | 38 | 12 | 32 |
| 22 | 25 | 3 | 76 | 25 | 38 | 13 | 34 |
| 25 | 26 | 1 | 92 | 26 | 39 | 13 | 29 |
| 25 | 26.5 | 1.5 | 88 | 25 | 40 | 15 | 70 |
| 23 | 25 | 2 | 84 | 24 | 28 | 4 | 61 |
| 21 | 26 | 5 | 62 | 29 | 36 | 7 | 61 |
| 25 | 26 | 1 | 92 | 27 | 34 | 7 | 61 |
| 26 | 29 | 3 | 73 | 27 | 34 | 7 | 40 |
| 25 | 28 | 3 | 77 | 26 | 37 | 11 | 45 |
| 25 | 29 | 4 | 71 | 28 | 38 | 10 | 36 |
| 23 | 28 | 5 | 64 | 26 | 37.5 | 11.5 | 40 |
| 25 | 28 | 3 | 77 | 27 | 38 | 11 | 61 |
| 23 | 25 | 2 | 84 | 25 | 31 | 6 | 63 |
| 25 | 28 | 3 | 77 | 30 | 36 | 6 | 40 |
| 26 | 27 | 4 | 77 | 27 | 38 | 11 | 50 |
| 26 | 28 | 3 | 85 | 29 | 38 | 9 | 34 |
| 26 | 29 | 3 | 78 | 26 | 39 | 13 | 34 |

## 4.8 COLOR SENSORY EVALUATION OF STORED FRUIT AND VEGETABLE (MANGO AND TOMATO) IN THE METAL-IN-POT EVAPORATIVE COOLER STRUCTURE.

Storage trial was conducted in the metal-in-pot evaporative coolant storage structure using mango and tomato samples. The samples were evaluated for changes in physical parameters namely color and texture, using an eight point Hedonic scoring questionnaire as shown in appendix 1,2,3 and 4.

The result of the observed panelists scores for color and texture for the two spacemen's (mango and tomato) are shown in tables 8 through 9

## 4.9 COLOR EVALUATION FOR MANGO STORED IN THE METAL-IN-POT E.C.S

To determine weather the observed color scores differs significantly from the expected or original color of the mango, observed panelists score for a period of ten (10) days per replication are statistically analyzed .The data for mango is shown in table 8 below.

A statistical hypothesis is then set up about the sample population. It is hypothised that there is no significant difference between the color quality of the fresh mango and those stored in the modified evaporative coolant structure at the end of the storage period.

$H_0: \mu = 8$

$H_1: \mu < 8$

## 4.10 COLOR EVALUATION OF MANGO IN THE METAL-IN-POT E.C.S.

**Table 8** RESULTS OF COLOR SENSORY EVALUATION OF STORED MANGO IN THE METAL-IN-POT E.C.S.

| SAMPLE | Y1(replication) Panelist 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ | Y2(replication) Panelist 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ | Y3(replication) Panelist 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ |
|---|---|---|---|---|---|---|
| A11 | 8 8 8 8 8 8 8 7 8 7 | 7.8 | 6 6 8 8 6 8 8 8 8 8 | 7.4 | 8 8 8 8 7 8 8 7 8 8 | 7.8 |
| A11 | 8 8 7 8 8 7 7 6 7 7 | 7.3 | 6 5 8 8 6 8 8 7 7 7 | 7.0 | 8 8 8 8 7 8 7 6 8 7 | 7.5 |
| A11 | 7 6 6 8 6 6 6 5 7 6 | 6.3 | 7 5 7 8 6 7 7 7 7 7 | 6.8 | 7 7 6 7 6 7 6 5 4 6 | 6.1 |
| A11 | 6 5 6 8 4 5 5 4 5 5 | 5.3 | 4 4 6 7 5 6 5 6 5 6 | 5.4 | 5 6 5 7 5 7 5 4 3 5 | 5.2 |
| A11 | 5 4 4 8 3 5 4 3 4 4 | 4.4 | 3 3 4 7 4 5 3 4 4 3 | 4.0 | 3 6 4 7 3 5 4 3 3 1 4 | 4.3 |
| | Y | **6.22** | ..Y | **6.12** | ..Y | **6.18** |
| A12 | 8 8 8 8 8 8 8 7 7 7 | 7.7 | 7 6 8 8 6 8 7 7 8 7 | 7.2 | 8 8 8 8 8 8 8 7 7 8 | 7.8 |
| A12 | 7 8 8 7 7 7 7 7 6 6 | 7.0 | 7 6 8 7 5 7 7 6 7 7 | 6.6 | 8 8 7 8 8 7 7 7 7 7 | 7.4 |
| A12 | 6 6 7 7 6 7 6 6 6 5 | 6.2 | 7 6 7 7 5 6 6 6 6 6 | 6.2 | 7 8 6 7 5 6 7 6 5 5 | 6.2 |
| A12 | 5 4 7 6 4 6 4 5 4 4 | 4.9 | 4 4 5 6 6 5 4 5 4 4 | 4.7 | 4 7 5 7 3 6 5 5 4 4 | 5.0 |
| A12 | 4 2 4 6 2 5 3 4 3 3 | 3.0 | 2 3 4 6 4 3 2 3 3 2 | 3.2 | 3 7 3 6 2 5 3 4 3 3 | 3.9 |
| | ..Y | **5.76** | ..Y | **5.58** | ..Y | **6.06** |
| A13 | 8 8 8 8 7 7 8 8 7 8 | 7.7 | 6 6 8 8 5 8 7 7 7 7 | 6.9 | 8 8 8 7 8 8 8 7 8 7 | 7.6 |
| A13 | 7 7 7 8 7 6 6 7 6 7 | 6.8 | 6 5 7 8 5 7 6 6 6 6 | 6.2 | 7 8 6 7 7 7 7 8 6 6 | 6.9 |
| A13 | 5 5 6 8 8 5 6 5 7 6 | 6.0 | 6 6 6 8 5 7 5 5 5 5 | 5.8 | 6 8 5 6 5 5 7 7 4 5 | 5.8 |
| A13 | 4 3 5 7 3 5 5 5 4 5 | 4.6 | 5 5 6 7 5 6 4 4 3 4 | 4.9 | 3 8 4 6 3 5 4 6 4 4 | 4.7 |
| A13 | 3 1 3 7 1 4 2 4 3 3 | 3.1 | 2 2 3 7 3 4 3 2 2 2 | 2.9 | 2 2 3 7 3 4 2 2 2 2 | 3.5 |
| | ..Y | **5.64** | ..Y | **5.34** | ..Y | **5.68** |

To determine weather the observed frequencies (obtained from table 8 above) differs significantly from the expected frequencies, a measure of discrepancy existing between the observed and the expected frequencies is supplied by the statistic chi-square. Given by,

$$\chi^2 = \frac{(O_1-E_1)^2}{E_1} + \frac{(O_2-E_2)^2}{E_2} + \ldots\ldots\frac{(O_K-E_K)^2}{E_K}$$

$$= \frac{\Sigma_{J=i}^{K}(O_j\_E_J)^2}{E_J}$$

Using the mean values of obtained in table 8 to calculate the chi-square values as shown below.

$$\chi^2 = \frac{(6.22-8)^2}{8} + \frac{(5.76-8)^2}{8} + \ldots\ldots\ldots\ldots \frac{(5.68-8)^2}{8}$$

$=0.396+0.627+0.696+0.442+0.732+0.884+0.415+0.470+0.673$

$=5.33$

Degree of freedom =1.

Checking the calculated value of 5.33, opposite degree of freedom 1, shows that the probability of obtaining the result by chance alone is less than.5%.

Applying the result to the discrete data to determine its goodness of fit using Yates correction factor to further check the discrepancy and the validity of the previous result obtained.

$$\chi^2(\text{corrected}) = \frac{\{(O_1-E_1)^2 - 0.5\}^2}{E_1} + \frac{\{(O_2-E_2)-0.5\}^2}{E_2} + \ldots \frac{\{(O_K-E_K)-0.5\}^2}{E_K}$$

$$= \frac{\{(6.22-8)-0.5\}^2}{8} + \frac{\{(5.76-8)-0.5\}^2}{8} + \ldots\ldots\ldots\ldots$$

$$\frac{\{(5.68-8)-0.5\}^2}{8}$$

$=0.649+0.938+1.022+0.708+1.066+1.248+0.673+0.744+$
$0.994$

$= 8.04.$

Referring to the chi-square table under degree of freedom 1, we would expect a value of not less than 6.63 at 1%. Since the chi-square corrected value is higher than 6.63, we reject the hypothesis at 1% level.

