INVESTIGATIVE STUDY OF THREE STORAGE FACILITIES FOR SOME FRUITS AND VEGETABLES

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG.) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

FEBRUARY, 2010

DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any University or Institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

Agbachi Patrick Abraham

17/02/2010

Date

CERTIFICATION

This Project entitled "Investigative Study of Three Storage Facilities for Some Fruits and Vegetables" by Agbachi Patrick Abraham, meets the regulations governing the award of Degree of Bachelor of Engineering (B.ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This humble project is dedicated to my loving parents, who were my first guides to a happy life.

ACKNOWLEDGEMENTS

"Man proposes but God disposes". This proverb is a clear indication to man that without the will of God nothing is possible. I am grateful to God for giving me the opportunity and inspiration to write my project. I place my heartfelt gratitude to my supervisor, Mrs. Bosede Orhevba for her support academically. I also thank Mr. Sadeeq for his explanation about project work and other staff who spent their time in encouraging me.

I cannot but express my gratitude to my parents who bought me up in a whole some and spiritual atmosphere. I am indebted to the following for their support which made my project a success: Ekene D. Ugwuokpe, Orobosa Egbe, Obi Samson N, Henry Ojukwu, and all others for their help and timely corrections.

Agbachi Patrick A.

ABSTRACT

Several storage systems have been designed and are being used for storing Fruits and Vegetables. Therefore, this study was carried out to investigate some of these storage systems for some Fruits and Vegetables. To fulfill the objectives of this study, the following storage systems, were used for the experiment: Metal-in-pot evaporative cooler, Pot-in-pot evaporative cooler, Refrigerator and storage at ambient conditions. The study was limited to temperature, relative humidity and other physical changes, such as chilling injury and drying injury. Storage trials for Banana, Tomato, Okra, Lettuce and Spinach were carried out for eighteen (18) days. The temperature and relative humidity inside the storage system and ambient conditions was taken two times daily (i.e morning and afternoon) and the average calculated and recorded. The results obtained showed that the Metal-in-pot evaporative cooler was the best, because it gave the best expected results due to its low temperature of 20°C - 27 °C and very high relative humidity of 76% - 88%.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Agronomy of Fruits and Vegetables

The term Fruit has different meanings dependent on context, and the term is not synonymous in food preparation and biology. Fruits are the means by which flowering plants disseminate seeds, and the presence of seeds indicate that a structure is most likely a Fruit. A fleshy Fruit can be defined as the enlarged ovary of a flower or additional floral part of a flower. Some Fruits however, are formed from other flower part 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 apple.

Further more, no single terminology really fits the enormous variety that is found among plant Fruits. The term false Fruit (pseudocarp, accessory Fruit) is sometimes applied to a Fruit like the fig (a multiple-accessory Fruit) or to a plant structure that resembles a Fruit but is not derived from a flower or flowers. Some gymnosperm, such as yew, have fleshy arils resembling Fruits. Balthasar (2004).

Vegetable is basically an edible plant or part of a plants other than a sweet Fruits or seed. They could be described as fresh, edible portion of herbaceous plant consumed raw, and some may be cooked in various ways. The edible portion may be the root, stem, leaf, flower structure, fleshy Fruit, seed or a combination of such parts. Vegetables are relatively high in water content and as such, usually requires no milling or special treatment before preparation. (Balthasar Van der Ast, 2004).

1.2 **Importance of Fruits and Vegetables**

1.2.1 **In Human Diet**

Fresh Fruits and Vegetables supply some elements in which other food materials are deficient. They serve mostly as source of food. They are also main sources of minerals, vitamins and protein in the diet. Some of the various vitamins contained in Fruits and Vegetables are Vitamins A,B,C and K and minerals such as calcium, phosphorus, iron, potassium e.t.c. Deficiency of these vitamins and minerals causes various disease such as light blindness, weakness of the bones and teeth, shortage of blood, mal-nutrition and indigestion.

Fruits and vegetables also neutralize the acidic substances produced during digestion thereby aiding digestion. (Williams, 1993)

1.2.2 Benefits to the Economy

The major importance of Fruits and vegetables to the farmer are: they serve as a source of income to them. For example, bananas and plantains are carried in trucks to the Northern part of Nigeria for sale, while pepper and tomatoes are carried to the southern part of Nigeria for sale.

They also serve as source of raw materials to industries. Example are: Tinned tomato industries uses tomatoes as its main raw material, local wine and bear, beverage industries use Fruits like coconut, mango, Orange, and pine-apple as its raw material.

Fruits and vegetables, directly or indirectly are source of revenue to, the government, since market women as well as agriculturally based industries pay taxes.

1.3 Statement of problem

There are many factors which contribute to the rapid deterioration of Fruits and vegetables after harvest. Some of these factors are due to the nature of Fruits and vegetables handling and the storage method employed.

a. Nature of Fruits and Vegetables

Most Fruits and vegetables contain about 80-95% water. They are thus classified as highly perishable agricultural product, examples are cucumber, lettuce, watermelon, and paw-paw, they still transpire after harvest and this results in loss of water which brings about deterioration, most especially in leafy vegetables.

Fruits and vegetables also contain some enzymes in them which are responsible for active metabolic processes even after harvest.

b. Handling

Deterioration of Fruits and vegetables is also caused by poor mechanical handling. This includes poor harvesting process such as harvesting immature Fruits or shaking Fruits-branches as method of harvesting, which often cause mechanical damage to the farm produce.

c. Storage Systems

Concentration of heat during pilling of Fruit and vegetables on a spot allows micro-organisms to be active which causes a lot of deterioration to the Fruits and vegetables.

During storage, leafy vegetables and Fruits lose moisture, and the vitamin C in them degrades rapidly. They should be stored for as short a time as possible in a cool place.

