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DESIGN AND FABRICATION OF AN EVAPORATIVE COOLER AS AN ALTERNATIVE FOR STORING FRUITS AND VEGETABLES

***ADEYOLANU, A.S.[1], MUIDEEN, R.A.[1] AND OLANITE, W.A.[2], ASHIRU, A.R.[2] AND ARIWOOLA, L.A.[2]**

[1]Agricultural and Bio-Environmental Engineering Department, The Oke-Ogun Polytechnic, Saki. [2]Mechanical Engineering Department, The Oke-Ogun Polytechnic, Saki

ABSTRACT

Fresh fruits and vegetables deteriorate easily when stored under ambient condition, mainly due to physiological and microbial activities, which are accelerated at high temperature and low relative humidity of the storage environment. This work designed, constructed and tested an evaporative

Introduction

Vegetables and fruits are very important food items that are widely consumed in many parts of the world. They form an essential part of a balanced diet. Fruits and vegetables are important sources of digestible carbohydrates, minerals and vitamins A and C. In addition, they provide roughage (indigestible carbohydrates), which is needed for normal healthy digestion (Salunkhe and Kadam, 1995). In Nigeria, the deterioration rate of vegetables and fruits is very high and detrimental to the income of fruit farmers and marketers across the country. Nigeria post-harvest Losses of fruits

cooling system using solar battery for storage of fruits and vegetables. The design of the evaporative system was based on the principle of evaporation being always accompanied by a cooling effect to its surrounding reducing the temperature of ambient air hence the shelf life of the tomatoes was improved. Locally-sourced materials that won't contaminate the produce were used and powered by solar energy. The evaporative cooling system was able to lower the temperatures of the interior by a noticeable amount of celcius degree (about 7°C) and cooling efficiency as high as necessary to temporarily preserve the common fruits and vegetables in Nigeria especially under the harsh climatic conditions of derived savanna region of Oke-Ogun in Oyo State hence reducing post-harvest loses of fruits and vegetables thus increasing fruits and vegetables supply on the market. Although the performance of the evaporative cooling facility fell slightly short of expectations, it can however be used to prolong the storage life of fruits and vegetables better than keeping them under ambient conditions. Produce quality shows a delay in firmness and colour change when compared with produce kept at ambient conditions. The evaporative cooler can be used as a temporary means of storage for fruits and vegetables thereby reducing postharvest losses.

Keywords: *Design, Fabrication, Tomatoes, Evaporative cooler, Performance evaluation.*

and vegetables amounts to 35-45% of the annual production. These losses were noted to have occurred during transportation, storage and marketing resulting from poor handling and inappropriate storage facilities (Dzivama, 2000).

Maintenance of fresh produce quality requires precise application of optimum cold chain conditions from harvest, grading, packaging, storage and transportation to the consumer (Sibomana *et al*., 2016). The optimum fresh produce conditions vary according to the intended use and the targeted market; either consumption at household level, local country consumption or export and the distance to the destination (Kyriacou and Rouphel, 2018). It is important, therefore, to understand the correlation between PHL and increased fresh produce prices resultant from a constraint output market because of spoilage. PHL may occur due to factors like environmental (Tyagi *et al.,* 2017), biological and chemical, physiological (Joas and Lechaudel, 2008; Tyagi *et al.,* 2017), as well as technical factors (Gebru and Belew, 2015). The main environmental factors that result in significant PHL in F&V are temperature and RH (Workneh and Osthoff, 2010; Prusky, 2011; Misra and Ghosh. 2018).

There are inadequate storage facilities for crops in Nigeria (Aremu *et al.,* 2015a). Losses of fruit and vegetable occur at different stages from the field to ultimate consumer and depend on the degree of peristaltic of the produce. Fresh fruits and vegetables deteriorate easily when stored under ambient condition, mainly due to physiological and microbial activities, which are accelerated at high temperature and low relative humidity of the storage environment. In evaporative cooling system, the latent heat of evaporation is used to carry heat away from an object and cool it. FAO (2003) has advocated a strong system based on the evaporative cooling for the storage of fruits and vegetable, which is simple, relatively efficient and of low running cost. This was aimed at increasing the shelf life of the farm produce and improving the quality of market produce to yield higher earning and improve the living standard of the farmers.

This study designed and fabricated an evaporative cooling system for preserving the freshness of fruits and vegetables and tested the fabricated evaporative cooler using tomato as a test crop.

Materials and Methods

Capacity of the Storage System

The capacity of the evaporative cooling system was obtained from the actual size of the storage baskets used in markets to store tomatoes where by the average dimensions of the different sizes of the baskets was taken whose capacity is 0.216m^3 and considered as the size of the system. It was designed in such a way that it can be scaled up to accommodate different production capacities of different farmers (small, medium and large-scale tomato production farmers).