## 4.11 COLOR EVALUATION OF TOMATO STORED IN THE METAL-IN-POT E.C.S.

TABLE 9 RESULTS OF COLOR SENSORY EVALUATION OF STORED TOMATO IN THE METAL-IN-POT E.C.S.

| SAMPLES | Y1(replication) Panelist 1 2 3 4 5 6 7 8 9 10 | $\overline{x}$ | Y1(replication) Panelist 1 2 3 4 5 6 7 8 9 10 | $\overline{x}$ | Y1(replication) Panelist 1 2 3 4 5 6 7 8 9 10 | $\overline{x}$ |
|---|---|---|---|---|---|---|
| B11 | 8 8 8 8 7 8 8 8 8 8 | 7.9 | 8 7 8 8 7 8 8 8 8 8 | 7.8 | 8 8 8 7 8 8 8 8 8 8 | 7.3 |
| B11 | 8 7 8 8 7 8 8 8 8 8 | 7.8 | 7 7 8 8 7 8 8 8 8 8 | 7.7 | 8 8 8 7 7 8 8 8 8 8 | 7.6 |
| B11 | 8 7 8 7 6 7 8 7 7 8 | 7.3 | 7 8 7 8 6 8 7 8 7 8 | 7.4 | 7 8 7 6 8 7 7 7 8 8 | 6.6 |
| B11 | 7 7 8 7 4 7 7 7 7 7 | 6.8 | 7 7 7 8 7 7 7 8 7 7 | 7.2 | 8 5 8 6 6 8 6 7 8 8 | 7.0 |
| B11 | 7 6 8 8 7 3 6 7 7 7 | 6.4 | 7 7 7 7 6 7 7 7 7 7 | 6.9 | 4 7 7 7 8 6 6 7 7 7 | 6.6 |
| | $\overline{..Y}$ | 7.24 | $\overline{..Y}$ | 7.4 | $\overline{..Y}$ | 7.02 |
| B12 | 8 8 8 8 7 8 8 7 8 8 | 7.8 | 8 7 8 6 7 8 8 8 8 8 | 7.6 | 8 8 8 8 8 8 8 8 8 8 | 8.0 |
| B12 | 8 8 8 7 7 8 8 8 7 8 | 7.7 | 7 7 8 6 7 8 7 7 8 8 | 7.3 | 8 7 8 8 6 8 8 8 8 8 | 7.3 |
| B12 | 8 7 8 6 5 8 7 8 6 8 | 7.1 | 7 7 8 6 7 8 6 7 8 8 | 7.4 | 8 6 8 7 5 8 8 8 8 8 | 7.4 |
| B12 | 7 7 8 6 3 8 6 8 6 8 | 6.7 | 7 7 7 6 7 8 6 7 8 8 | 7.1 | 7 6 7 7 4 8 7 8 7 8 | 6.9 |
| B12 | 7 7 7 6 2 7 6 7 5 6 | 6.0 | 7 6 7 5 6 7 6 7 7 7 | 6.5 | 6 5 7 7 1 8 7 7 6 7 | 6.1 |
| | $\overline{..Y}$ | 7.06 | $\overline{..Y}$ | 7.18 | $\overline{..Y}$ | 7.14 |
| B13 | 8 8 8 8 8 8 8 8 8 8 | 8.0 | 8 8 8 8 8 8 8 8 8 8 | 8.0 | 8 8 8 8 8 8 8 8 8 8 | 8.0 |
| B13 | 8 8 8 8 8 8 8 8 8 8 | 8.0 | 6 8 8 7 6 8 7 7 8 8 | 7.3 | 8 8 8 7 6 8 8 8 8 8 | 7.7 |
| B13 | 8 8 8 8 5 8 7 8 7 7 | 7.5 | 6 7 8 7 6 8 6 7 8 7 | 7.0 | 8 7 8 7 5 8 8 8 7 7 | 7.3 |
| B13 | 8 7 7 8 3 7 6 8 7 7 | 6.4 | 6 7 8 7 5 8 6 6 7 7 | 6.7 | 7 5 8 7 3 8 7 8 8 7 | 6.7 |
| B13 | 8 7 7 7 2 7 6 8 7 7 | 6.6 | 6 7 6 7 5 8 6 6 7 6 | 6.4 | 7 8 7 1 7 7 7 6 6 6 | 5.6 |
| | $\overline{..Y}$ | 7.3 | $\overline{..Y}$ | 7.08 | $\overline{..Y}$ | 7.06 |

To determine weather the observed frequencies (obtained from table 9 above) differs significantly from the expected frequencies; a measure of discrepancies existing between the observed and the expected frequencies is supplied by the statistic chi-square.

$$\chi^2 = \frac{(O_1-E_1)^2}{E_1} + \frac{(O_2-E_2)^2}{E_2} + \ldots\ldots \frac{(O_K-E_K)^2}{E_K}$$

Using the mean values obtained in table 9 to calculate the chi-square values as shown below.

$$\chi^2 = \frac{(7.24-8)^2}{8} + \frac{(7.06-8)^2}{8} + \ldots\ldots\ldots\ldots \frac{(7.06-8)}{8}$$

$$= 0.072+0.110+0.061+0.045+0.084+0.106+0.120+0.092+0.110$$

$$=0.80$$

Checking the calculated value of 0.80, opposite degree of freedom 1, shows that the probability of obtaining the result observed by chance alone is over 5%. Since the calculated chi-square of 0.80 is less than 1.323 found at 5% level.

Applying the result to the discrete data to determine its goodness of fit using Yates correction factor to further check the discrepancy and the validity of the previous result obtained.

$$\chi^2 \text{ (corrected)} = \frac{\{(7.24-8)-0.5\}^2}{8} + \frac{\{(7.06-8)-0.5\}^2}{8} + \ldots\ldots \frac{\{(7.06-8)-0.5\}^2}{8}$$

$$=0.198+0.259+0.18+0.151+0.218+0.252+0.274+0.231+0.259$$

$$=2.02.$$

Referring to the chi-square table under degree of freedom 1 , we would expect a value either less than 3.84 at 5% level and not greater than 6.634 at

1% level. Since the calculated chi-square is less than 3.84, the hypothesis is accepted at 5% level of significant.

## 4.12 TEXTURE EVALUATION FOR MANGO STORED IN THE METAL-IN-POT E.C.S.

**TABLE 10** RESULTS OF TEXTURE SENSORY EVALUATION OF STORED MANGO IN THE METAL-IN-POT E.C.S.

| SAMPLE | Y1(replication) PANELISTS 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ | Y2(replication) PANELISTS 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ | Y3(replication) PANELISTS 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ |
|---|---|---|---|---|---|---|
| B11 | 8 8 8 8 8 8 8 7 8 8 | 7.9 | 7 5 8 8 8 8 8 7 8 8 | 7.5 | 8 8 8 8 8 8 8 8 8 8 | 8.0 |
| B11 | 8 7 8 6 7 7 7 7 6 7 | 7.0 | 6 6 7 7 7 8 7 6 6 7 | 6.7 | 8 8 7 7 8 8 8 7 6 7 | 8.4 |
| B11 | 7 7 7 5 6 6 6 6 5 7 | 6.2 | 5 5 6 6 6 7 6 5 4 6 | 5.8 | 6 7 6 6 6 7 7 6 5 6 | 6.5 |
| B11 | 6 6 5 6 4 5 4 5 4 6 | 5.1 | 5 5 5 5 6 6 5 4 3 5 | 4.8 | 4 6 5 5 5 5 6 5 4 5 | 5.0 |
| B11 | 4 4 4 5 3 3 3 4 3 4 | 3.7 | 3 4 4 4 4 5 4 3 2 4 | 4.1 | 3 5 3 4 3 4 4 4 3 4 | 3.7 |
| | $\bar{..Y}$ | **5.98** | $\bar{..Y}$ | **5.78** | $\bar{..Y}$ | **6.06** |
| B12 | 8 8 8 8 8 7 8 7 8 7 | 7.7 | 7 6 8 7 7 8 7 8 7 7 | 7.2 | 8 8 8 7 8 8 7 7 7 7 | 7.5 |
| B12 | 7 8 7 4 6 6 7 7 7 6 | 6.5 | 7 6 7 6 6 6 8 6 7 7 | 6.6 | 7 8 6 6 8 7 6 6 7 6 | 6.7 |
| B12 | 6 8 5 3 5 5 5 6 6 6 | 5.4 | 5 6 5 5 6 8 5 6 5 5 | 5.6 | 5 6 5 5 5 6 5 5 6 5 | 5.3 |
| B12 | 3 5 3 1 2 2 2 3 4 3 | 4.4 | 5 5 4 4 6 7 4 5 4 4 | 4.8 | 4 6 5 5 5 5 6 5 4 5 | 4.1 |
| B12 | 5 7 4 2 3 4 4 4 6 5 | 2.8 | 2 3 3 3 4 5 3 4 3 3 | 3.3 | 3 5 3 4 2 2 3 3 4 3 | 2 .8 |
| | $\bar{..Y}$ | **5.36** | $\bar{..Y}$ | **5.5** | $\bar{..Y}$ | **5.28** |
| B13 | 8 8 8 7 7 8 6 8 7 7 | 7.4 | 7 7 7 7 7 8 7 8 8 8 | 7.4 | 8 8 7 7 8 8 8 8 7 7 | 7.6 |
| B13 | 7 8 7 4 6 6 7 7 7 6 | 6.3 | 5 6 6 6 6 7 6 7 6 7 | 6.2 | 8 7 5 6 8 7 8 7 6 6 | 6.8 |
| B13 | 7 6 5 3 4 5 5 5 6 5 | 5.1 | 5 6 5 4 5 6 5 6 6 6 | 5.4 | 5 5 4 5 5 5 7 6 6 4 | 5.2 |
| B13 | 5 5 4 2 4 4 3 4 5 4 | 4.0 | 5 5 3 3 5 5 4 5 5 5 | 4.5 | 4 4 4 4 3 3 6 5 5 3 | 4.1 |
| B13 | 1 3 2 1 1 1 2 2 3 2 | 1.8 | 2 3 3 3 4 5 3 4 3 3 | 2.6 | 2 2 2 2 2 2 3 4 3 2 | 2.4 |
| | $\bar{..Y}$ | **4.92** | $\bar{..Y}$ | **5.22** | $\bar{..Y}$ | **5.22** |

TO determined weather the observed frequencies (obtained form table 10 above) differs significantly from the expected frequencies, a measure of discrepancy existing between the observed and the expected frequencies is supplied by the static chi-square.

