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Predicting Storability of Fruits and Vegetables in Passive Evaporative Cooling Structures

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ABSTRACT

Post-harvest losses of fruits and vegetables in developing countries are mostly as a result of in proper storage facilities. While refrigerated cool-stores are the best method of preserving fruits and vegetables, they are expensive to buy and run. Consequently, in developing countries there is an interest in simple low-cost alternatives, many of which depends on evaporative cooling, which is simple and does not require any external power supply. Evaporative cooling occurs when air, that is not too humid, passes over a wet surface; the faster the rate of evaporation the greater the cooling. The efficiency of an evaporative cooling structure depends on the humidity of the surrounding air. Therefore, this paper reviews the concept, principles and methods of evaporative cooling for the preservation of fruits and vegetables. The evaporative cooling structures has prospect for use for short term preservation of fruits and vegetables after harvested. It reduces the storage temperature and also increases the relative humidity within the optimum level of the storage thereby helps in keeping the fruits and vegetables fresh.

Keywords: **Cooling, evaporative, predicting, structures, storability**

I. Introduction

Losses in post-harvest of fruits and vegetables in developing countries are mostly due to the in proper storage facilities. While refrigerated cool stores are the best method of preserving fruits and vegetables. They are expensive to buy and run. Consequently, in developing countries there is an interest in simple low-cost alternatives, many of which depend on evaporative cooling which is simple and does not require any external power supply (FAO, 1996).

The basic principle relies on cooling by evaporation. When water evaporates it draws energy from its surroundings which produce a considerable cooling effect. Evaporative cooling occurs when air, that is not too humid, passes over a wet surface; the faster the rate of evaporation the greater the cooling. The efficiency of an evaporative cooler depends on the humidity of the surrounding air. Very dry air can absorb a lot of moisture, so greater cooling occurs. In the extreme case of air that is totally saturated with water, no evaporation can take place and no cooling occurs. Generally, an evaporative cooling structure is made of a porous material that is fed with water. Hot dry air is drawn over the material. The water evaporates into the air raising its humidity and at the same time reducing the temperature of the air (FAO, 1995).

In Nigeria and other countries of the world vegetables and fruits are important food items that are widely consumed because they form an essential part of a balanced diet. Fruits and vegetables are important sources of minerals and vitamins especially A and C. They also provide carbohydrates and protein, which are needed for normal healthy growth (Abdul, 1989; Salunkhe and Kadam, 1995; Adetuyi et al., 2008; Olusunde et al., 2009).

In developing countries like Nigeria, agriculture constitutes the bulk of the informal sector of the economy. It is reported that among the various types of activities that can be termed as agriculturally based, fruit and vegetable processing are among the most important (FAO 1995). However, farmers are not getting enough value for their product due to weak infrastructure, poor transportation, and perishable nature of the crops, which result in substantial economic losses. During the post-harvest glut, the loss is considerable and often some of the produce has to be fed to animals or allowed to rot. According to Ndirika and Asota, (1994), the damage that occurs in some bio products is primarily by loss of moisture, change in composition and pathological attack.

An aspect to consider when handling fruits and vegetables is the temperature and relative humidity of the storage environment. For fresh harvested produce, any method aimed at increasing the relative humidity of the storage environment (or decreasing the vapour pressure deficit (VPD) between the commodity and its environment) will slow the rate of water loss and other metabolic activities (Katsoulas et al., 2001). This will slow both the respiratory processes and activities of micro-organisms (pathogens) which are the most destructive activity during storage of fruits and vegetables (Barre et al, 1988).

Although, refrigeration is very popular but it has been observed that several fruits and vegetables, for example banana, plantain, tomato etc. cannot be stored in the domestic refrigerator for a long period as they are susceptible to chilling injury (Shewfelt, 1994; Olusunde et al., 2009). Apart from this, the epileptic power supply and low income of farmers in the rural communities' makes refrigeration expensive.

FAO (1983) advocated a low cost storage system based on the principle of evaporative cooling for storage of fruits and vegetables, which is simple, and relatively efficient. The basic principle relies on cooling by evaporation. However, sometimes when evaporative cooling system is used in preservation, it is used with shade on top (Kittas et al., 2003).