1.4 The need for better storage system

To store fresh Fruits and vegetables effectively implies keeping them in such conditions in which the life process will be retarded by avoiding death of tissues which initiate gross deterioration and drastic differences in flavour, texture and appearance. Storing of fresh Fruits and vegetables are very necessary because of the following reasons:

- Storing stabilize price by carrying over produce from periods of surplus to periods of scarcity, thereby extending the period of consumption of various kinds of Fruits and vegetables (Wikipedia, 2004)
- Storage of Fruits and vegetables contribute to the preservation of natural living state of edible portion and the prevention of deterioration through control of temperature, relative humidity and the quality of the stored product.
- Storing maximizes profit and prevents wastage.
- Storing encourages farmers to produce more profit since wastage is minimized.

1.4 AIMS AND OBJECTIVES

1. To investigate the effectiveness and limitation of some existing storage systems for Fruits and Vegetables.
2. To investigate the temperature in Celsius relative humidity in percentage and shelf life in 18 storage days for some selected Fruits and Vegetables.
3. To find out which of the storage system would be the best method for storing Fruits and Vegetables.

1.5 JUSTIFICATION OF THE PROJECT

Fresh Fruits and Vegetables, due to their composition are very perishable. Therefore, their continuous supply to the market for consumption is very pertinent. Hence, to be able to do this relatively to meet their societal demand there must be good storage system for them (Fruits and vegetables) at least during the period of surplus. Hence the need to investigate which of the storage system best stores Fruits and Vegetables.

1.6 SCOPE OF STUDY

The project work is limited to the investigation of the effectiveness and limitation of some existing storage system (i.e Metal-in-pot evaporation cooler, Pot-in-pot cooler, Refrigerator) and storage under ambient condition for some Fruits(Tomato Banana) and vegetables (i.e Okra, Lettuce and Spinach) being widely grown and consumed in Nigeria and the world at large were considered. The following were also investigated: temperature, relative humidity and approximate shelf life (weeks) of the Fruits and Vegetables.

CHAPTER TWO

2.0 LITERATURE REVIEW

There have been several research projects on Fruits and vegetables concerning their physiology, factors affecting their deterioration when stored, suggested methods of reducing such losses, and storage systems for Fruits and vegetables. This chapter is the review of some research works carried out on Fruits and vegetables storage, so as to prolong their continuous availability.

2.1 Physiology of Fruits and vegetables after harvesting

Onyekwelu and Anor (1984)confirmed that Fruits and vegetables are still physiologically active after harvest, therefore, respiration and transpiration continue in their tissues and eventually lead to their deterioration of Fruits and vegetables. This deterioration is caused by high respiration and transpiration rate in addition to spoilage due to fungal attack. This leads to drying, softening or rotting of the Fruits and vegetables.

Nigerian Stored Products Research Institute (N.S.P.R.I, 1990) described heavy losses in Fruits and vegetables as a result of loss in moisture content (transpiration), change in composition (Metabolic factors) and pathological attack (micro-organisms). This makes Fruits and vegetables to be highly perishable particularly under hot tropical conditions.

2.2 Factors affecting storage losses of Fruits and Vegetables

Fruits and Vegetables are classified as highly perishable products due to their high moisture contents and their physiological factors (N.S.P.R.I, 1990). Other factors which affects the storage of Fruits and vegetables include the following.

- **Poor Mechanical Handling**

Safe arrival of Fruits at its final destination depends on the way it is handled from the time it is picked from the tree until it is processed for sale at its final market. (N.S.P.R.I, 1990)

Nigerian Stored Product Research Institute (1990), reported that fast deterioration of Fruits and vegetables are caused by faulty harvesting practices like harvesting immature Fruits and shaking the tree which causes the Fruits to be bruised. It further concluded that, when Fruits and vegetables are heaped or thrown, they are squeezed and softened, hence, rapid deterioration occurs.

- **Micro-Organism and Insect Pests**

According to Nigerian Stored Product Research Institute (1990), Fruits and vegetables may be pathologically damaged due to disease causing micro-organisms which attack them even on the field before harvest. Damages to the surface tissues may occur due to attack by the pests of diseases which result in increased rate of water loss and hence, loss in quality of produce.

2.3 Suggested methods of reducing post-harvest losses in Fruits and Vegetables.

Nigerian Stored Product Research Institute. (1990) confirmed that the varietals differences, good harvesting and handling, sorting, packaging transportation, storage and processing practices play vital roles in the reduction of post-harvest losses of Fruits and vegetables.

Some suggested methods of reducing post-harvest loses in Fruits and vegetables are:

2.3.1 High Initial Quality of Fruits And Vegetables

Nigerian Stored Product Research Institute (1990), stated that the variety of Fruits and vegetables to be stored must be one that have long shelf – life

2.3.2 Good Harvesting Method

Nigerian Stored Product Research Institute (1990), suggested that Fruits should be harvested when matured but yet in green state (Not ripe) because immature Fruits may not ripen while ripen Fruits have short storage life.

2.3.3 Good Handling and Transportation

Mechanical injuries provides room for pest attack and increases physiological losses. Therefore, mechanical injuries that occur during harvesting should be avoided 9 (N.S.P.R.I, 1990). It was recommended that well ventilated vehicle with the top covered should be used for transportation of Fruits and vegetables.

2.3.4 Good Storage and Processing

Nigerian Stored Product Research Institute (1990), stated that Fruits and vegetables can be preserved for long periods by drying, freezing, cooling and canning. The following are suggested precautions for minimum deterioration during storage.

- **Addition of Ethylene Absorbents**

Samson (1982) confirmed that when ethylene absorbent is introduced to Fruits, their ripening is delayed. Nigerian Stored Product Research Institute (1990) further explained that Fruits like bananas, mangoes, pineapple, tomatoes and plantains when harvested and wrapped in polythene bag of 0.04mm thickness; adding ethylene absorbent and kept in a cool environment can preserve them for up to 15 days before opening to ripen normally.

- **Wax Coating**

Nigerian Stored Product Research Institute (1990) and Samson (1982) concluded that fungicidal wax coating can be applied to Fruits like oranges, grapes and lemons after washing with pure or chlorinated water. This reduces loss of moisture over long period at ambient conditions, wax emulsion or wax proof paper are also needed instead of wax coating. This increases storage period to about 8 weeks.

- **Packing in Sealed Polythene Bags**

According to Nigerian Stored Product Research Institute (1990), green leafy vegetables are stored in sealed polythene bags after washing. This can preserve its frèshness for about 6 days.