Design of the Cooling System

The storage system is rectangular shaped to ensure uniform pad saturation area with the design specifications for the system as well as the reservoir troughs were done in accordance with Adeniran *et al*., (2011)

Design of the Different Parts and Components of the Evaporative Cooling System

The following assumptions were taken into account during the design of the system as shown in the isometric view of the system (Figure 1).

- Assuming the system to have a rectangular cross section storage chamber with internal dimensions of length 0.45m, breadth 0.32m and height 0.55m
- The rate of evaporation from the system is independent of the material used to construct the cooling system

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- The evaporation is considered after the jute pads have reached saturation
- The rate of evaporation from the jute pad is equal to the rate of soaking with water from the troughs.

Design of the sides of inside compartment of the Storage System

The design for the outside compartment of storage system was done in in way that there a gap 50mm between it and the inside compartment of the system Storage chamber for the insertion of jute pads and it was achieved using equation 1

$Al = Ll \times Bl$ ………………………..*Equation 1*

$Ll = 0.45m$ $Bl = 0.32m$

$Al = 0.45 \times 0.32 = 0.144m^2$

Where; A l= Area of the sides, Ll= length of the sides, Bl = Breadth of the sides.

Volume of the Storage System chamber

The capacity of the storage system was determined using equation 2

$Vc = A1 \times H1$ …………………..*Equation 2*

$H1 = 0.55m$

$Vc = 0.144 \times 0.55 = 0.079m^3$

Where; **Vc**= Volume of the storage system, **L1**= Length of the storage system, **B1**= Breadth of the storage system, **H1**= Height of the storage system

Design of Front Door (cover) of the Storage System

The design for the cover of the storage system was done using Equation 3 with a hole of 240mm diameter for insertion of suction fan

$Af = Lf \times Bf$ ……………………. Equation 3

$Lf = 0.57m$ $Bf = 0.48m$

Af = 0.274m2
Where; *Af* = Area of the front door (cover) of the storage system, *Lf* = Length of the cover of the storage system *Bf* = Breadth of the cover of the storage system

Design of the sides of outside compartment of the Storage System
The design for the outside compartment of storage system was done in a way that there is a gap of 50mm between it and the inside compartment of the system Storage chamber for the insertion of jute pads and it was achieved using equation 4
Al =Ll×Bl ………………………..*Equation 4*
Ll=0.50m Bl=0.37m
Al= 0.50×0.37=0.185m^2
Where; **A l**= Area of the sides, **Ll**= length of the sides, **Bl** = Breadth of the sides.

Design and Selection of Suction Fan
The fan capacity was determined in accordance with Bartok, (2013) as given in equation 5
Fan Capacity=8cfm/sqft × front area in squared foot…………..Equation 5
Af= 0.274m2=2.95sqft
At a given factor of safety (Fs) used to cater for the losses

Fan capacity= 2.95 × 8=23.60 cfm
Considering a factor of safety of 10%
Fs=0.1×23.60=2.360 cfm
Required fan capacity= 23.60 + 2.36
= 25.96 cfm
Design of the water reservoir troughs
This was done in accordance to diameter of the reservoir tank and placed at 10cm height above the top of the system.

Dimensions of the troughs
Length=width=0.32m and Height=1.34m
Area of the stand= (1.34×0.32×) m2
$=0.4288m^2$

Cooler Construction Material Type and Selection Criterion

Selection of cooler frame construction material

This was dependent on the following factors; Affordability, Workability, Strength, Availability, suitability, Weight, Corrosively, Cost, political and Cultural acceptance and metallic material was considered.

Selection of cooling Pad

In this work, Jute bag padded with half inch foam was selected for an efficient performance of the evaporative cooling system since it has good water holding capacity, high moisture content, and percentage dry basis, high bulk density as reported in literatures (Manuwa and Odey, 2012; Igbeka and Olurin, 2009).

Materials Used

Materials used for the construction and testing of the evaporative cooling system include:

- Tomato
- Mild Steel
- Galvanized Steel
- Insulated Tray
- Angle Iron
- Jute Bag
- Foam
- Fan
- Battery
- Control switch

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- Electric wire

Principles of Operation of the Evaporative Cooling System

The design of the evaporative system was based on the principle of evaporation being always accompanied by a cooling effect to its surrounding. It is an enclosed system which comprises of four sides, such that all the sides were made of rectangular iron framework and pad (jute material), equipped with one suction fan placed at the back of the system. Air is allowed to pass through the pads into the system with the aid of suction fan. Water soaks the jute pad thereby making it wet constantly through water troughs at the top and bottom of the evaporative cooler. As the water soaks the pad, air is cooled by passing through the wet pad before it passes through the packages and around the produce by the suction fan. During this process the warm air which is the sensible heat passes through the wetted pad then changed to latent heat due to the evaporation that has occurred as a result of the water being evaporated which causes the cooling within the system to achieve cooling to within a few degrees of the wet bulb temperature of ambient air (about 7°C difference) hence the shelf life of the tomatoes expected to increase.