Different designs of evaporative coolers have been reported in literature for the preservation of fruits and vegetables (Redulla, 1984a; FAO 1986; Roy 1989; Thompson and Scheureman 1993; Acedo 1997, Noble 2008). The design ranges from straw packing house to some sophisticated design. FAO (1986) reported that the packing houses of typical evaporative coolers are made from natural materials that can be moistened with water. Wetting the walls and roof first thing in the morning which is tedious creates conditions for evaporative cooling of the packing house. The major problem of these structures is the constructing material which deteriorates quickly and is susceptible to rodent attack.

Redulla (1984b) presented an evaporative cooler for preservation of fruit and vegetable which complements natural air with forced air to cool small lots of produce. Redulla (1984b) also showed some other evaporative cooler which he called drip coolers and can be constructed from simple material such as burlap and bamboo. They operate solely through the process of evaporation without the use of fan. These coolers are cumbersome and have the same problem of the packing house.

Acedo (1997) developed two simple evaporative coolers with jute bag and rice husk as the cooling pad in the Philippines for cooling and storage of vegetables. He prevented decay by washing the product first in the chlorinated water. Jain (2007) presented a two stage evaporative cooler for fruits and vegetable which incorporated a heat exchanger. This design is expensive but he could only achieve a storage life of 14 days for tomato. Anyanwu (2004) developed a porous wall (pot in pot) evaporative cooler for preservation of fruits and vegetables. He got a storage life of less than four days (93hours) on tomato. In this research work, an evaporative cooler with locally sourced materials for the construction was developed and evaluated. The evaporative cooler fabricated with mud (clay) directly excavated from the swamp is not electricity dependent will help farmers and marketers of fruits and vegetables to be able to store and preserve efficiently their products.

II. Advances in Evaporative Cooling Technology

Vakis, (1981) developed a cheap cool store in Kenya, with the help of local grass for storage of vegetables. He kept the roof and walls wet by dripping water from the top of the roof. Evaporative coolers, which rely on wind pressures to force air through wet pads, have also been designed and constructed, especially in some developing countries like India, China and Nigeria (FAO, 1986).

Construction of various evaporative systems was done by Rusten, (1985) using available materials as absorbent (pads). Materials used include canvas, jute curtains and hourdis clay blocks. Also a mechanical fan was introduced to some of the coolers constructed.

Rusten, (1985) did an extensive research in the construction of different evaporative cooling systems using locally available absorbent materials such as canvas, jute curtains, etc. Mechanical fans were used in some of the designs which drew air through a continuously wetted pad. The continuous wetting of the pad was achieved by placing elevated water basins on the fabric material, which absorbed the water gradually and eventually got saturated. He described the functionality of a hourdis clay block coolers which was constructed by two researchers.

Alebiowu, (1985) worked on the development of hexagonal wooden evaporative cooling systems and the system could be sub-divided into three parts head tank and pipe lines work ,the through and the frame work made of woods and its adjoints. The pipe line works at the top of the hexagonal frame supplied water constantly to wet the pad which is made of jute fibre. Wind pressure forced the air through the wetted jute pad. Limitation of this design is that the sufficiency of the evaporative cooler depends on wind velocity FAO/SIDA (1986). Roy and Khurdiya, (1986) constructed an evaporative cooled structure for storage of fruits and vegetables with a double wall made of baked bricks and the top of the storage space covered with *khaskhas*/gunny cloth in a bamboo framed structure.

Abdalla and Abdalla, (1995) worked on the development of a fan driven evaporative cooler. The research was study the suitability of using palm leaves as a wetted medium. This research was made possible due to the availability of palm leaves in Saudi Arabia. According to the research it was claimed that palm leaves could be used as the wetted media which is locally available to the masses.

Sanni, (1999) did a research on the development of evaporative cooling system on the storage of vegetable crops .The major development was implemented by adding a regulated fan speed, water flow rate and wetted-thickness .This was possible as a result of varying temperature and relative humidity within the facility.

Dzivama, (2000) did a research on the performance evaluation of an active cooling system using the principles of evaporative cooling for the storage of fruits and vegetables. He developed mathematical models for the evaporative process at the pad-end and the storage chamber and a stem variety of sponge was considered to be the best pad material from the local materials tested as pad material.

Mordi and Olorunda, (2003) in their study on storage of tomatoes in Evaporative cooler environment reported a drop of 8.2°c from ambient condition of 33°c while the relative humidity increased by 36.6% over an ambient 60.4%. They further reported storage life of unpacked fresh tomatoes in evaporative cooler environment as 11 days from the 4 days. Storage life under ambient conditions while in combination with sealed but perforated polyethylene bags; it was 18 days and 13 days respectively.