- **Curing**

Rustan (1985), said that surplus Fruits and vegetables can be preserved by curling, if canning, freezing or drying will not serve the purpose.

- **Drying**

Onyekwelu (1984), in an experiment carried out confirmed that vegetables dried at 32^0c for about 50 hours and stored at ambient temperature can be kept for over two years. The nutrient value can be compared very favorably with that of freshly harvested ones.

- **Reduced Temperature and Pressure**

Coursey *et al* (1976), concluded that the lower the temperature, the lower the respiration in storage therefore, the greater the shelf life. However, Samson (1982) confirmed that storage of Fruits at controlled atmosphere, lower oxygen of about 2% and higher carbon dioxide of about 10% can prolong the life of some tropical Fruits. He also added that irradiation delays ripening, retard spoilage and minimize infestation.

- **Packaging and Storage Containers**

N.S.PR.I (1990), stated that dufaylite cells can be used to pack Fruits individually to prevent contact of one Fruit to another in a package to prevent compression of Fruits. The dufaylite cells are made from cardboard and used to separate Fruits packed in large containers like the ventilated fibre board carton for storage and transportation over a long distance. Other packaging containers are ventilated collapsible and non-collapsible plywood, slated wooden boxes and ventilated plastic crates.

- **Cold Storage Systems**

N.S.P.R.I. (1990), recorded that evaporative cooler structures works with the principle of cooling resulting from evaporation of water from the surface of the structures. This cooling results in high relative humidity of the air chamber from which the evaporation takes place. Rustan (1985), however enumerated some factors which makes evaporative cooling possible in these structures. The factors are low relative humidity of the surrounding air, high air temperature, high rate of air movement, large surface area for evaporation and abundant supply of water.

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Material

The following are the materials used for the investigation carried out at the Department of Agricultural and Bio-resources Engineering, Federal University of Technology Minna.

d. Triple beam balance

i. Wet and dry hygrometer

ii. Mercury-in-glass thermometer

iii. Refrigerator

iv. Evaporative cooler structures

3.2 Crops used

The crops used for the investigation are

i. Banana – *Musa sapientum*

ii. 2 varieties of Tomato-elongated *(lycopersicum lycopersicon)* and round type *(lycopersicum osculentorm)*

ii. Okra – *Hibiscus esculents*

iv. Lettuce – *Lactuca sativa*

v. Spinach – *spinacia oleracca*

3.3 Storage systems

Four storage systems were used for the investigations.

1. Pot-in-pot evaporative cooler structure
2. Metal-in-pot evaporative cooler structure
3. Refrigerator
4. Storage at ambient condition.

3.3.1 Pot-In-Pot Evaporative Cooler Structure

The pot-in-pot evaporative cooler structure consists of 2 clay pots one smaller than the other, the smaller has an external diameter 19.5cm, 46cm height and 1cm thickness covered with polyethylene bag, the largest pot has an external diameter of 48cm, 2cm thickness and 54.5cm height, filled with river bed sand.

3.3.2 Metal In-Pot Evaporative Cooler Structure

The metal in-pot evaporative cooler structure is similar to that of the pot-in-pot evaporative cooler structure except that the smaller pot is replaced with a metal tin of 24 x 24 x 35cm external diameter and 2mm thickness.

3.4 Investigation Procedure

Four storage media were investigated, they are: pot-in-pot (ESC evaporative cooler structure, metal-in-pot evaporative cooler structure, refrigerator and storage at ambient temperature.

In each of the storage medium, the following crops were stored.

Four bananas, and their average weight were calculated which is 42g.

Four tomatoes, and their average weight were calculated which is 38g.

Six Okra, and their average weight were calculated which is 26g.

Two bunches of lettuce and a bunch of spinach, each weight 52g and 54g

The crops were weighed on the triple beam balance and their corresponding weights recorded before storage.

Various measurements such as temperature reading, relative humidity, weight and visual observation such as ripening, color changes, rotting and shriveling were recorded for the period of eighteen (18) storage days.

3.4.1 Weight Measurement

The triple bean balance was used for weight measurements. Each of the crops were taken out and weighed through out the storage period of eighteen (18) days and percentage weight losses were recorded.

3.4.2 Temperature Reading

The temperature was measured using mercury-in – glass thermometer and the average temperature of each of the storage system were calculated for the whole storage period.

3.4.3 Relative Humidity Reading

The relative humidity was taken using a dry and wet bulb hygrometer. The relatives humidity reading was taken by reading the measurement on the dry bulb (i.e difference between the dry and wet bulb). The relative humidity was calculated in percentage and recorded.

3.4.4 Ripening Observation

Ripening were observed in each of the storage system, during the storage period and they were estimated and recorded.

3.4.5 Rotting (Decaying) Observation

Observations were carried out to determine when rotting occurred on the stored crops in each of the storage medium.

3.4.6 Shriveling Observations

Shriveling occurred in crops stored in the storage system, because of the presumptions that most of the crops stored as such often loose their quality.

3.4.7 Observations for other Physical Changes

Other physical changes such as chilling injury and color changes were observed for crops stored in the refrigerator.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The results obtained from the investigation are discussed below. Various observations made during the storage period of the different crops used were also presented.

4.1 Storage conditions

With low temperature, spoilage with attendant loss in the quality of the commodity is minimized. The degree of spoilage of vegetables also depends on the vegetable type and anatomical conditions especially relative humidity (Onyekwelu, 1984). The condition of the storage system therefore affects the physiology and quality of the crops stored. These are temperature, relative humidity and duration of storage. From the experiment, low temperature and high relative humidity increased the duration of storage before spoilage occurred.

4.1.1. Temperature

There was reduction in temperature in the evaporative cooling structure compared with the room temperature and temperature of the control experiment even though the control was kept in the same place. (that is, cool environment where there was free circulation of air). The temperature in the refrigerator ranged between 8.5^0C-17^0C. Table 4.1 shows that average temperature of the pot-in-pot evaporative cooler structure ranged between, 18^0C to 26.5^0C while that of the metal-in-pot evaporative cooler ranged between 18.5^0C to 27^0C but average temperature of the control experiment ranged from 24.5^0C to 31^0 C.