Determination of Performance Evaluation

The performance evaluation involved the no-load and the load tests. In the no-load test, the evaporative cooler was tested without putting any food material in it. The ambient temperature and the cooler temperature were taken and the average values of the readings at two hours intervals were found to be 32.6°C and 25.2°C for ambient and cooler conditions respectively. This shows a significant reduction of over 7°C in the temperature. During the load test, the stored products were kept inside the evaporative cooler

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and a control experiment kept at ambient air. The initial weight of each product was 5g.

Results and Discussions

Physiological Weight Loss of Tomatoes

Tables 1 and 2 showed the experimental results of physiological weight loss and percentage of weight loss of tomatoes during the experiment. The experimental results revealed that tomatoes weight loss in the evaporative cooler ranged from 0.1g to 0.4g over the storage period of eight days and ambient storage systems (transparent plastic, transparent nylon bag and black nylon bag) ranged from 0.2g to 1.4g over the storage period of eight days. The percentage weight loss of tomatoes in the evaporative cooler ranged from 0.1% to 8.0% compared to Zakari *et al.*, (2016) and Ogbuagu *et al.,* (2017) who reported percentage weight loss of 0.30 to 0.60% and 20% for 14 days of storage respectively and ambient ranged 0.87% to 3.45% per day. The difference in quality of stored tomatoes between the ambient and evaporative cooling was noticeably significant. Therefore, the use of evaporative cooler is significant for preserving and improving the shelf life of tomatoes and also maintaining the water constituent of the tomatoes which add up the total weight unlike the loss of water will reduce the weight of the tomatoes and begins to shrink hence becoming unusable as reported by FAO (2008). Hence it is on this note that maintaining the weight of fresh tomatoes will maximize profit.

Color change of the tomatoes stored in the cooling system and ambient conditions

During the testing, the color changes of the tomatoes were monitored for the samples kept under ambient and evaporative cooler. The change in colour was more pronounced in the products kept at ambient conditions. The color change of tomatoes stored

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under ambient condition was very obvious within five days of storage whose color changed from yellowish red to a deep red color while some turned slightly reddish black. It was also observed that the tomatoes stored in the cooler still retained their color within six (6) days of storage with no color changes noticed in most of the tomatoes compared to ambient conditions (Figure 2a and 2b).

Firmness and growth of moulds of the tomatoes stored in the cooling system and ambient conditions

Firmness was determined by feeling. The produce stored in the evaporative cooler retained their freshness longer than those stored at ambient conditions. The loss of firmness was very obvious in the tomatoes stored under ambient conditions as some were observed to have started rotting and growing moulds after five days of storage, compared to evaporative cooler (Figure 3a and 3b). Therefore, the testing of the evaporative cooler showed that the tomatoes could be stored for an average of six (6) days without rotting which agrees with the results of Zakari *et al*., (2016) who exported that the tomatoes retained their firmness after six days of storage.

Conclusions

Throughout the period between harvest and consumption, temperature control has been found to be the most important factor in maintaining product quality. Fruits, vegetables and cut flowers are living, respiring tissues separated from their parent plant. Keeping products at their lowest safe temperature will increase storage life by lowering respiration rate, decreasing sensitivity to ethylene gas and reducing water loss. Reducing the rate of water loss slows the rate of shriveling and wilting, causes of serious postharvest losses. This study designed, fabricated and tested an evaporative cooling system for fruits and vegetables. It was carried out in order to provide an alternative storage facility for fruits and vegetables. Although the performance of the evaporative cooler facility fell slightly short of expectations, it can however be used to prolong the storage life of fruits and vegetables better than keeping the produce in ambient air conditions. Produce quality shows a delay in colour change and shrivelness when compared with produce kept at ambient conditions. The evaporative cooler can be used as a temporary means of storage for fruits and vegetables. Its use can help reduce postharvest losses and also generate more income for farmers.

References

Adeniran, M.O.A, Ale, S.O. and Egbe, E. (2011). Mathematics for senior secondary schools, Book Three, Third Edition. ISBN 978 030 753 2.