Given by $\chi^2 = \frac{(O_1 - E_1)^2}{E_1} + \frac{(O_2 - E_2)^2}{E_2} + \ldots\ldots \frac{(O_k - E_k)^2}{E_2}$

$$= \sum_{J=1}^{K} \frac{(O_j - E_j)^2}{E_J}$$

Using the mean values obtained as table 10 to calculate the chi-square values as shown bellow.

$$\chi^2 = \frac{(5.98-8)^2}{8} + \frac{(5.36-8)^2}{8} + \frac{(4.92-8)^2}{8} + \frac{(5.78-8)^2}{8} + \frac{(5.5-8)^2}{8} +$$
$$\frac{(5.22-8)^2}{8} + \frac{(6.06-8)^2}{8} + \frac{(5.28-8)^2}{8} + \frac{(5.22-8)^2}{8}$$
$= 0.51+0.87+1.19+0.62+0.78+0.96+0.47+0.92+0.97$
$=7.29.$

Checking the calculated values of 7.29 under degree of freedom shows that the probability of obtaining the result by chance alone about 1%, since the observed chi-square of 7.29 is close to 7.87 Found at 1% point.

Applying the result to the discrete data to determine its goodness of fit using Yates correction factor to further check the discrepancy and the validity of the previous results obtained.

$$\chi^2\ (\text{corrected}) = \frac{\{(5.98-8)-0.5\}^2}{8} + \frac{\{(5.36-8)-0.5\}^2}{8} + \ldots\ldots\ldots \frac{\{(5.22-8)-0.5\}^2}{8}$$

$=0.794+1.232+1.602+0.925+1.125+1.345+0.744+1.296+1.345$
$=10.41$

Referring to the chi-square table under degree of freedom 1 we would expect a value not greater than 7.87 at 5% and not greater than10.828 at 1% level. Since the calculated chi-square is less than 10.828 the hypothesis is accepted at 1%level of error

## 4.13 TEXTURE EVALUATION OF TOMATO STORED IN THE METAL-IN-POT E.C.S.

TABLE 11 RESULTS OF TEXTURE SENSORY EVALUATION OF STORED TOMATO IN THE METAL-IN-POT STRUCTURE.

| SAMPLE | Y1(replicate) Panelists 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ | Y1(replicate) Panelists 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ | Y1(replicate) Panelists 1 2 3 4 5 6 7 8 9 10 | $\bar{x}$ |
|---|---|---|---|---|---|---|
| B11 | 8 8 8 8 8 8 8 8 8 8 | 8.0 | 8 8 8 8 7 8 8 8 8 8 | 7.9 | 8 8 8 8 8 8 8 8 8 8 | 8.0 |
| B11 | 8 7 8 8 8 8 8 8 8 8 | 7.7 | 7 6 8 8 8 8 8 7 8 8 | 7.6 | 8 8 8 8 8 8 8 8 8 8 | 8.0 |
| B11 | 8 7 8 7 8 8 8 8 8 8 | 7.6 | 7 5 8 8 7 7 8 7 8 8 | 7.3 | 8 8 7 8 6 7 8 6 8 8 | 7.6 |
| B11 | 7 6 8 7 7 7 8 7 7 7 | 7.1 | 7 6 8 7 7 6 8 6 7 7 | 6.9 | 7 7 7 8 5 8 6 7 7 8 | 7.0 |
| B11 | 7 5 8 7 7 7 8 7 7 6 | 6.9 | 7 5 8 7 6 7 6 7 7 6 | 6.4 | 7 7 6 7 3 6 7 7 7 7 | 6.4 |
| | ..$\bar{Y}$ | 7.46 | ..$\bar{Y}$ | 7.22 | ..$\bar{Y}$ | 7.4 |
| B12 | 8 8 8 8 8 8 8 8 8 8 | 8.0 | 8 7 8 8 7 8 8 8 8 8 | 7.8 | 8 8 8 8 8 8 8 8 8 8 | 8.0 |
| B12 | 8 8 8 8 8 8 8 8 8 8 | 8.0 | 7 6 8 8 7 8 7 8 8 8 | 7.5 | 7 7 8 8 8 8 8 7 8 8 | 7.0 |
| B12 | 7 7 6 7 8 8 8 8 7 8 | 7.4 | 7 6 8 7 7 8 7 8 8 8 | 7.4 | 7 7 8 7 5 7 8 6 7 7 | 6.9 |
| B12 | 8 7 7 7 6 8 8 7 6 8 | 7.2 | 7 6 8 7 7 8 7 7 7 7 | 7.1 | 7 6 8 7 4 7 7 6 6 7 | 6.5 |
| B12 | 6 7 6 6 6 8 7 7 6 7 | 6.6 | 7 5 8 7 6 7 6 7 7 6 | 6.6 | 7 6 8 6 2 6 7 5 6 6 | 6.4 |
| | ..Y | 7.44 | ..Y | 7.28 | ..Y | 6.96 |
| B13 | 8 8 8 7 8 8 8 8 8 8 | 7.7 | 7 8 8 8 8 8 7 8 7 8 | 7.7 | 8 8 8 8 8 8 8 8 8 8 | 8.0 |
| B13 | 7 8 8 6 7 8 7 7 7 8 | 7.3 | 8 6 8 7 7 8 7 8 7 8 | 7.4 | 7 7 8 8 7 8 8 8 8 8 | 7.7 |
| B13 | 7 8 8 6 7 8 7 7 7 8 | 7.3 | 7 5 8 7 7 8 7 8 6 8 | 7.1 | 7 7 8 7 5 7 8 6 7 7 | 6.8 |
| B13 | 7 7 8 6 7 7 7 6 6 8 | 6.9 | 7 6 7 7 6 7 6 7 6 8 | 6.7 | 7 6 8 7 4 7 7 6 6 7 | 6.7 |
| B13 | 7 7 8 5 7 7 6 6 6 7 | 6.6 | 7 6 7 6 5 7 5 7 5 7 | 6.2 | 7 6 8 6 2 6 2 7 5 6 | 6.1 |
| | ..Y | 7.16 | ..Y | 7.02 | ..Y | 7.06 |

To determine weather the observed frequencies (obtained from table 11 above) differs significantly from the expected frequencies, a measure of discrepancy existing between the observed and the expected frequencies is supplied by the statistics chi-square. Given as

$$\chi^2 = \frac{(O_1-E_1)^2}{E_1} + \frac{(O_2-E_2)^2}{E_2} + \ldots\ldots\ldots \frac{(O_K-E)^2}{E_K}$$

Using the mean values obtained in table 11 to calculate the chi-square value as shown below.

$$\chi^2 = \frac{(7.46-8)^2}{8} + \frac{(7.44-8)^2}{8} + \frac{(7.16-8)^2}{8} + \ldots\ldots\ldots\ldots\ldots\ldots \frac{(7.06-8)^2}{8}$$

$=0.036+0.039+0.088+0.076+0.065+0.0120+0.045+0.135+0.114$

$=0.714$

Checking the calculated value of 0.714 opposite degree of freedom 1 shows that the probability of obtaining the result by chance is greater than 5%. Since the observed chi-square value is less than table chi-square.

Using Yates correction factor to further check the discrepancies,

$$\chi^2(\text{corrected}) = \frac{\{(7.46-8)-0.5\}^2}{8} + \frac{\{(7.44-8)-0.5\}^2}{8} + \ldots\ldots\frac{\{(7.06-8)-0.5\}^2}{8}$$

$$=0.135+0.140+0.224+0.205+0.186+0.274+0.151+0.296+0.259$$

$$=1.870.$$

Referring to the chi-square table under degree of freedom 1 we would expect a value either less than 1.323 at 5% but, not greater.

TABLE 12 COMPARISM OF THE POT-IN-POT AND METAL-IN-POT EVAPPORATIVE COOLER STORAGE SYSTEMS.

| OBSRVATIONS | POT-IN-POT E.C.S.S | METAL-IN-POT E.C.S.S |
|---|---|---|
| Mean Temperature | 26.2$^0$C | 25$^0$C |
| Mean Temp. drop. | 9.8$^0$C | 12$^0$C |
| Relative Humidity | 76% | 88% |
| Chi-square for mango (color) | 8.45 | 5.33 |
| Chi-square for mango (texture) | 10.63 | 7.29 |
| Chi-square for tomato (color) | 2.65 | 0.80 |
| Chi-square for tomato (texture) | 1.35 | 0.714 |