Table 4.1 Average temperature (^{0}c) of the storage systems

DATE	STORAGE SYSTEMS				
	POT-IN-POT EVAPORATIVE COOLER SYSTEM (^{0}C)	METAL-IN-POT ECS(^{0}C)	REFRIGERATOR (^{0}C)	CONTROL EXPERIMENT (^{0}C)	ROOM (^{0}C)
25/11/2009	25	26	12	30	30
26/11/2009	22	23	17	28	28
27/11/2009	22	22	10	29	32
28/11/2009	23	23.5	13	29	31
29/11/2009	23.5	23.5	12.5	29.5	30.5
30/11/2009	18	19	10.5	24.5	29.5
1/12/2009	19	18.5	10.5	26.5	28.5
2/12/2009	18	18.5	13.5	27	28
3/12/2009	19	19	13	28	30
4/12/2009	25	25	14	26	30
5/12/2009	25.5	26	15.5	30	31
6/12/2009	24	25	12	27	27
7/12/2009	25	25.5	10	30.5	32
8/12/2009	25.5	26	11	30.5	32
9/12/2009	26	27	11	30.5	32
10/12/2009	26.5	26.5	8.5	31	32.5

4.1.2. Relative Humidity

Table 4.2 shows that the relative humidity in the Pot-in-pot evaporative cooler system and Metal-in-pot evaporative cooler system were very high compared to that of the control experiment and room relative humidity. The average relative humidity of the Pot-in-pot evaporative cooler system varied from 80.5% to 100% while that of the metal-in-pot ECS ranged from 76% to 88%. While the average relative humidity of the control experiment ranged from 37.5 to 73.5% and that of the room ranged from 30% to 69.5%.

The high relative humidity in the evaporative cooler structure was due to the cooling of the storage systems resulting from evaporation of water from the outer chamber.

The average relative humidity of the refrigerator ranged between 55.6% to 69.5%; of which its minimum average relative humidity was 18% higher than that of the control experiment and 25.5% higher than that of the room. Its maximum relative humidity was 4% lower than in the control experiment

Table 4.2 Average relative humidity of the storage systems

DATE	STORAGE SYSTEMS				
	POT-IN-POT EVAPORATIVE COOLER SYSTEM (%)	METAL-IN-POT ECS(%)	REFRIGERATOR (%)	CONTROL EXPERIMENT (%)	ROOM (%)
26/11/2009	82	82	62	45	45
27/11/2009	82	82	62	52	34
28/11/2009	92	91	65.5	57	53
29/11/2009	100	85.5	59	63.5	56
30/11/2009	95.5	83	55.5	40.5	42.5
1/12/2009	86.5	82	62	37.5	30
2/12/2009	91	83	61.5	47	33
3/12/2009	87.5	78.5	62	44	44.5
4/12/2009	87.5	76	69.5	43	69.5
5/12/2009	80.5	78.5	62.5	64.5	66.5
6/12/2009	96	91	68	73.5	61
7/12/2009	88	77	61.5	66	61
8/12/2009	92	88	66.5	67	66.5
9/12/2009	89	82	62	58.5	55.5
10/12/2009	84.5	81	61	65	59

4.2 Physiology of the crops stored

The visual observations made are discussed below:

4.2.1 Ripening

Burton (1981), reported that ripening is a subjective term which indicate to us that the Fruit has reached the peak of edibility, i.e sweet, and texture has softened. The crops stored were good, acceptable and unripe at the commencement of the investigation.

In the control, banana started ripening on the third day of storage while ripening occurred on the 8th day of storage in the Pot-in-pot evaporative cooler system and Metal-in-pot evaporative cooler system. The banana and tomatoes in the refrigerator did not ripen but there was a noticeable colour change. Two varieties of tomatoes were used in the experiment; the round type. (*lycopersicon osculentorm*) and elongated type (*lycopersicum lycopersicon).* The round type started ripening on the 17th and 18th day of storage for the Pot-in-pot evaporative cooler system and Metal-in-pot evaporative cooler system respectively. While ripening started on the 7th day in the control experiment.

In the other variety (elongated type), ripening started on the 3rd day of storage for those in the control experiment while it occurred on the 8th day for those in the pot-in-pot evaporative cooler system and Metal-in-pot evaporative cooler system.

Rotting

The advancement in the process of ripening and senescence of Fruits is rotting or decaying and softening of the Fruits.

Bananas in the pot-in-pot ECS and metal-in-pot ECS started rotting on the 10^{th} day of storage in the control experiment.

The round type of tomatoes stored in Metal-in-pot evaporative cooler system and pot-in-pot evaporative cooler system started decaying at 14th and 18th day of storage respectively.

While tomatoes stored in the control experiment started rotting on the 11th day of the storage period.

For the elongated type of tomatoes, rotting had started since the 7th day of storage in the control experiment while the tomatoes started rotting on the 9th day for the Pot-in-pot evaporative cooler system and Metal-in-pot evaporative cooler system.

Rotting occurred in the Okra inside the Pot-in-pot evaporative cooler system and Metal-in-pot evaporative cooler system because they are always cool. This started on the 8th day of storage for the Pot-in-pot evaporative cooler system and 10th day for the metal-in-pot evaporative cooler system.

For the leafy vegetables, Lettuce and spinach rotting started on the 7^{th} day and 9th day of storage for Pot-in-pot evaporative cooler system and Metal-in-pot evaporative cooler system, banana and tomato stored in the control experiment started rotting on the 5th and 7th days of storage.

4.2.2 Shriveling

Hawkins (1984) described shriveling as shrink and wrinkle as a result of great heat or cold or lack of moisture. However, N.S.P.R.I (1990) confirmed that transpiration is loss of water from fresh Fruits and vegetables especially lettuce. Shriveling occurs due to transpiration mostly in leafy vegetables, this results in high weight loss and high loss in nutritive value.