Olosunde, (2006) also did a research on the performance evaluation of absorbent, materials in evaporative cooling system for the storage of fruits and vegetables. Three materials were selected to be used as pad materials: jute, Hessian and cotton waste. The design implemented a centrifugal fan, high density polystyrene plastic, Plywood used as covering for the walls and basement and the top and the main body frame was made of thick wood. The performance criteria included the cooling efficiency, amount of heat load removed and the quality assessments of stored products. The result showed that the jute material had the overall advantage over the other materials. The cooling efficiency could be increased if two sides were padded.

Sushmita et al., (2008) did a research on Comparative Study on Storage of Fruits and Vegetables in Evaporative Cool Chamber and in Ambient. An evaporative cool chamber was constructed with the help of baked bricks and riverbed sand. It was recorded that weight loss of fruits and vegetables kept inside the chamber was lower than those stored outside the chamber. The fruits and vegetables were fresh up to 3 to 5 days more inside the chamber than outside.

III. Factors Affecting the Shelf Life of Fruits and Vegetables

There are various factors that do affect the shelf life of fruits and vegetables which would lead to their spoilage. The various factors include:
i) Ambient Condition
ii) Temperature
iii) Relative Humidity
iv) Variety and stage of ripening
2.3.1 Ambient Condition
The environmental condition has a great influence on the shelf life of fruits and vegetables and the factors can be sub-divided into temperature and relative humidity.

A. Temperature

Temperature is defined as the degree of hotness or coldness of a material. Temperature has a great influence on the shelf life on agricultural products. FAO, (1998) found that all produce are subject to damage when exposed to extreme temperatures which will lead to increase in their level of respiration. Also, it was further disclosed that agricultural products vary in their temperature tolerance.

Wilson et al., (1999) suggested that deterioration of fresh commodities can result from physiological breakdown due to natural ripening processes, water loss, temperature injury, physical damage, or invasion by microorganisms. All of these factors can interact, and all are influenced by temperature. He further said that exposure to alternating cold and warm temperatures may result in moisture accumulation on the surface of commodities (sweating), which may enhance decay development.

Gravani, (2008) observed that for every 18°F (-7.7°C) rise in temperature within the moderate temperature range (50°F-100°F)/(10°C-37.8°C) where most food is handled, the rate of chemical reactions is approximately doubled. As a result, excessive temperatures will increase the rate of natural food enzyme reactions and the reactions of other food constituents.

B. Relative Humidity

This is the measurement of the amount of water vapour in the air as a percentage of the maximum quantity that the air is capable of holding at a specific temperature. Mathematically it can be represented by

$$\text{Re}\,lative\ humidity = \frac{Actual\ vapour\ density}{Saturated\ vapour\ density}x100$$

It has a great effect on the deterioration of fruits and vegetable because it has a direct relationship with the moisture content in the atmosphere which determines whether the shelf life will not be exceeded. Bachmann and Earles, (2000) said that the relative humidity of the storage unit directly influences water loss in produce. Wilson et al., (1995) also said water loss means salable weight loss and reduced profit.

C. Variety and Stage ripening

Post-harvest operation does not stop the fruits and vegetables from respiring which if not controlled will lead to the over-ripening of the fruits which will lead to early deterioration. Depending on the stage the fruits are harvested, which in practice varies from mature green to fully ripened, the commodities have different storage conditions Olosunde, (2007).

IV. Factors accountable for deterioration in fruits and Vegetables

A. Physiological Activity

During post-harvest operation the fruits and vegetables still continue their normal physiological activities. Olosunde, (2006) disclosed that ripening transforms a physiological mature but inedible plant organ into a visually attractive and edible organ which marks the complete development of a fruit and the commencement of senescence, and it is normally and irreversible event. Major changes which do make up fruit ripening are : seed maturation, abscission, production of volatile compounds, development of wax on skin and changes in ;colour, respiration rate, rate of ethylene production, tissue permeability, composition of pectin and carbohydrates ,organic acids and protein (Pratt, 1975).

B. Pathological Infection

Pathogens are one of the major causes of deterioration of fruits and vegetables when they infest any food material they destroy and make it not pleasing to the sight. (Bachmann and Earles, 2000) disclosed that crops destined for storage should be as free as possible from skin breaks, bruises, spots, rots, decay, and other deterioration (Olosunde, 2006) also said that insects and pests can cause considerable damage of fruits and vegetables through either complete removal of the fruits or feeding on them, thus causing skin breaks which may facilitate entry of decay organism.