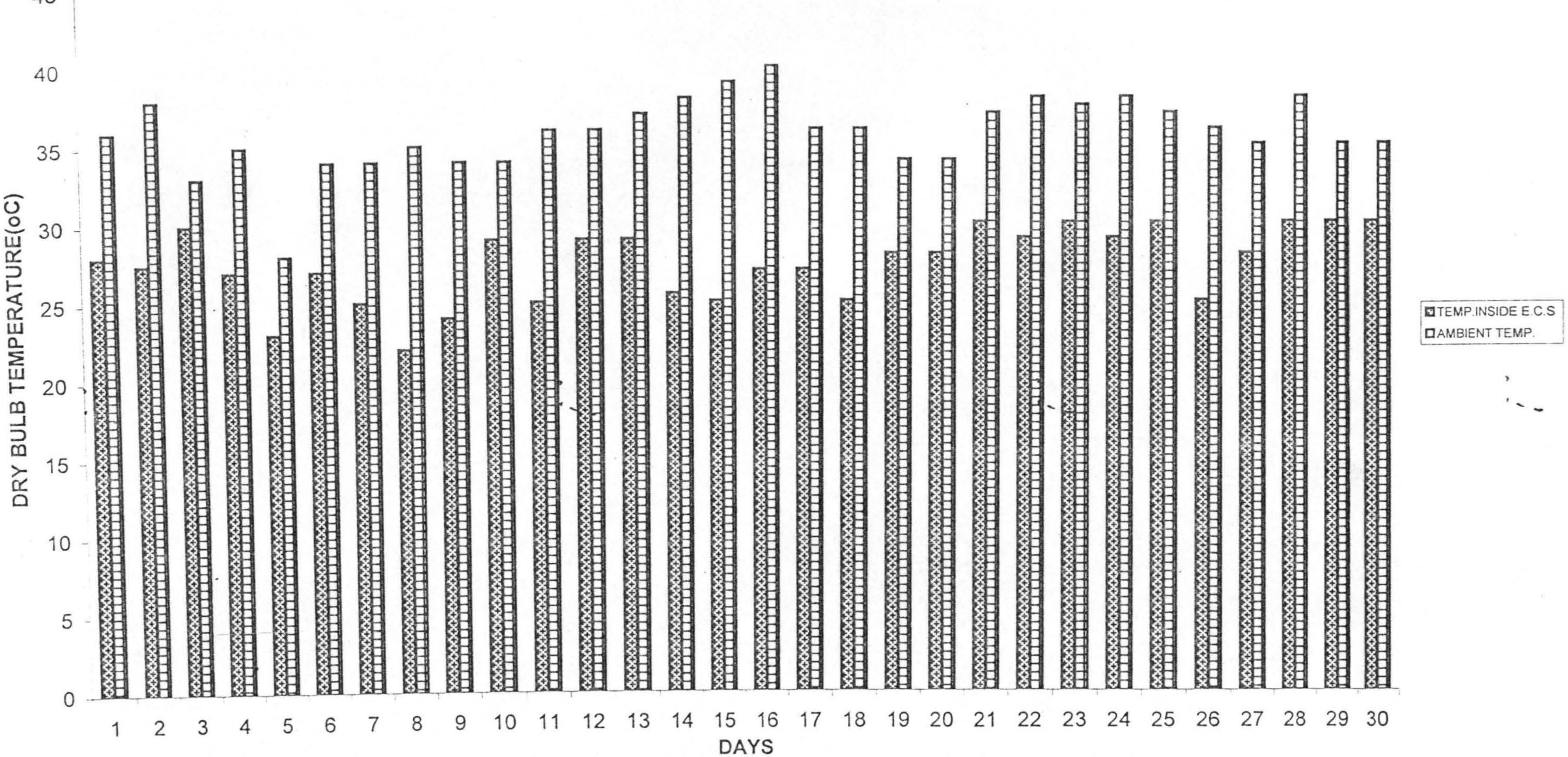



FIGURE.4 MULTIPLE BAR CHART SHOWING DROP IN TEMPERATURE IN THE POT - IN - POT E.C.S.

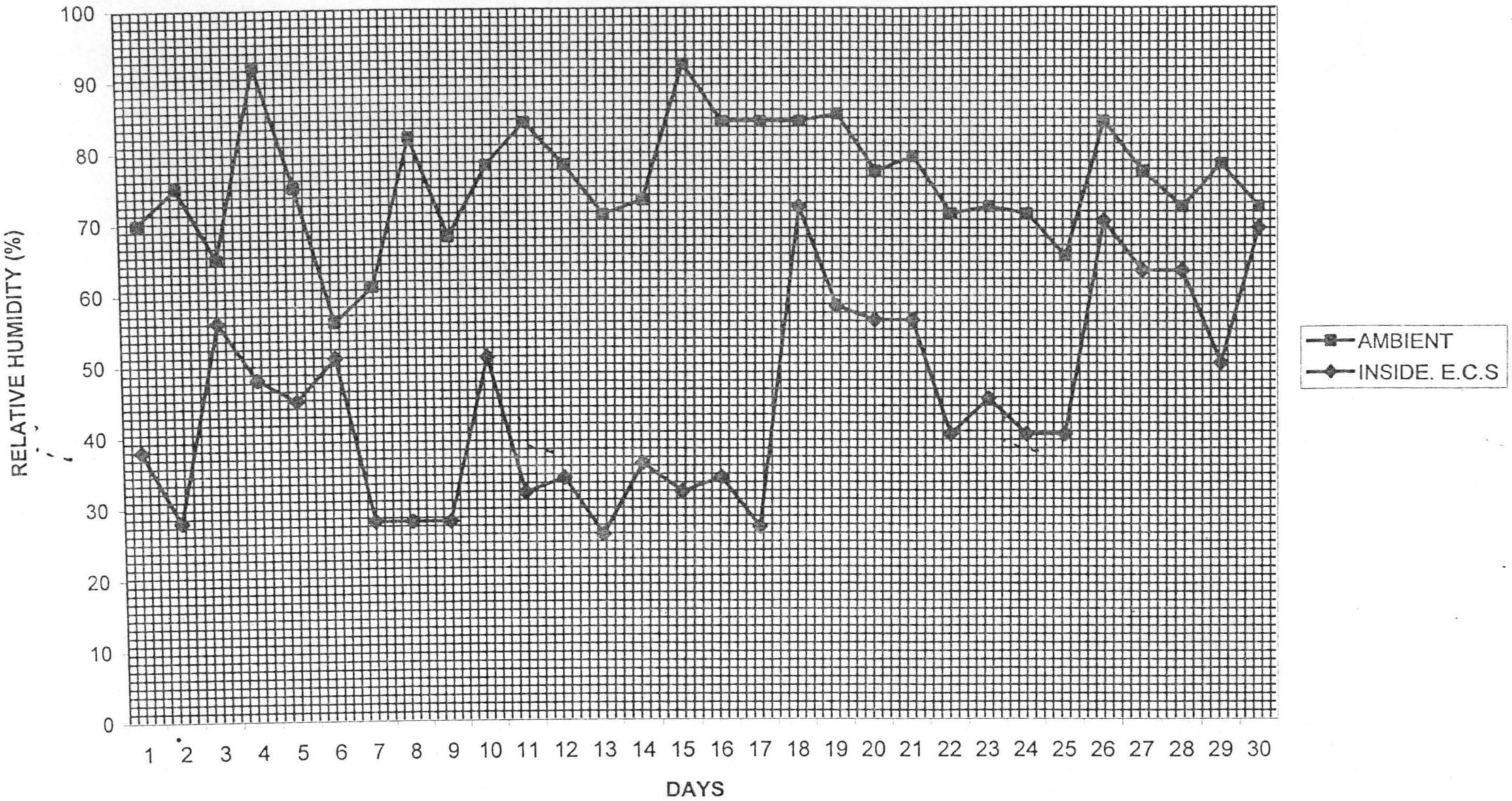



FIG.5 -HYGROGRAPH SHOWING DROP IN RELATIVE HUMIDITY INSIDE THE POT - IN - POT E.C.S.

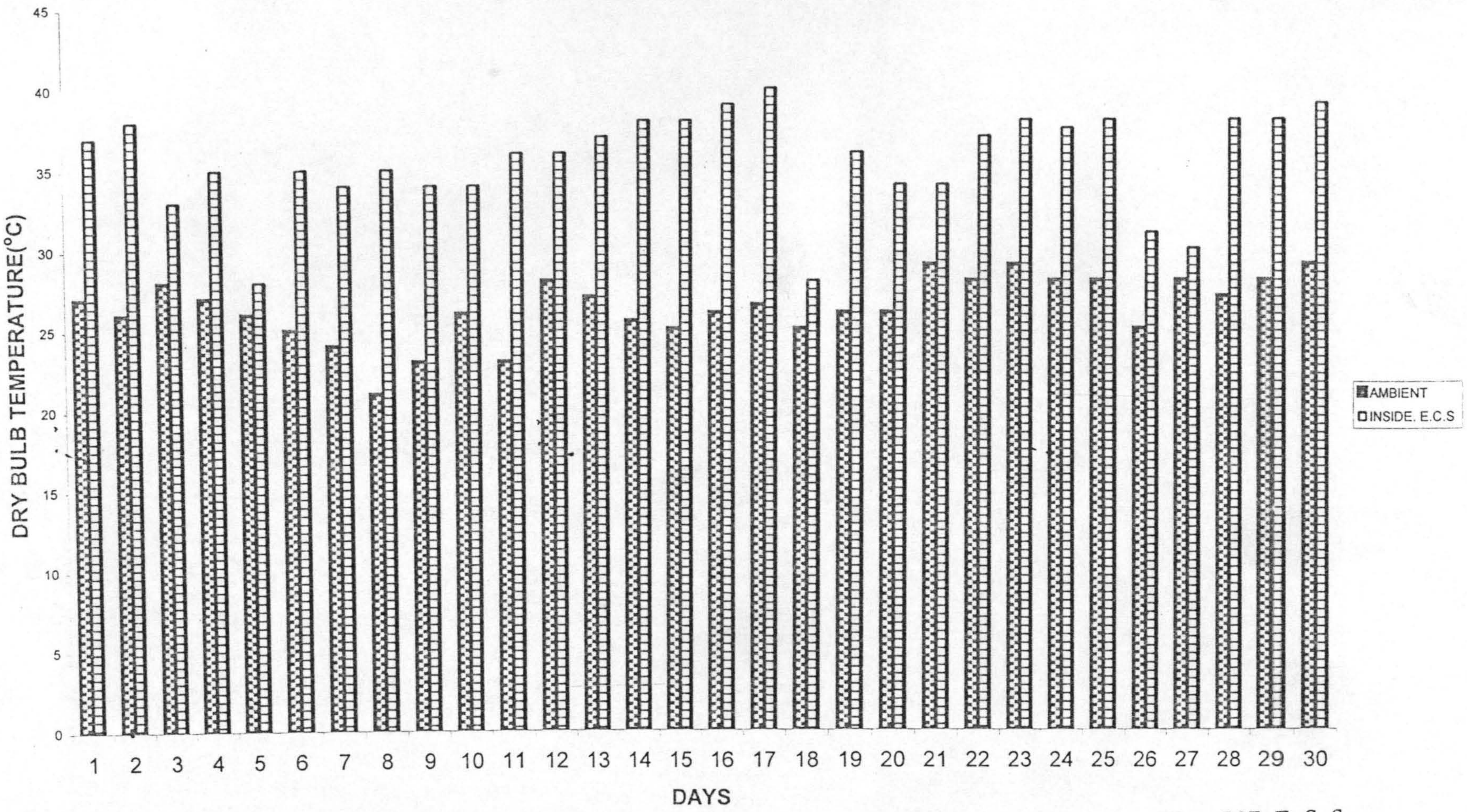



FIG.6 MULTIPLE BAR CHART SHOWING THE DROP IN TEMPERATURE IN THE METAL - IN - POT E.C.S.