In the control experiment, shriveling occurred on the 2nd day of storage for the lettuce and spinach. While others in the evaporative cooler system did not experience shriveling at all, this was because of high moisture in the evaporative cooler system the system evaporative cooler system. Shriveling occurred on the 3rd day of storage for Okra, lettuce spinach stored in the refrigerator, this was because of low relative humility and low temperature.

Table 4.3 Visual observations for ripening, rotting, shriveling, color changes and drying in Pot-in-pot

VISUAL OBSERVATION	CROPS BANANA	(A) TOMATO	OKRA	SPINACH	LETTUCE	(B) TOMATO
I	8	8	-	-	-	17
II	10	9	8	7	7	18
III	-	-	-	-	-	-
IV	-	-	-	7	7	-
V	-	-	-	-	-	-

Table 4.3.1 Visual observations for ripening, rotting, shriveling, color changes and drying in Metal-in-pot

VISUAL OBSERVATION	CROPS BANANA	(A) TOMATO	OKRA	SPINACH	LETTUCE	(B) TOMATO
I	8	8	-	-	-	15
II	10	9	10	9	9	18
III	-	-	-	-	-	-
IV	-	-	-	7	7	-
V	-	-	-	-	-	-

Table 4.3.2. Visual observations for ripening, rotting, shriveling, color changes and drying in Refrigerator.

VISUAL OBSERVATION	CROPS					
	BANANA	(A) TOMATO	OKRA	SPINACH	LETTUCE	(B) TOMATO
I	-	-	-	-	-	-
II	-	-	-	-	-	-
III	-	-	3	3	3	-
IV	-	-	3	-	-	-
V	-	-	3	2	2	-

Table 4.3.3. Visual observations for ripening, rotting, shriveling, color changes and drying in Control experiment.

VISUAL OBSERVATION	CROPS					
	BANANA	(A) TOMATO	OKRA	SPINACH	LETTUCE	(B) TOMATO
I	3	3	-	-	-	7
II	5	7	-	-	-	11
III	-	-	-	2	2	-
IV	-	-	-	3	3	-
V	-	-	3	2	2	-

NOTE: TOMATO (A) REP. ELONGATED (LYCOPERSICUM LYCOPERSION)
TOMATO (B) REP: ROUND TYPE (LYCOPERSICUM OSCULENTORM)

VISUAL OBSERVATION:

I Stands for duration of days before ripening occurs

II Stands for duration of days before rotting occurs

III Stands for duration of days before shriveling occurs

IV Stands for duration of days before color changes occurs

V Stands for duration of days before drying occurs

4.2.3 Weight Losses

To quantify the degree of deterioration of the, stored, the weight of each crop was measured on daily basis. The result showed that the weight loss is directly proportional to the storage period. However, the weight loss still depends on the storage medium.

From Tables 4.4 to 4.9, the control experiment had the highest weight loss, followed by that in the Refrigerator, Pot-in-pot evaporative cooler system and the least in Metal-in-pot evaporative cooler system. The only peculiarity was in round type where it had the leant weight loss in Pot-in-pot evaporative cooler system.

Comparing the type of crops, the lettuce and spinach had the highest weight losses while the tomatoes had the least

Table 4.4 Percentage loss in weight of banana during storage

DATE	POT-IN-POT ECS WEIGHT LOSS (%)	METAL-IN-POT ECS WEIGHT LOSS (%)	REFRIGERATOR WEIGHT LOSS (%)	CONTROL EXPERIMENT WEIGHT LOSS (%)
25/11/2009	0	0	0	0
26/11/2009	0.3	0.9	1	2
27/11/2009	2	2	2	5
28/11/2009	3	3	3	9
29/11/2009	5	5	7	19
30/11/2009	6	6	8	23
1/12/2009	7	7	10	27
2/12/2009	8	8	11	30
3/12/2009	8	9	12	33
4/12/2009	9	11	15	35
5/12/2009	11	13	17	37
6/12/2009	11	14	18	39

'able 4.5 Percentage loss in weight of lettuce (lactuca sativa)

DATE	POT-IN-POT ECS WEIGHT LOSS (%)	METAL-INPOT ECS WEIGHT LOSS (%)	REFRIGERATOR WEIGHT LOSS (%)	CONTROL EXP. WEIGHT LOSS (%)
25/11/2009	0	0	0	0
26/11/2009	19	9	25	20
27/11/2009	28	11	37	31
28/11/2009	34	16	49	46
29/11/2009	42	25	79	76
30/11/2009	43	29	81	76
1/12/2009	45	33	83	78
2/12/2009	47	39	85	78

Table 4.6 Percentage loss in weight of spinach (spinach oleracea)

DATE	POT-IN-POT ECS WEIGHT LOSS (%)	METAL-INPOT ECS WEIGHT LOSS (%)	REFRIGERATOR WEIGHT LOSS (%)	CONTROL EXP. WEIGHT LOSS (%)
25/11/2009	0	0	0	0
26/11/2009	24	6	27	17
27/11/2009	30	13	55	48
28/11/2009	34	22	71	76
29/11/2009	56	38	84	86
30/11/2009	56	45	84	88
1/12/2009	57	50	87	92
2/12/2009	59	56	89	93

Table 4.7 **Percentage loss in weight of okra**

	POT-IN-POT ECS WEIGHT LOSS (%)	METAL-INPOT ECS WEIGHT LOSS (%)	REFRIGERATOR WEIGHT LOSS (%)	CONTROL EXP. WEIGHT LOSS (%)
25/11/2009	0	0	0	0
26/11/2009	15	7	23	26
27/11/2009	23	9	32	51
28/11/2009	32	13	51	62
29/11/2009	34	17	56	63
30/11/2009	35	19	58	65
1/12/2009	36	22	61	68
2/12/2009	38	25	63	70

Table 4.8 Percentage loss in weight of tomato (A)