C. Mechanical Injuries

The injuries that are visible on fruits and vegetables are caused by mishandling or other cause which leads to cracks, bruises, cuts or abrasion which makes the produce not attractive and also less marketable. Aworh, (1988) disclosed that impact bruising of tomatoes results in higher respiration and ethylene production rates, increased damage and lower levels of titratable and ascorbic acid, which can alter taste and nutritive value. Olosunde, (2006) also disclosed that mechanical damage can also accelerate the rate of water loss from produce, bruising damages the surface organization of the tissue and allows a much greater flow of gaseous material through the damaged area.

D. Evaporation of Water

Evaporative loss from the surface of fruits and vegetable has an effect on the quality of the produce. The higher the rate of evaporation, the lower the moisture content and shelf life of the agricultural produce. (Olosunde, 2006) further said that weight loss results from moisture loss via evaporation of water from the tissues when the fruits and vegetables are attempting to be in equilibrium with the environment with the environment which is usually at lower water activity.

V. Post- Harvest Changes in Quality of Fruits and Vegetables

Changes do occur during post-harvest operations for fruits and vegetables which leads to decrease in their shelf life which it on the long run leads to decrease in the quantity supplied for consumption and for export market. Dzivama, (2000) described the common and notable changes that do occur during post-harvest in the quality of fruits and vegetables which include:

i Colour Change
ii Loss of weight
iii Change in the firmness.
iv Change in total soluble solids

A. Colour Change

Fruits ripening process continues even after harvesting which could be an important factor to be noted during post-harvest operations. Wilson et al., (2005) disclosed that immature or over mature produce may not last as long in storage as that picked at proper maturity.

Colour is the most obvious change that occurs in many fruits and vegetables and this a major criterion that most consumers uses to determine whether the fruit is ripe, unripe, overripe or spoiled and the assessment of colour change is done by comparing the colour of produce under investigation against a standard colour chart (Dzivama, 2000).

B. Loss of weight

Most fresh produce contains from 65 to 95 percent water when harvested (FAO, 1989). Water is an important constituent of most fruits and vegetables and it adds up to the total weight. Losses of water will definite reduce the weight. When the harvested produce loses 5 or 10% of its fresh weight, it begins to wilt and soon becomes unusable (FAO, 1989). The loss of weight comprises of both respiratory and evaporative losses. The former, which occurs as a result of respiration, depends mainly on the temperature of the surrounding air. The latter occurs as a result of water vapour deficit of the environment compared with that of the produce (Dennis, 1979). FAO, (1989) disclosed that the faster the surrounding air moves over fresh produce the quicker water is lost. Air movement through produce is essential to remove the heat of respiration, but the rate of movement must be kept as low as possible.

C. Fruit firmness

Ripening of fruits has a direct relationship with the fruit firmness and since respiration continues even after harvest the fruits have the tendency of become over-ripen. Dzivama,(2000) declared that as a result of continued chemical activity within the fruits tissues even after harvest after which it becomes over-ripe and soft which makes any factor that can slow down the rate of respiration will automatically slow down the fruit firmness change which can be achieved by storing at low temperature.

D. Change in total soluble solid

During ripening, carbohydrate are broken down into simpler unit particularly the conversion of starch to sugar ,giving the fruits its characteristics sweet taste on ripening and the degree of ripening can be measured by measuring the sugar content in an extracted fruit juice (Dzivama, 2000).

VI. Principles of Evaporative Cooling

A. Evaporative Cooling with Psychrometric Chart

According to Rusten, (1985) cooling through the evaporation of water is an ancient and effective way of cooling water. He further disclosed that this was the method been used by plant and animal to reduce their temperature. He gave the conditions at which evaporative cooling would take place which are stated below:

(1) Temperatures are high
(2) Humidity is Low
(3) Water can be spared for its use
(4) Air movement is available (from wind to electric fan)

Also he disclosed that the change of liquid stage to vapour requires the addition of energy or heat. The energy that is added to water to change it to vapour comes from the environment, thus making the environment cooler.

Therefore, the use of the psychrometric chart is of great importance in order to discover whether evaporative cooling has taken place. Air conditions can be quickly characterized by using a special graph called a psychrometric chart. Properties on the chart include dry-bulb and wet-bulb temperatures, relative humidity, humidity ratio, specific volume, dew point temperature, and enthalpy Beiler, (2009).