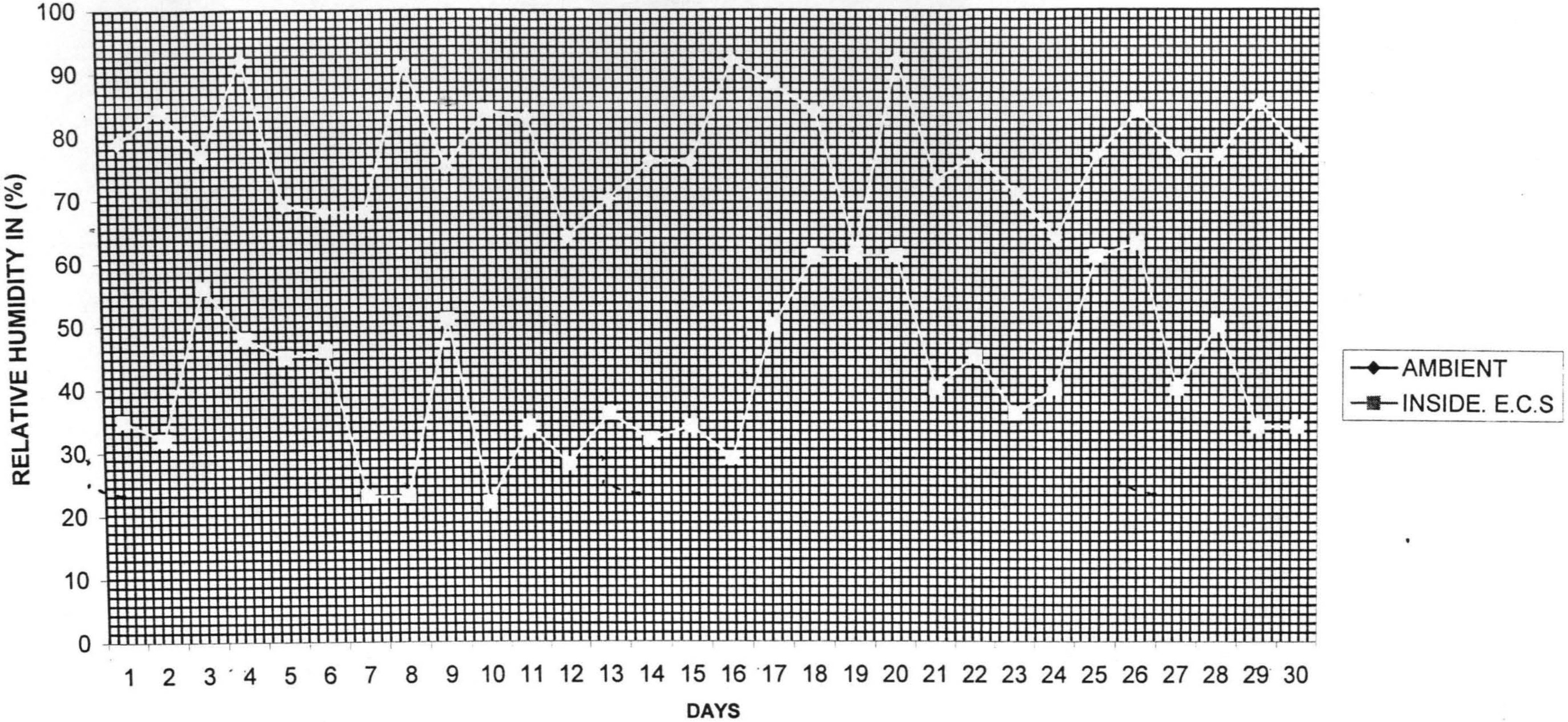



FIG. 7 HY ROGRAPH SHOWING DROP IN RELATIVE HUMIDITY IN THE METAL - IN - POT E. C. S.

# CHAPTER FIVE

## DISCUSSION AND INTERPRETATION OF RESULT

## INTERPRETATION OF COLOR CHI – SQUARE VALUES IN THE POT-IN- POT E.C.S

TABLES 5.1 SUMMARY OF THE COLOR ASSESSMENT

| Product | $\chi^2$ calculated | Corrected | Table 5% | 1% |
|---|---|---|---|---|
| Mango | 8.45 | 9.02 | 3.84146 | 6.63490 |
| Tomatoes | 1.12 | 2.65 | | |

### MANGO

Referring to table 5.1 being the summary of the analysis of the result obtained. Since the calculated chi-square value of color of mango is greater than the chi-square table both at 5% and 1% level we could therefore say that the observes color frequencies for Mango, do differ significantly from the expected frequencies. Therefore the hypothesis is rejected at 5% level of error. This indicates that resultant color of mango at the 10days storage under the given condition could be said to be significantly acceptable color.

### TOMATOES

Referring to tables 5.1, since the calculated chi-square color value for tomatoes is less than the chi-square table value both at 5% and 1% level, it could be said that the observed color frequencies for tomato do not differ significantly from the expected frequencies. This indicates the he resultant color of tomatoes at the end of the storage under the given condition, could be of no significant different from that of the fresh tomatoes prior to storage.

## 5.2 INTERPRETATION OF CHI – SQUARE VALUES FOR TEXTURE IN THE POT IN POT E. C. S.

TABLES 5.2 SUMMARY OF TEXTURE ASSESSMENT

| Product | $\chi^2$ Calculated | Corrected | Table | |
|---|---|---|---|---|
| | | | 5% | 1% |
| Mango | 10.32 | 14.32 | 3.84146 | 6.63490 |
| Tomatoes | 1.35 | 2.85 | | |

### MANGO TEXTURE

Referring to table 5.2 the summary of the result analysis of the obtained for texture in the existing color structure. Since the calculated chi-square value mango is greater than the table chi-square value at 5% and 1% level, we could therefore say that the observed texture frequencies for mango do differ significantly from the expected frequencies. Therefore, the hypothesis is reject at 5% level of error. This indicates that the resultant texture of mango at the end of the storage condition could be said to be significantly different from the original texture of the fresh mango, hence would not give well acceptable texture.

### TOMATOES TEXTURE

Referring to tables 5.21, since the calculated chi-square value for tomatoes is less than the chi-square table value both 5% and 1% level, it could be said that the observed texture frequencies for tomatoes do not differ significantly from the expected frequencies. Therefore, the hypothesis is accepted at 5% level since the chi-square corrected value obtained Is less than that of the critical Table value at 5% point. This indicates that the resultant of tomato at the of the storage, under the given conditions, could be said to be of no significantly difference from that of the fresh tomato prior to storage.

## 5.3 INTERPRETATION OF CHI-SQUARE VALUES FOR COLOR IN THE METAL IN POT E.C.S.

TABLES 5.3 SUMMARY OF COLOR ASSESSMENT

| Product | $\chi 2$ Calculated | Corrected | Table | |
|---|---|---|---|---|
| | | | 5% | 1% |
| Mango | 5.33 | 8.04 | 3.84146 | 6.63490 |
| Tomatoes | 0.80 | 2.02 | | |

### MANGO COLOR

Referring to table 5.3 being the summary of chi-squares obtained for colors in the modified Evaporative coolant structure, since the calculated chi-square value for mango is greater at 5% level and less at 1% level, we could therefore say that the observed color frequencies for mango do differ significantly from the expected frequencies at 5% level and do not differ significantly at 1s% level. Therefore, the hypothesis is rejected at 55 level and accepted at 1% level.

### TOMATOES COLOR

Referring to tables 5.3, since the calculated chi-square value for tomato is less than the chi-square table value both at 5% and 1% level, it could be said that the observed color frequencies for tomato do not differ significantly from the expected frequencies. Therefore, the hypothesis is accepted at 5% level. Since the chi-square corrected value is less than that of the critical Table value at 55 point. This indicated that the resultant color of Tomatoes at the end of the storage, under the given conditions, could be said to be of no significantly difference from that of the fresh tomatoes prior to storage.

## 5.4 INTERPRETATION OF CHI-SQUARE VALUE FOR TEXTURE IN THE METAL -IN -POT E.C.S.

TABLES 5.4SUMMARY OF TEXTURE ASSESSMENT

| Product | $\chi^2$Calculated | Corrected | Table 5% | 1% |
|---|---|---|---|---|
| Mango | 7.29 | 10.41 | 3.84146 | 6.63490 |
| Tomatoes | 0. 714 | 1.870 | | |

### MANGO TEXTURE

Referring to table 5.4 being the summary of chi-square obtained for texture in the modified Evaporative coolant structure, since the calculated chi-square value for mango is greater at 5% and 1% level, we could therefore say that the observed texture frequencies for mango do differ significantly from the expected frequencies both at 5% and 1% level. Therefore, the hypothesis rejected at 5% and 1% levels.