DATE	POT-IN-POT ECS WEIGHT LOSS (%)	METAL-INPOT ECS WEIGHT LOSS(%)	REFRIGERATOR WEIGHT LOSS (%)	CONTROL EXP. WEIGHT LOSS (%)
25/11/2009	0	0	0	0
26/11/2009	0.6	0.4	0.3	1.3
27/11/2009	1	0.6	1.1	1.9
28/11/2009	2	0.9	1.6	3
29/11/2009	3	1.2	3.2	8.2
30/11/2009	5	1.4	3.9	13
1/12/2009	6	1.5	4.5	12.5
2/12/2009	8	1.9	5	17
3/12/2009	9	2.3	5.7	20
4/12/2009	11	2.5	7.3	24
5/12/2009	14	2.6	8.1	24
6/12/2009	14	2.9	8.8	26
7/12/2009	16	2.9	9.2	27
8/12/2009	18	3.1	9.8	28
9/12/2009	19	3.1	12	28
10/12/2009	19	3.2	12	30

Table 4.9 Percentage loss in weight of tomato (b)

DATE	POT-IN-POT ECS WEIGHT LOSS (%)	METAL-INPOT ECS WEIGHT LOSS (%)	REFRIGERATOR WEIGHT LOSS (%)	CONTROL EXP. WEIGHT LOSS (%)
25/11/2009	0.0	0	0	0
26/11/2009	0.4	0.6	0.1	0.4
27/11/2009	0.6	1.5	0.7	1.0
28/11/2009	0.9	1.7	0.7	1.9
29/11/2009	1.1	1.7	1.7	2.5
30/11/2009	1.4	2.2	2.3	3.2
1/12/2009	1.4	2.2	2.4	3.4
2/12/2009	1.4	2.6	2.4	4.0
3/12/2009	1.6	2.6	2.7	4.5
4/12/2009	1.7	2.8	3.6	5.5
5/12/2009	1.8	3.2	4.1	6.0
6/12/2009	2.0	3.7	4.7	6.2
7/12/2009	2.0	4.4	5.3	6.3
8/12/2009	2.5	5.2	6.1	6.6
9/12/2009	3.2	6.7	8.4	6.6
10/12/2009	3.2	7.4	9.0	6.9

4.2.4 Color Changes

The color changes can be attributed to ripening and rotting as the case of banana and tomatoes which was yellow and red respectively. There were other color changes observed during the storage period not due to ripening or rotting. This color changes occurred on the banana stored inside the refrigerator. The color turned brownish black on the 4th day of storage and gradually increased.

Furthermore, black patches (color) were observed on the Okra kept inside the refrigerator on the 3rd day of storage.

The lettuce and spinach in the control experiment turned yellow in color on the 3rd day of storage due to loss of chlorophyll. However, change in color of the vegetable did not occur in the Pot-in-pot and Metal-in-pot evaporative cooler system respectively.

Loss of chlorophyll was a visible sign that the vegetable has been stored too long, and hence used as an index of acceptability (Burton, 1982).

4.2.5 Chilling Injury

This occurred in the crops kept in the refrigerator due to low temperature of 8^0C. The banana and tomatoes started experiencing chilling injury from the 2nd day of storage.

4.2.6 Drying Injury

Drying injury occurred in the vegetable stores inside the refrigerator. The Okra, lettuce and spinach became dehydrated and eventually dried up. The loss in the moisture content can be explained from the high percentage weight losses of spinach and lettuce which are 55% on the 3rd day and 49% on the 4th day of storage respectively. Drying started in the refrigerator for Okra, Lettuce and spinach on the 2nd, 3rd and the 4th day of storage respectively.

4.3 Factors affecting the storability of the crops in the storage systems

There are four main factors that affects the physiology of the Fruits and vegetables stored in each of the systems.

The factors are:

(i) Duration of storage of the Fruits and vegetable

(ii) Temperature of the storage systems

(iii) Relative humidity of the storage systems

(iv) Types of crops stored.

4.3.1 Effect Of Duration Of Storage On The Crops Stored

Weight losses increase with increase in number of days of storage. Other physiology changes like shriveling, rotting, drying and color increase as number of days increases. Therefore, the higher the number of days the lower the quality of the stored crops, and the higher the weight losses.

Table 4.10 shows the number of days for which the crops were stored and they still maintained their values.

Table 4.10 Effect of duration of storage on the quality of crops stored

CROP	DAYS OF STORAGE POT-IN-POT ECS	METAL-INPOT ECS	REFRIGERATOR	CONTROL EXP
BANANA	9	9	7	4
TOMATO (A)	9	10	15	4
TOMATO (B)	19	16	15	8
OKRA	4	8	2	2
LETTUCE	4	7	2	2
SPINACH	4	7	2	2

4.3.2 Effect of Temperature on crops stored in the storage systems

From Table 4.1, there was reduction in temperature of about 4.5^0 C to 6.5^0 C and 4^0 C to 6^0 C in the pot-in-pot ECS and metal in pot evaporative cooler system respectively compared with temperature of the control experiment. Furthermore, from Table 4.4 to 4.9 and Figures 4.4 to 4.9 it can be seen that the crops stored in the evaporation cooler structure (which have lower temperature) had the least weight losses and was best when observed visually, while those in the control experiment were the worst.

In contrast, the average temperature of the refrigerator ranges between 8.5^0 C to 17^0 C that is 14^0 C to 16^0 C lower than that of the control experiment. The crops was not as good as those stored in the evaporative coolers.

Coursey (1976) stated that the lower the temperature the lower the respiration in storage system, but this cannot be extended too far to about 10^0 C, because most tropical Fruits will suffer chilling. However, Adegboyega (1990) confirmed that most tropical Fruits and vegetables suffer various kinds of breakdown at the temperature well above normal cold storage temperatures – sometimes as high as 10^0 C or 12^0 C, the Fruits and vegetables tend to loose freshness and flavor when stored in the refrigerator despite the fact that refrigerators are not available to rural dwellers.

4.3.3 Effect of relative humidity of storage systems of the crops stored

N.S.P.R.I, (1990) proclaimed that high relative humidity was necessary for Fruits and vegetables storage.

From Table 4.2 the average relative humidity of the evaporative cooler structure ranges from 76% to 88% while that of the control experiment ranges from 37.5 to 73.5%. From tables 4.4 to 4.9 and figures 4.4. to 4.9, the crops stored in the evaporation coolers were found to have the least weight and best by visual observation. Therefore, the low relative humidity as low as 37.5% of the control experiment caused rapid deterioration of the stored there.