When considering water evaporating into air, the wet-bulb temperature, as compared to the air's dry-bulb temperature is a measure of the potential for evaporative cooling. The greater the difference between the two temperatures, the greater the evaporative cooling effect. When the temperatures are the same, no net evaporation of water in air occurs, thus there is no cooling effect (Wikipedia.com).

Therefore for optimum cooling efficiency using the evaporative cooling technique temperature and the relative humidity measurement is needed to be taken and the psychrometric chart defines these variables at various stages.

B. Factors Affecting Rate of Evaporation

Evaporative cooling results in reduction of temperature an increase in relative humidity (Olosunde, 2006).It is necessary to understand the factors that can limit the efficiency of the system from producing the intended results. There are four major factors that affect the rate of evaporation which was analysed by (Rusten, 1985). He later added that though they are discussed separately but it is important to keep in mind that they all interact with each other to influence the overall rate of evaporation, and therefore the rate of cooling. The factors discussed by (Rusten, 1985) include:

(1) Air Temperatures:

Evaporation occurs when water is absorbs sufficient energy to change from liquid to gas. Air with a relatively high temperature will be able to stimulate the evaporative process and also be capable of holding a great quantity of water vapour. Therefore, areas with high temperatures will have a high rate of evaporation and more cooling will occur. With lower temperature, less water vapour can be held and less evaporation and cooling will take place.

(2) Air Movement (Velocity)

Air movement either natural (wind) or artificial (fan) is an important factor that influences the rate of evaporation. As water evaporates from wet surface, it raises the humidity of the air that is closest to the water surface (moist area) .If the humid air remains in place, the rate of evaporation will start to slow down as the humidity rises. On the other hand if the humid air near the water surface is constantly being moved away and replaced with drier air, the rate of evaporation will either increase or remain constant.

(3) Surface Area

The area of the evaporating surface is another important factor that affects the rate of evaporation. The greater the surface area from which the water evaporates, the greater the rate of evaporation.

(4) Relative Humidity of the Air

This is the measurement of the amount of water vapour in the air as a percentage of the maximum quantity that the air is capable of holding at a specific temperature. When the relative humidity of the air is low, this means that only a portion of the total quantity of water which the air is capable of holding is being held. Under this condition, the air is capable of taking additional moisture, hence with all other conditions favourable, the rate of evaporation will be higher, and thus the efficiency of the evaporative cooling system is expected to be higher.

VII. Methods of Evaporative Cooling

Rusten, 1985 specified that there are two main methods of evaporative cooling namely:

(1) Direct evaporative cooling (2) Indirect evaporative cooling

(1) Direct Evaporative Cooling

This is a method by which air is passed through a media that is flooded with water .The latent heat associated with the vaporizing of the water cools and humidifies the air streams which now allows the moist and cool air to move to its intended direction. (Sellers, 2004) Sanjeev, (2008) disclosed that direct evaporative cooling has the following major limitations:

1) The increase in humidity of air may be undesirable.

2) The lowest temperature obtainable is the wet-bulb temperature of the outside air,

3) The high concentration and precipitation of salts in water deposit on the pads and the other parts, which causes blockage, and corrosion, and requires frequent cleaning, replacement, and servicing.

(2) Indirect Evaporative cooling:

A heat exchanger is combined with an evaporative cooler and the common approach used is the passes return/exhaust air through an evaporative cooling process and then to an air-to air heat exchanger which in turn cools the air, another approach is the use of a cooling tower to evaporatively cool a water circuit through a coil to a cool air stream (Sellers, 2004).

Sanjeev, (2008) also said indirect cooling differs from direct cooling in the sense that in indirect cooling the process air cools by the evaporation of water. But there is no direct contact of water and process air. Instead a secondary airstream is used for evaporation of water. So the moisture content of process air remains the same

Forms of Direct Evaporative Cooling

Dzivama, (2000) did a study on the forms of evaporative cooling process and discovered that there are two forms in which the evaporative cooling principle can be applied. The difference is based on the means of providing the air movement across/through the moist materials .These is the passive and non-passive forms. The passive form of evaporative cooling relies on the natural wind velocity, to provide the means of air movement across/through the moist surface to effect evaporation. This form can be constructed on the farm, for short term on farm storage while the non- passive form uses a fan to provide air movement.