### TOMATOES TEXTURE

Referring to tables 5.4, since the calculated chi-square value for tomato is less than the chi-square table value both at 5% and 1% level, it could be said that the observed texture frequencies for tomatoes, do not differ significantly from the expected frequencies. Therefore, the hypothesis is accepted at 55 level since the chi-square corrected value obtained is less than that of the critical table value at 5% point. This indicates that the resultant texture of tomatoes at the end of the storage period, under the given conditions, would be said be of no significantly different from that of the fresh tomatoes prior to storage.

## 5.5 CONCLUSION AND RECOMMENDATIONS

### CONCLUSION

1. The statistical analysis of the evaluation of the stored fruit and vegetable Indicates that
   - (a) There are no significant difference in color and texture of tomato Stored in both the existing and the modified evaporative color structures, and that obtained from the fresh prior to storage.
   - (b) There is a significant difference in the color and texture of mango Stored in existing evaporative coolant structure , and that obtained when fresh prior to storage.
   - (c) There is significant difference in the color of mango in the modified Evaporative coolant structure but a significant difference in the texture from that obtained when fresh.

### RECOMMENDATION

(a) Statistical analysis of the evaluation of color and texture in mango Shows that there is a significant difference in the color and texture at the end of the ten days storage period. Hence the storage period for mango under this storage system should be lowered from ten (10) days in this project work to 5 or 7 days.

(b) Since there is no significant difference in the color and texture of Tomato all the color end of the storage period an extension of the storage period for this vegetable should be tried to ascertain duration of storage under the system.

(c) The experiment should be carried out during other season, to see its effectiveness during different season's or weathers condition.

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APPENDIX I

**COLOUR SCORING QUESTION FOR SPACEMENT A**
NAME ..............................................
DATE ..............................................
**Please evaluate these samples of stored fruits for** *Colour* **[APPEARANCE]. Check the point on the scale that best describes your eveluation of the sample as compared with original, standard [Fresh] sample [R].**

| SAMPLE CODE | COLOUR NUMERICAL SCORING SCALE | | | DATE |
|---|---|---|---|---|
| [Fresh] [R] Replications | 1234567[8] Y1 | 1234567[8] Y2 | 1234567[8] Y3 | |
| A11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| A12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| A13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| A11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| A12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| A13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| A11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| A12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| A13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| A11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| A12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| A13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| A11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| A12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| A13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |

**COLOUR SCORING RATING**
Extremely dull brown- yellow = 1
Very dull brown- yellow = 2
Moderately dull brown- yellow = 3
Slightly dull brown- yellow = 4
Slightly bright golden-yellow = 5
Moderately bright Golden-yellow=6
Very bright Golden-yellow = 7
Extremely bright golden-yellow = 8
**Comments** ..................................

ATE .....................................................

lease evaluate these samples of stored fruits for texture [APPEARANCE]. Check the point on the scale that best describes your eveluation of the sample as compared with original, standard [Fresh] sample [R].

| SAMPLE CODE | TEXTURE NUMERICAL SCORING SCALE | | | DATE |
|---|---|---|---|---|
| [Fresh] [R] Replications | 1234567[8] Y1 | 1234567[8] Y2 | 1234567[8] Y3 | |
| A11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| A12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| A13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| A11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| A12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| A13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| A11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| A12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| A13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| A11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| A12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| A13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| A11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| A12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| A13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |

**TEXTURE SCORING RATING**

Extremely dull rough = 1
Very dull rough = 2
Moderately dull rough = 3
Slightly dull rough = 4
Slightly bright rough = 5
Moderately bright smooth =6
Very bright smooth = 7
Extremely bright smooth = 8

**Comments** ...............................

**COLOUR, SCORING QUESTION FOR SPACEMENT B**

NAME..................................................

DATE..................................................

**Please evaluate these sample of stored vegetables for colour (APPEARANCE).Check the point on the scale that best describes your evaluation of the sample as compared with original standard (FRESH) Sample [ R].**

| SAMPLE CODE | COLOUR NUMERICAL SCORING SCALE | | | DATE |
|---|---|---|---|---|
| [Fresh] [R] Replications | 1234567[8] Y1 | 1234567[8] Y2 | 1234567[8] Y3 | |
| B11 | 1 2 3 4 5 6 7 8 | 1 2 3 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| B12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| B13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| B11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| B12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| B13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| B11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| B12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| B13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| B11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| B12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| B13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| B11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| B12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| B13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |

**Scoring Rating**

Extremely dull red =1
Very dull red = 2
Moderately dull red =3
Slightly dull red = 4
Slightly bright red = 5
Moderately bright red = 6
Very bright red = 7
Extremely bright red =8

**Comments:** ........................................

**TEXTURE SCORING QUESTION FOR SPACEMENT B**

NAME ..............................................

DATE ..............................................

Please evaluate these samples of stored vegetables for texture [APPEARANCE]. Check the point on the scale that best describes your eveluation of the sample as compared with original, standard [Fresh] sample [R].

| SAMPLE CODE | TEX TURE NUMERICAL SCORING SCALE | | | DATE |
|---|---|---|---|---|
| [Fresh] [R]<br>Replications | 1234567[8]<br>Y1 | 1234567[8]<br>Y2 | 1234567[8]<br>Y3 | |
| B11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| B12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| B13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| B11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 78 | 1 2 3 4 5 6 7 8 | Y1 |
| B12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| B13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| B11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| B12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| B13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| B11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| B12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| B13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |
| B11 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y1 |
| B12 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y2 |
| B13 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | 1 2 3 4 5 6 7 8 | Y3 |

**TEXTURE SCORING RATING**

Extremely dull rough = 1
Very dull rough = 2
Moderately dull rough = 3
Slightly dull rough = 4
Slightly bright rough = 5
Moderately bright smooth =6
Very bright smooth = 7
Extremely bright smooth = 8

**Comments** ..................................

## APPENDIX V

Thermal conductivity, Specific heat and Specific gravity's of some metals and Alloys.

K=BTU/(hr)(ft$^2$)($^o$F/t)

| Substance | Temp.$^o$F | K* | Specific heat Btu/(lb)($^o$F) | Specific gravity |
|---|---|---|---|---|
| Aluminum | 32 | 117 | 0.0183 | 2.555-7.8 |
| " | 212 | 119 | 0.1824 | |
| " | 932 | 115 | 0.1872 | |
| Iron cast | 32 | 32 | 0.1064 | 7.03-7.13 |
| " | 212 | 30 | 0.117 | |
| Iron wrought | 64 | 34.6 | see iron | 7.6-7.9 |
| " | 212 | 27.6 | " | 7.83 |
| Steel | 32 | 26 | " | |
| " | 212 | 26 | " | |
| " | 1112 | 21 | " | |

Source:- process heat transfer. Donald.Q. Kern,(1989).$P_P$795-797.

## APPENDIX VI TABLE (I)

| S/No. | Commodity | Temp- (°c) | R.H. (%) | Period | Highest freezing point (°c) | Water Content |
|---|---|---|---|---|---|---|
| 1. | Beans green snap | 4 - 7 | 90 - 95 | 7 - 10 days | - 0.7 | 88.9 |
| 2. | Beans lima | 0 - 4 | 90 | 1 - 2 wks. | - 0.56 | 66.5 |
| 3. | Asparagus | 0 - 2 | 95 | 2 - 3 wks. | - 0.6 | 93.0 |
| 4. | Cabbage ( early) | 0 | 90 - 95 | 2 - 6 wks. | - 0.89 | 92.4 |
| 5. | " (late) | 0 | 90 - 95 | 3 - 4 month | - 0.89 | 92.4 |
| 6. | Beets bunched | 0 | 95 | 10 - 14 days | - 0.39 | - |
| 7. | " topped | 0 | 95 | 3 - 5 months | - 0.95 | 87.6 |
| 8. | Carrot, mature (tapped) | 0 | 90 - 95 | 4 - 5 months | - 1.4 | 88.2 |
| 9. | Carrot immature (tapped) | 0 | 90 - 95 | 4 - 6 months | - 1.4 | 88.2 |
| 10. | Corn sweet | 0 | 90-95 | 4 - 8 days | - 0.6 | 73.9 |
| 11. | Cocumbers | 7 - 10 | 90 - 95 | 10 - 14 days | - 0.5 | 96.1 |
| 12. | Egg plants | 7 - 10 | 90 | 1 wk. | - 0.78 | 92.7 |
| 13. | Ginger shizomes | 13 | 65 | 6 Months | - | 87.0 |
| 14. | Greens leafy | 0 | 90 - 95 | 10 - 14 days | - | |
| 15. | Lettue | 0 | 95 | 2 - 3 wks | - 0.17 | 94.8 |
| 16. | Watermelon | 4 - 10 | 80 - 85 | 2 - 3 wks. | - 0.39 | 92.6 |
| 17. | Okro | 7 - 10 | 90 - 95 | 7 - 10 days | - 1.8 | 89.8 |
| 18. | Onion (dry) | 0 | 65-70 | 1 - 8 months | - 0.78 | 87.5 |
| 19. | " (green) | 0 | 90 - 95 | - | - 0.9 | 89.4 |
| 20. | Potatoes | - | 90 | - | - 0.6 | 81.2 |
| 21. | Punpkins | 10 - 13 | 70 - 75 | 2 - 3 months | - 0.83 | 90.5 |
| 22. | Tomatoes firm-ripe | 4 - 7 | 85 - 95 | 4 - 7 days | - 0.5 | 94.7 |

Appendix (VI) Table (I) Shows the characteristics of commodity in terms of temperature relative humidity, period (storage life), the highest freezing point and the amount of water content in each.

(Wave and McCollum, 1980).