The average relative humidity of the refrigerator was in the range of 55.5%. it shows that the crops stored were still better than those in the control experiment but not as good as those in the evaporative cooler facilities.

4.3.4 Effect of types of crops based on their storability

It was obvious from the result of percentage weight lose on Table 4.9 that the type of crops affect the percentage weight loss of the stored crops. The lettuce – *lactuca sative* and spinach according to N.S.P.R.I (1990) were classified as high perishable commodities due to their high water content.

These losses greater percentage of their weight within few days of storage unlike other crops stored in the same medium. Lettuce lost 20% of its weight and spinach 17% of its weight just on the second day of storage in the control experiment while Banana lost only 2% of its weight on the same day within the same storage environment.

The spinach lettuce and Okra dried up quickly inside the refrigerator due to dehydration and lost about or even half of the total weight within four days of storage while the other crops lost relatively lower percentage of their weight.

The tomatoes in the storage systems only lost small percentage of their weight. Even though tomatoes contained high percentage of water in composition, water did not dehydrate quickly from its surface as aforementioned crops.

CHAPTER FIVE

5.0 RECOMMENDATIONS AND CONCLUSIONS

5.1 Conclusion

From the experimental results, the evaporative cooler structures stored mature banana for 9 days in fresh and acceptable form while the control experiment could only store them for days. Okra was stored for 8 days, while spinach and lettuce were both stored for 7 days inside the metal-in-pot evaporation cooler structures. Tomatoes (local type) were stored for 19 and 16 days respectively inside the Pot-in-pot evaporative cooler system and Metal-in-pot evaporative cooler system.

From the results, it was re-affirmed that these evaporative cooler facility have low temperature and high relative humidity. Therefore, low temperature of 20^0 C to 27^0 C and high relative humidity of 76 to 88% are proper for extending the shelve lives of fresh Fruits and vegetables.

In the refrigerator, chilling injuries, drying or dehydration, shriveling and color changes were noticed in stored crops. The bananas and tomatoes changed to black while the lettuce-*lactuca sativa* spinach and Okra were dehydrated. This implies that too low temperature of 8.5^0 C to 17^0 C and low relative humidity of 55.5% to 73% are not suitable for fresh Fruits and vegetable.

There was rapid deterioration of Fruits and vegetables stored in the control experiment implying that local atmosphere i.e conditions of temperature ranging between 24.5^0 C to 30.5^0 C and relative humidity of 37.5 to 73% are not suitable for storing fresh Fruits and Vegetables.

5.2 RECOMMENDATIONS

1. Fresh Fruits and Vegetables should be harvested when they are mature but not ripe; and harvesting, handling and transportation should be done with utmost care to prevent mechanical damage to the crops.

2. Fresh Fruits and Vegetables should be stored in evaporative coolant structures either Pot-in-pot evaporative cooler system or Metal-in-pot evaporative cooler system for proper storage, most especially by rural farmers because, they are relatively cheaper, easy to construct and can preserve the Fruits and vegetables for longer period than any other known systems.

3. Investigative work should be done to see the possibility of increasing the relative humidity of the refrigerator so as to be able to store Fruits and vegetables more effectively. Also, the reason(s) for color change and lose of flavors of Fruits and vegetables stored in the refrigerator should be investigated so as to make necessary corrections.

REFERENCES

American Society Agricultural Engineers (ASAE) handbook (1987)

Bathasar Van Der Ast (2004) Agronomy of Fruits and Vegetables

Donald Q. Kern (1989). Process heat transfer. Pp 795.797

Hall, E.G. (1973) Mixed Storage of Foodstuff C.S.I.R.O. Division of Food Research Circular No.9

Hawcine (1984) Physiology of Crops Under Storage

Nigeria Stored Product Research Institute Briefs (1986)

Nigerian Stored Product Research Institute Briefs (1990).

Norman, WD (1977) Element of food Technology. AV1 Publishing Company inc. West Point Connecticut. Pp 7-20, 219-246

Opadakun, J.S (1987) Proceedings of Natural Crop Production on food crop storage. AERIS A.B.U. Zaria (1987)

Robertson, P.E and Creech (1984) consideration for harvesting and storage of Vegetables and Fruits in Guatemala high lands. Prepared for U.S. Agency for international development Guatemala. Report No.pp/Guatemala/Oct. Nov.84/No. 52. University of Idaho. 19.

Rustan (1985) Curing of Fruits and Vegetables

U.S Department of Agriculture, Agricultural Research Service (2005) Physical Characteristics of Fruits and Vegetables.

Wikipedia (2004) the need for better storage system for Fruits and vegetables.

William A.A. (1982) scoring methods in sensory analysis of food and beverages at long Aston research station. Journal of Food Technology. pp 17, 163-175

Williams (1993) quality in stored and processed vegetables and Fruits. Academic press Incorporation Limited London pp-17

APPENDIX (i)

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

$K=BTU/(hr)(ft^2)(^0F/f)$

ubstance	Temp. ^0F	K*	Specific heat Btu (1b) (^0F)	Specific gravity
luminum	32	117	0.0183	2.555-7.8
"	212	119	0.1824	
"	932	115	0.1872	
Cast iron	32	32	0.1064	7.03-7.13
"	212	30	0.117	
Vrought iron	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). Pp795-797.