A. Passive-direct evaporative cooling system

Construction and design varies but the general principles are the same. The main components include:

i) The cabinets where the produce is stored.

ii) The absorbent material used to expose the water to the moving air

iii) An overhead tank/through through which the water seeps down on to and wet the absorbent material. The absorbent material covering the cabinet absorbs water from the tank on top of the cabinets, the entire cloth that was used as cabinet is soaked in water and the air moves past the wet cloth and evaporation occurs. As long as evaporation takes place, the contents of the cabinet will kept at a temperature lower than that of the environment and the temperature reduction obtained in this type of cooler ranged from 5°C to 10°C. Different researches have been done by researches names like Rusten, (1985), Susanta and Khurdiya, (1986), Olosunde, (2007), Sushmita et al., (2008) have designed various forms of coolers.

B. Non- passive direct evaporative cooling system

This uses a small fan, a water pump which is powered by electricity. The products are kept in storage cabins inside the coolers, Absorbent material which receives the water and expose it to evaporation with the help of the fan which draws air through the pad and a overhead tank which is constantly supplying water to the absorbent material. Materials used as the absorbent materials are hessian materials, cotton waste and celdek and the body frame is made of wood. The pad and the fan are directly opposite to each other.

VIII. Conclusion

The evaporative cooling structures has prospect for use for short term preservation of fruits and vegetables after harvested. It reduces the storage temperature and also increases the relative humidity of the storage thereby helps in keeping the fruits and vegetables fresh.

REFERENCES

i. *Abdalla, K.N. and Abdalla, A.M. (1995). Utilization of Date Palm Leaves and Fibres as Wetted Pads in Evaporative Coolers. Agricultural Mechanization in Asia Africa and Latin America Vol. 26 26(2), Pp 52-54*

ii. *Abdul A.K (1989). Postharvest losses during processing and preservation of fruits and vegetables. A PhD thesis submitted to University of Punjab Pakistan*

iii. *Acedo, A.L.(1997). Storage life of vegetables in simple evaporative coolers. Tropical Science37:169-175.*

iv. *Adetuyi ,F.O. , T.A. Ayileye and I.B.O. Dada .(2008) Comparative Study of Quality Changes in Shea Butter Coated Pawpaw Carica papaya fruit during Storage Pakistan Journal of Nutrition 7 (5): 658-662, 2008*

v. *Ajibola, O.O. (1991). Storage Facilities and Requirements for Fruits and Vegetables. Paper presented at the Nigeria Society of Engineers Course on Designing, Construction and Maintenance of Food Storage System. Pp. 9-*

vi. *Anyanwu E.E; (2004). Design and measured performance of a porous evaporative cooler for preservation of fruits and vegetables, Energy Conversion and Management (45) 2187–2195*

vii. *ASHRAE (2003) Evaporative Cooling System. American Society of Heating and Refrigeration and Air Conditioning.www.ashare.com*

viii. *Barre, H.J.; Sammet, L.L. and Nelson, G.L. (1988). Environmental and Functional Engineering of Agricultural Buildings, Van Nostrand Reinhold Company, New York.*

ix. *Carrasco, A.D. (1987) Evaluation of Direct Evaporative Roof-Spray Cooling System .Proceedings on Improving Building Systems in Hot and Humid Climates,Houston ,Texas US., September 15-16 Pp.1-4*

x. *Dvizama, A. U. (2000). Performance Evaluation of an Active Cooling System for the Storage of Fruits and Vegetables. Ph.D. Thesis ,University of Ibadan , Ibadan.*

xi. *FAO (1983). FAO production yearbook, vol. 34. FAO, Rome.*

xii. *FAO. (1986). Improvement of post-harvest fresh fruits and vegetables handling- a manual. Bangkok :*

xiii. *FAO. (1995)a. Small-scale Post-harvestHandling Practices -A Manual for Horticulture Crops.*

xiv. *FAO. (1996). FAO Yearbook 1995. FAO Statistics Series No. 132. Rome*

a. *FAO/SIDA .(1986) .Farm Structures in Tropical Climates , 6*

xv. *FAO/SIDA . Rome. Harris, N.C. (1987). Modern Air Conditioning Practice, 3rd edition,McGraw-Hill Book Co., New York.*

a. *FG/IITA/USAID/UNICEF/USDA Report, 2004*

xvi. *Ihekoronye, A.I. and P.O. Ngoddy (1985): Tropical Fruits and Vegetables. In: Integrated Food Science and Technology for the Tropics, Macmillan Publ. Ltd.; London and Basingstoke ; 293 – 311.*