APPENDIX VIII TABLE (II)

| S/NO. | CROP | OPTIMUM STORAGE TEMPERATURE (°c) | APPROXIMATE SHELF LIFE (WEEKS) |
|---|---|---|---|
| 1. | Apple | 1-3 | 8-28 |
| 2. | Banana Green | 12 | 2 - 3 |
| 3. | Carrot | 0 | 12 - 20 |
| 4. | Grape fruit | 10 - 12 | 10 - 16 |
| 5. | Guava | 7 - 10 | 2 - 3 |
| 6. | Lemon | 12 | 12 - 20 |
| 7. | Mango | 10 - 12 | 2 - 3 |
| 8. | Onion | 0 | 12 - 28 |
| 9. | Orange | 5 - 7 | 6 - 12 |
| 10. | Pawpaw | 7 | 2 - 3 |
| 11. | Pineaple | 10 | 2 - 4 |
| 12. | Tomato (Coloured) | 7 - 10 | 1 - 2 |
| 13. | Tomato (Mature green) | 12 | 3 - 6 |

Appendix VIII (Table II)

Shows the optimum storage temperature and shelf life of fruits (Hall 1973).

WIT

## CELSIUS SCALE

| Dry bulb °C | DEPRESSION OF WET - BULB °C 0·5 | 1·0 | 1·5 | 2·0 | 2·5 | 3·0 | 3·5 | 4·0 | 4·5 | 5·0 | 5·5 | 6·0 | 6·5 | 7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -1 | 90 | 79 | 69 | 59 | 49 | 39 | 30 | -20 | 10 | 1 | | | | |
| 0 | 90 | 81 | 71 | 61 | 52 | 44 | 34 | 25 | 16 | 7 | | | | |
| +1 | 90 | 81 | 73 | 64 | 55 | 47 | 38 | 29 | 20 | 13 | 4 | | | |
| 2 | 91 | 82 | 73 | 64 | 57 | 49 | 41 | 33 | 24 | 17 | 9 | 1 | | |
| 3 | 91 | 83 | 74 | 65 | 57 | 49 | 43 | 36 | 28 | 21 | 14 | 7 | | |
| 4 | 92 | 83 | 75 | 67 | 59 | 51 | 43 | 35 | 32 | 25 | 18 | 11 | 4 | |
| 5 | 92 | 84 | 76 | 68 | 61 | 53 | 46 | 38 | 31 | 24 | 31 | 15 | 8 | 2 |
| 6 | 92 | 85 | 77 | 70 | 62 | 55 | 48 | 41 | 32 | 27 | 20 | 14 | 12 | 6 |
| 7 | 93 | 85 | 78 | 71 | 64 | 52 | 50 | 44 | 34 | 30 | 24 | 17 | 11 | 5 |
| 8 | 93 | 86 | 79 | 72 | 62 | 59 | 52 | 46 | 39 | 33 | 27 | 21 | 15 | 9 |
| 9 | 93 | 86 | 80 | 73 | 67 | 60 | 54 | 48 | 42 | 36 | 30 | 24 | 18 | 12 |
| 10 | 93 | 87 | 81 | 74 | 68 | 62 | 56 | 50 | 44 | 38 | 33 | 27 | 21 | 16 |
| 11 | 94 | 87 | 81 | 75 | 69 | 63 | 58 | 52 | 46 | 41 | 35 | 30 | 24 | 19 |
| 12 | 94 | 88 | 82 | 76 | 70 | 65 | 59 | 54 | 48 | 43 | 37 | 32 | 27 | 22 |
| 13 | 94 | 88 | 83 | 77 | 71 | 66 | 60 | 55 | 50 | 45 | 40 | 35 | 30 | 25 |
| 14 | 94 | 89 | 83 | 78 | 72 | 67 | 62 | 57 | 57 | 47 | 42 | 37 | 32 | 27 |
| 15 | 94 | 89 | 84 | 78 | 73 | 68 | 63 | 58 | 53 | 48 | 42 | 39 | 34 | 30 |
| 16 | 95 | 89 | 84 | 79 | 74 | 69 | 64 | 59 | 55 | 50 | 43 | 41 | 37 | 32 |
| 17 | 95 | 90 | 85 | 80 | 75 | 70 | 65 | 61 | 56 | 52 | 47 | 43 | 39 | 34 |
| 18 | 95 | 90 | 85 | 80 | 76 | 71 | 66 | 62 | 57 | 53 | 49 | 45 | 40 | 36 |
| 19 | 95 | 90 | 86 | 81 | 76 | 72 | 67 | 63 | 59 | 54 | 50 | 46 | 42 | 38 |
| 20 | 95 | 91 | 86 | 81 | 77 | 73 | 68 | 64 | 60 | 56 | 52 | 48 | 44 | 40 |
| 21 | 95 | 91 | 86 | 82 | 78 | 73 | 69 | 65 | 61 | 57 | 53 | 49 | 45 | 42 |
| 22 | 95 | 91 | 87 | 82 | 78 | 74 | 70 | 66 | 62 | 58 | 54 | 50 | 47 | 43 |
| 23 | 96 | 91 | 87 | 83 | 79 | 75 | 71 | 64 | 63 | 59 | 55 | 52 | 48 | 45 |
| 24 | 96 | 91 | 87 | 83 | 79 | 75 | 71 | 68 | 64 | 60 | 57 | 53 | 49 | 46 |
| 25 | 96 | 92 | 88 | 84 | 80 | 76 | 72 | 68 | 65 | 61 | 58 | 54 | 51 | 47 |
| 26 | 96 | 92 | 88 | 84 | 80 | 76 | 73 | 69 | 66 | 62 | 59 | 55 | 52 | 49 |
| 27 | 96 | 92 | 88 | 84 | 81 | 77 | 73 | 70 | 66 | 62 | 59 | 56 | 53 | 50 |
| 28 | 96 | 92 | 88 | 85 | 81 | 77 | 74 | 70 | 67 | 64 | 60 | 57 | 54 | 51 |
| 29 | 96 | 92 | 89 | 85 | 81 | 78 | 74 | 71 | 68 | 64 | 61 | 58 | 55 | [illegible] |
| 30 | 96 | 93 | 89 | 85 | 82 | 78 | 75 | 72 | 68 | 65 | 62 | 59 | 56 | [illegible] |
| 32 | 96 | 93 | 89 | 86 | 82 | 79 | 76 | 73 | 70 | 67 | 64 | 61 | 58 | [illegible] |
| 34 | 96 | 93 | 89 | 86 | 83 | 80 | 77 | 74 | 71 | 68 | 65 | 62 | 59 | [illegible] |
| 36 | 96 | 93 | 90 | 87 | 84 | 81 | 78 | 75 | 72 | 69 | 66 | 63 | 61 | [illegible] |
| 38 | 96 | 94 | 90 | 87 | 84 | 81 | 78 | 75 | 73 | 70 | 67 | 64 | 62 | [illegible] |
| 40 | 96 | 94 | 91 | 88 | 85 | 82 | 79 | 76 | 74 | 71 | 62 | 66 | 63 | [illegible] |
| 42 | 97 | 94 | 91 | 88 | 85 | 82 | 80 | 77 | 75 | 72 | 70 | 67 | 65 | [illegible] |
| 44 | 97 | 94 | 91 | 88 | 86 | 83 | 81 | 78 | 75 | 72 | 70 | 67 | 65 | [illegible] |
| 46 | 97 | 94 | 91 | 89 | 86 | 83 | 81 | 78 | 76 | 73 | 71 | 68 | 66 | |
| 48 | 97 | 95 | 92 | 89 | 86 | 83 | 81 | 78 | 76 | 74 | 72 | 69 | 67 | |
| 50 | 97 | 95 | 92 | 89 | 87 | 84 | 82 | 79 | 77 | 74 | 72 | 70 | 68 | |
| 52 | 97 | 95 | 92 | 89 | 87 | 84 | 82 | 79 | 77 | 75 | 73 | 70 | 68 | |
| 54 | 97 | 95 | 93 | 90 | 87 | 85 | 83 | 80 | 78 | 75 | 73 | 71 | 69 | |
| 56 | 97 | 95 | 93 | 90 | 87 | 85 | 83 | 80 | 78 | 76 | 74 | 71 | 69 | |
| 58 | 97 | 95 | 93 | 90 | 87 | 85 | 83 | 81 | 78 | 76 | 74 | 72 | 70 | |
| 60 | 98 | 96 | 93 | 90 | 87 | 85 | 83 | 81 | 79 | 77 | 75 | 72 | 70 | |