APPENDIX (ii)

/N	Commodity	Temp- (⁰c)	R.H (⁰c)	Period	Highest freezing point (⁰c)	Water Content
	Beans green snap	4 - 7	90-95	7-10 days	-0.7	88.9
	Bens lima	0-4	90	1-2 wks	-0.56	66.5
	Asparagus	0-2	95	2-3 wks	-0.6	93.0
	Cabbage (early)	0	90-95	2-6 wks	-0.89	92.4
	Cabbage (late)	0	90-95	3-4- months	0-89	92.4
	Beets bunched	0	95	10-14 days	-0.39	-
	Beets topped	0	95	3-5 months	-0.95	87.6
	Carrot, mature (tapped)	0	90-95	4-5 months	-1.4	88.2
	Carrot immature (tapped)	0	90-95	4-6 months	-1.4	88.2
0	Corn sweet	0	90-95	4-8 days	-0.6	73.9
1	Cucumbers	7-10	90-95	10-14 days	-0.5	96.1
2	Egg plants	7-10	90	1 wk	-0.78	92.7
3	Ginger shizomes	13	65	6 months	-	87.0
4	Greens leafy	0	90-95	10-14 days	-	
5	Lettue	0	95	2-3 wks	-0.17	94.8
6	Watermelon	4-10	80-85	2-3 wks	-0.39	92.6
7	Okra	7-10	90-95	7-10 days	-1.8	89.8
8	Onion (dry)	0	65-70	1-8 months	-0.78	87.5
9	Onion (green)	0	90-95	-	-0.9	89.4
0	Potatoes	-	90	-	-0.6	81.2
1	Pumpkins	10-13	70-75	2-3 months	0.83	90.5
2	Tomatoes firm-ripe	4-7	85-95	4-7 days	-0.5	94.7

Appendix (ii) 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 (iii)

S/N	CROP	OPTIMUM STORAGE TEMPERATURE (^0C)	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	Pineapple	10	2-4
12	Tomato (Coloured)	7-10	1-2
13	Tomato (Mature green)	12	3-6

Appendix iii

Shows the optimum storage temperature and shelf life Fruits (Hall 1973)

APPENDIX iv

Table of wet and dry bulb thermometer reading with corresponding percentages of humidity

CELSIUS SCALE

Dry bulb	DEPRESSION OF WET – BULB ^0C													
	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	7.0
-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	8
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	87	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	88	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	89	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	90	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	91	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	52
30	96	92	89	85	82	78	75	72	68	65	62	59	56	53
32	96	93	89	86	82	79	76	73	70	67	64	61	58	55
34	96	93	89	86	83	80	77	74	71	68	65	62	59	56
36	96	93	90	87	84	81	78	75	72	69	66	63	61	58
38	96	93	90	87	84	81	78	75	73	70	67	64	62	59
40	96	94	91	88	85	82	79	76	74	71	62	66	63	61
42	97	94	91	88	85	82	80	77	75	72	70	67	65	62
44	97	94	91	88	86	83	81	78	75	72	7	67	65	63
46	97	94	91	89	86	83	81	78	76	73	71	68	66	64
48	97	95	92	89	86	83	81	78	76	74	72	69	67	65
50	97	95	92	89	87	84	82	79	77	74	72	70	68	65
52	97	95	92	89	87	84	82	79	77	75	73	70	68	66
54	97	95	93	90	87	85	83	80	78	75	73	71	69	67
56	97	95	93	90	87	85	83	80	78	76	74	71	69	67
58	97	95	93	90	87	85	83	81	78	76	74	72	70	68
60	98	96	93	90	87	85	83	81	79	77	75	72	70	68

CELSIUS SCALE

Dry bulb	DEPRESSION OF WET – BULB ^{0}C												Dry Bulb
	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	28	21	17	12	8	4							15
16	30	24	19	15	11	7							16
17	32	26	22	18	14	10	3						17
18	34	28	24	21	17	13	6						18
19	36	30	27	23	19	16	9	2					19
20	38	32	29	25	22	18	11	5					20
21	40	34	31	27	24	20	14	7	1				21
22	41	36	33	29	26	23	16	10	4				22
23	43	38	34	31	28	25	18	12	6	1			23
24	44	39	36	33	30	27	20	15	9	3			24
25	45	41	38	35	31	28	22	17	11	6	1		25
26	47	42	39	36	33	30	24	19	13	8	3		26
27	48	44	41	38	35	32	26	21	15	10	5	1	27
28	49	45	42	39	36	33	28	23	17	12	8	3	28
29	50	46	43	40	37	35	29	24	19	14	10	5	29
30	52	47	44	42	39	36	31	26	21	16	12	7	30
32	54	49	46	44	41	39	34	29	24	20	15	11	32
34	55	51	48	46	43	41	36	32	27	23	19	15	34
36	57	53	50	48	45	43	38	34	30	26	22	18	36
38	58	54	52	50	47	45	40	36	32	28	24	20	38
40	60	56	53	51	49	47	42	38	34	30	27	23	40
42	61	57	55	52	50	48	44	40	36	32	29	25	42
44	62	58	56	54	52	50	46	42	38	34	31	27	44
46	63	59	57	55	53	51	47	43	39	36	33	29	46
48	63	60	58	56	54	52	48	44	41	37	34	31	48
50	64	61	59	57	55	53	49	45	42	38	36	32	50
52	65	62	60	58	56	54	50	47	43	39	37	34	52
54	66	63	61	59	57	55	51	48	44	40	38	35	54
56	66	64	62	60	58	56	52	49	45	41	38	37	56
58	67	65	63	61	59	57	53	50	46	42	40	38	58
60	69	67	64	62	60	58	54	51	47	43	41	39	60

Dry bulb	DEPRESSION OF WET – BULB ^{0}C													Dry Bulb
	17	18	19	20	21	22	23	24	25	26	27	28	29	
-1														-1
0														0
1														1
2														2
3														3
4														4
5														5
6														6
7														7
8														8
9														9
10														10
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25														25
26														26
27														27
28														28
29	1													29
30	3													30
32	7	3												32
34	11	7	3											34
36	14	10	7	3										36
38	17	13	10	7	4	1								38
40	20	16	13	10	7	4	1							40
42	22	19	16	13	10	7	4	2						42
44	24	21	18	15	12	10	7	4	1					44
46	26	23	20	18	15	12	10	8	5	3				46
48	28	25	22	20	17	14	12	10	8	5	1			48
50	29	27	24	21	19	16	14	12	9	7	3	1		50
52	30	28	26	23	21	18	16	14	11	9	5	3	1	52
54	31	30	27	25	22	20	18	15	13	11	7	5	3	54
56	32	32	29	27	24	21	19	17	15	13	9	7	5	56
58	33	33	30	28	25	23	21	19	17	15	11	9	7	58
60	34	34	32	29	27	25	23	20	18	16	13	11	9	60