xvii. *IITA, Nigeria Food Consumption and Nutrition Survey (2001-2003)*

xviii. *Jain .D (2007).Development and testing of two-stage evaporative cooler .Building and Environment) 2549–2554*

xix. *Katsoulas N; Baille A and Kittas C (2001);. Effect of misting on transpiration and Conductance of a greenhouse rose canopy.Agricultural and Forest Meteorology,106,233–47*

xx. *Kittas C.; Bartzanas T. and Jaffrin. A (2003). Temperature Gradients in a Partially Shade Large Greenhouse equipped with Evaporative Cooling*

xxi. *Ndirika, V.I.O and Asota, C.N. (1994). An Evaporative Cooling System for Rural Storage of Fresh Tomato. Journal of Agricultural Engineering and Technology, Vol. 2(4), pp.56-66.*

xxii. *Ndukwu. M. C. Development of a Low Cost Mud Evaporative Cooler for Preservation of Fruits and Vegetables. Agricultural Engineering International: CIGR Journal.Manuscript No.1781. Vol. 13, No.1, (2011).Provisional PDF Version. 3rd edition. Series No. 8.*

xxiii. *Noble, N. (2008) www.practicalaction.org*

xxiv. *Olosunde William Adebisi ; J.C. Igbeka and Taiwo Olufemi Olurin (2009). Performance Evaluation of absorbent materials in Evaporative Cooling System for the Storage of Fruits and Vegetables International Journal of Food Engineering Volume 5, Issue 3*

xxv. *Olosunde, W.A. (2006) .Performance Evaluation of Absorbent Materials in the Evaporative Cooling System for the Storage of Fruits and Vegetable M.Sc thesis, Department Of Agricultural Engineering, University of Ibadan, Ibadan.*

xxvi. *Parsons, R.A. and Kasmire, R.F. (1974). Forced-air unit to rapidly cool small lots of packaged produce. University of California cooperative extension, OSA #272. Tubers. Hortscience 12:294-298*

xxvii. *Redulla ,1984b. Keeping perishables without refrigeration: use of a drip cooler. Appropriate Postharvest Technology 1(2): 13-15)*

xxviii. *Redulla . 1984a. Temperature and relative humidity in two types of evaporative coolers. Postharvest Research Notes, 1(1): 25-28.*

xxix. *Roy S.K, (1989). A low cost cool chamber: an innovative technology for developing countries (Tropical fruits storage), Johnson GI,(Commonwealth Scientific and Industrial Research Organisation, St Lucia (Australia). Division of Horticulture),Editor. Postharvest handling of tropical fruits. Canberra, A.C.T., Australia: Australian Centre for International Agricultural Research 1994. p. 393–5.*

xxx. *Roy, S.K.and Khurdiya, D.S. (1986) cited in Dash S.K. paper, presented at training course on 'Zero Energy Cool Chamber' held at I.A.R.I. New Delhi, 8-10 Nov., 2000.*

xxxi. *Salunkhe, D.K., and S.S. Kadam. 1995. Handbook of Fruit Science and Technology.New York: Dekker*

xxxii. *Sanni, L.A (1999). Development of Evaporative Cooling Storage System for Vegetable Crops .M.Sc. project report, Department of Agricultural Engineering, Obafemi Awolowo*

xxxiii. *Sellers (2004). Evaporative Cooling: Design Considerations HPAC Engineering*

xxxiv. *Shewfelt, R. (1994). Quality characteristics of fruits and vegetables.*

xxxv. *Thompson, J.F. and Scheuerman, R.W. 1993. Curing and storing California sweet potatoes. Merced County Cooperative Extension, Merced , California 95340*

xxxvi. *UNFAO regional office for Asia and the pacific.University, Ile-Ife, Nigeria*

xxxvii. *Vakis, N.J. (1981) Handling Fresh Tropical Produce for Export. International Trade Forum 17(1): 13-23*

xxxviii. *Wilson, C.L. , El-Ghaouth, A. ,Wisniewski, M.E., (1999) .Prospecting in Nature's Storehouse for Biopesticides Conference Magistra Revista Maxicana de Fitopatologia 17,Pp 49-53.*

xxxix. *www.dualheating .com*

xl. *Yun K (2008). California building energy efficiency standards August 16, 2007 Residential evaporative cooling, Southern California Gas Company pp 1-18*