SOURCE GEOGRAPHY DEPARTMENT, FUT, MINNA

## OF WET & DRY BULB THERMOME...

## CORRESPONDING PERCENTAGES OF HUMID

CELSIUS SCALE

| Dry Bulb °C | DEPRESSION OF WET BULB °C | | | | | | | | | | | Dry Bulb °C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7·5 | 8·0 | 8·5 | 9·0 | 9·5 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | |
| -1 | | | | | | | | | | | | | -1 |
| 0 | | | | | | | | | | | | | 0 |
| +1 | | | | | | | | | | | | | +1 |
| 2 | | | | | | | | | | | | | 2 |
| 3 | | | | | | | | | | | | | 3 |
| 4 | | | | | | | | | | | | | 4 |
| 5 | | | | | | | | | | | | | 5 |
| 6 | | | | | | | | | | | | | 6 |
| 7 | | | | | | | | | | | | | 7 |
| 8 | 3 | | | | | | | | | | | | 8 |
| 9 | 7 | 1 | | | | | | | | | | | 9 |
| 10 | 10 | 5 | | | | | | | | | | | 10 |
| 11 | 14 | 9 | 4 | | | | | | | | | | 11 |
| 12 | 17 | 12 | 7 | 2 | | | | | | | | | 12 |
| 13 | 20 | 15 | 11 | 6 | 1 | | | | | | | | 13 |
| 14 | 23 | 18 | 14 | 9 | 6 | 1 | | | | | | | 14 |
| 15 | 25 | 21 | 17 | 12 | 8 | 4 | | | | | | | 15 |
| 16 | 28 | 24 | 19 | 15 | 11 | 7 | | | | | | | 16 |
| 17 | 30 | 26 | 22 | 18 | 14 | 10 | 3 | | | | | | 17 |
| 18 | 32 | 28 | 24 | 21 | 17 | 13 | 6 | | | | | | 18 |
| 19 | 34 | 30 | 27 | 23 | 19 | 16 | 9 | 2 | | | | | 19 |
| 20 | 36 | 32 | 29 | 25 | 22 | 18 | 11 | 5 | | | | | 20 |
| 21 | 38 | 34 | 31 | 27 | 24 | 20 | 14 | 7 | 1 | | | | 21 |
| 22 | 40 | 36 | 33 | 29 | 26 | 23 | 16 | 10 | 4 | | | | 22 |
| 23 | 41 | 38 | 34 | 31 | 28 | 25 | 18 | 12 | 6 | 1 | | | 23 |
| 24 | 43 | 39 | 36 | 33 | 30 | 27 | 20 | 15 | 9 | 3 | | | 24 |
| 25 | 44 | 41 | 38 | 35 | 31 | 28 | 22 | 17 | 11 | 6 | 1 | | 25 |
| 26 | 45 | 42 | 39 | 36 | 33 | 30 | 24 | 19 | 13 | 8 | 3 | | 26 |
| 27 | 47 | 44 | 41 | 38 | 35 | 32 | 26 | 21 | 15 | 10 | 5 | 1 | 27 |
| 28 | 48 | 45 | 42 | 39 | 36 | 33 | 28 | 23 | 17 | 12 | 8 | 3 | 28 |
| 29 | 49 | 46 | 43 | 40 | 37 | 35 | 29 | 24 | 19 | 14 | 10 | 5 | 29 |
| 30 | 50 | 47 | 44 | 42 | 39 | 36 | 31 | 26 | 21 | 16 | 12 | 7 | 30 |
| 32 | 52 | 49 | 46 | 44 | 41 | 39 | 34 | 29 | 24 | 20 | 15 | 11 | 32 |
| 34 | 54 | 51 | 48 | 46 | 43 | 41 | 36 | 32 | 27 | 23 | 19 | 15 | 34 |
| 36 | 55 | 53 | 50 | 48 | 45 | 43 | 38 | 34 | 30 | 26 | 22 | 18 | 36 |
| 38 | 57 | 54 | 52 | 50 | 47 | 45 | 40 | 36 | 32 | 28 | 24 | 20 | 38 |
| 40 | 58 | 56 | 53 | 51 | 49 | 47 | 42 | 38 | 34 | 30 | 27 | 23 | 40 |
| 42 | 60 | 57 | 55 | 53 | 50 | 48 | 44 | 40 | 36 | 32 | 29 | 25 | 42 |
| 44 | 61 | 58 | 56 | 54 | 52 | 50 | 46 | 42 | 38 | 34 | 31 | 27 | 44 |
| 46 | 62 | 59 | 57 | 55 | 53 | 51 | 47 | 43 | 39 | 36 | 33 | 29 | 46 |
| 48 | 63 | 60 | 58 | 56 | 54 | 52 | 43 | 44 | 41 | 37 | 34 | 31 | 48 |
| 50 | 63 | 61 | 59 | 57 | 55 | 53 | 49 | 45 | 42 | 38 | 36 | 32 | 50 |
| 52 | 64 | 62 | 60 | 58 | 56 | 54 | 50 | 47 | 43 | 40 | 37 | 34 | 52 |
| 54 | 65 | 63 | 61 | 59 | 57 | 55 | 51 | 48 | 44 | 41 | 38 | 35 | 54 |
| 56 | 66 | 64 | 62 | 60 | 58 | 56 | 52 | 49 | 45 | 42 | 39 | 37 | 56 |
| 58 | 66 | 64 | 63 | 61 | 59 | 57 | 53 | 50 | 47 | 43 | 40 | 38 | 58 |
| 60 | 67 | 65 | 64 | 62 | 60 | 57 | 54 | 51 | 48 | 45 | 42 | 39 | 60 |

## CELSIUS SCALE

| DEPRESSION OF WET BULB °C | | | | | | | | | | | | | | Dry Bulb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | °C |
| | | | | | | | | | | | | | | -1 |
| | | | | | | | | | | | | | | 0 |
| | | | | | | | | | | | | | | +1 |
| | | | | | | | | | | | | | | 2 |
| | | | | | | | | | | | | | | 3 |
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| | | | | | | | | | | | | | | 5 |
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| | | | | | | | | | | | | | | 11 |
| | | | | | | | | | | | | | | 12 |
| | | | | | | | | | | | | | | 13 |
| | | | | | | | | | | | | | | 14 |
| | | | | | | | | | | | | | | 15 |
| | | | | | | | | | | | | | | 16 |
| | | | | | | | | | | | | | | 17 |
| | | | | | | | | | | | | | | 18 |
| | | | | | | | | | | | | | | 19 |
| | | | | | | | | | | | | | | 20 |
| | | | | | | | | | | | | | | 21 |
| | | | | | | | | | | | | | | 22 |
| | | | | | | | | | | | | | | 23 |
| | | | | | | | | | | | | | | 24 |
| | | | | | | | | | | | | | | 25 |
| | | | | | | | | | | | | | | 26 |
| | | | | | | | | | | | | | | 27 |
| | | | | | | | | | | | | | | 28 |
| 1 | | | | | | | | | | | | | | 29 |
| 3 | | | | | | | | | | | | | | 30 |
| 7 | 3 | | | | | | | | | | | | | 32 |
| 11 | 7 | 3 | | | | | | | | | | | | 34 |
| 14 | 10 | 7 | 3 | | | | | | | | | | | 36 |
| 17 | 13 | 10 | 7 | 4 | 1 | | | | | | | | | 38 |
| 20 | 16 | 13 | 10 | 7 | 4 | 1 | | | | | | | | 40 |
| 22 | 19 | 16 | 13 | 10 | 7 | 4 | 2 | • | | | | | | 42 |
| 24 | 21 | 18 | 15 | 12 | 10 | 7 | 4 | 1 | | | | | | 44 |
| 26 | 23 | 20 | 18 | 15 | 12 | 10 | 8 | 5 | 3 | 1 | | | | 46 |
| 28 | 25 | 22 | 20 | 17 | 14 | 12 | 10 | 8 | 5 | 3 | 1 | | | 48 |
| 29 | 27 | 24 | 21 | 19 | 16 | 14 | 12 | 9 | 7 | 5 | 3 | 1 | | 50 |
| 31 | 28 | 26 | 23 | 21 | 18 | 16 | 14 | 11 | 9 | 8 | 5 | 3 | 1 | 52 |
| 32 | 30 | 27 | 25 | 22 | 20 | [illegible] | 15 | 13 | 11 | 10 | 7 | 5 | 3 | 54 |
| 34 | 32 | 29 | 27 | 24 | 21 | 19 | 17 | 15 | 13 | 11 | 9 | 7 | 5 | 56 |
| 35 | 33 | 30 | 28 | 25 | 23 | 21 | 19 | 17 | 15 | 13 | 11 | 9 | 7 | 58 |
| 36 | 34 | 32 | 29 | 27 | 25 | 23 | 20 | 18 | 16 | 15 | 13 | 11 | 9 | 60 |

PLATE 1 : PRODUCT IN THE POT - IN - POT EVAPORATIVE COOLER AT THE END OF TEN (10) DAYS STORAGE.

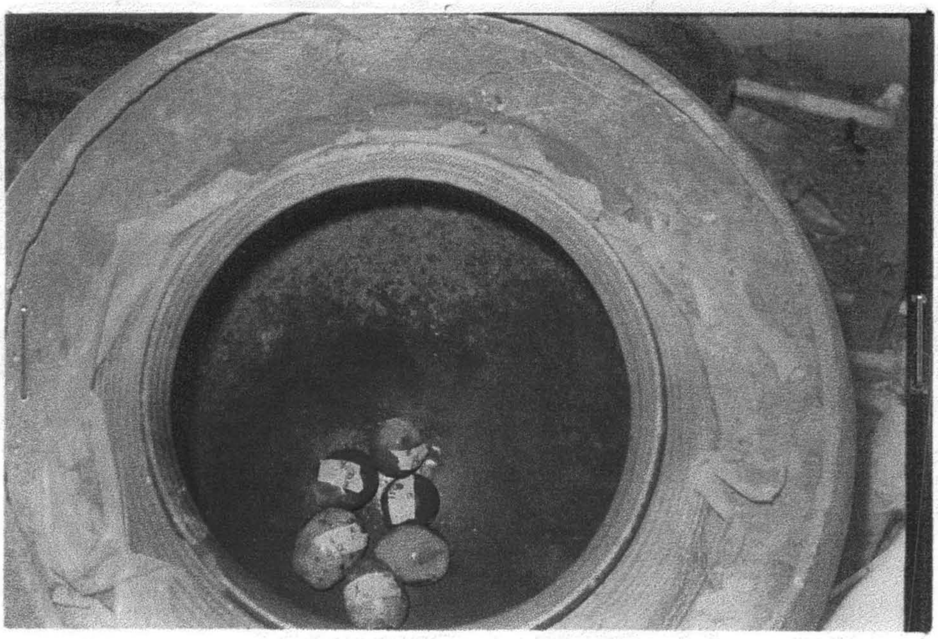

PLATE 2: PRODUCT IN THE METAL IN - POT EVAPORATIVE COOLER AT THE END OF TEN (10) DAYS STORAGE.