Aremu, D.O., Babajide, N.A., Ogunlade, C.A., Oyeniran, T. and Kadiri, A.O. (2015a). Effects of storage media and duration on nutritional qualities of cowpea (*Vigna unguiculata* L. Walp). *IOSR Journal of Agriculture and Veterinary Science (IOSR_JAVS)*, Vol. 8, Issue 2, Version 1: PP 60-65.

Bartok, J.W. (2013). Fan and pad evaporative cooling sytem. Integrated pest management article from Department of Natural Resources and the Environment, University of Connecticut, Storrs CT.

Dzivama, A.U. (2000). Performance Evaluation of an Active Cooling System for the Storage of fruits and Vegetables. Ph.D. Thesis, Department of Agricultural Engineering, University of Ibadan, Nigeria.

FAO (2008). The world vegetable center. Newsletter. Food and Agriculture Organisations of the United Nations, Rome.

FAO (2003). General Post Harvest Handling Practices in Southern Nigeria; a Manual for Sustainable Agriculture. Food and Agricultural Organization. Rome

Gebru, H. and Belew, D. (2015). Extent, Causes and Reduction Strategies of Postharvest Losses of Fresh Fruits and Vegetables – A Review. *Journal of Biology, Agriculture and Healthcare*, 5(5).

Igbeka, J.C, and Olurin T.O. (2009). Performance Evaluation of Absorbent Materials in Evaporative Cooling System for the Storage of Fruits and Vegetables. Int. J. Food Eng., 5(3): 2.

Joas, J. and Lechaudel, M. (2008). A comprehensive integrated approach for more effective control of tropical fruit quality. *Stewart Postharvest Review*, 4, 1-14.

Kyriacou, M,C. and Rouphel, Y. (2018). Towards a new definition of quality for fresh fruits and vegetables. *Scientia Horticulturae*, 234, 463-469. doi.org/10.1016/j.scienta.2017.09.046

Manuwa, S.I. and Odey, S.O. (2012). Evaluation of pads and geometrical shapes for constructing evaporative cooling system. *Modern Applied Science*, 6(6), 45-53.

Misra, D. and Ghosh, S. (2018). Evaporative cooling technologies for greenhouses: a comprehensive review. *Agricultural Engineering International: CIGR Journal*, 20(11), 1-14.

Ogbuagu, N.J., Oluka, S.I. and Ugwu, K.C. (2017). Development of a passive evaporative cooling structure for storage of fresh fruits and vegetables. *Journal of Emerging Technologies and Innovative Research*, 4(8), 179-186. ISSN-2349-5162.

Prusky, D. (2011). Reduction of the incidence of postharvest quality losses, and future prospects. *Food Security*, 3(4), 463-474.

Salunkhe, D.K. and Kadam, S.S. (1995). Handbook of Fruit Science and Technology, New York.

Sibomana, M.S., Ziena, L.W. and Schmidt, S. (2017). Influence of transportation conditions and postharvest disinfection treatments on microbiological quality of fresh market tomatoes (cv. Nemo-netta) in a South African supply chain. *Journal Food Protection*, 80(2), 345–354.

Tyagi, S., Sahay, S., Imran, M., Rashmi, K. and Mahesh, S.S. (2017). Pre-harvest Factors Influencing the Postharvest Quality of Fruits: A Review. *Current Journal of Applied Science and Technology*, 23(4), 1-12. ISSN: 2231-0843.

Workneh, T.S. and Osthoff, G. (2010). A review on integrated agro-technology of vegetables. *African Journal of Biotechnology*, 9(54), 9307-9327.

Zakari M.D., Abubakar, Y.S., Muhammad, Y.B., Shanono, N.J., Nasidi, N.M., Abubakar, M.S., Muhammad, A.I., Lawan, I. and Ahmad, R.K. (2016). Design and construction of an evaporative cooler for the storage of tomato. *ARPN Journal of Engineering and Applied Sciences*, 11(4), 2340-2348.

Table 1 Physiological weight loss of the stored tomatoes

	Ambient			Cooler		
Days	Transparent Nylon	Black Nylon	Transparent Plastic Bowl	Upper Tray	Middle Tray	Lower Tray
2	4.8	4.7	4.8	5.0	5.0	5.0
4	4.7	4.4	4.6	5.0	5.0	4.9
6	4.5	4.2	4.6	5.0	4.9	4.7
8	4.0	3.6	4.1	4.8	4.8	4.6

Table 2 Percentage of weight loss of stored tomatoes

	Ambient			Cooler		
Days	Transparent Nylon	Black Nylon	Transparent Plastic Bowl	Upper Tray	Middle Tray	Lower Tray
2	4	6	4	0	0	0
4	6	12	8	0	0	2
6	10	16	8	0	2	6
8	20	28	18	4	4	8

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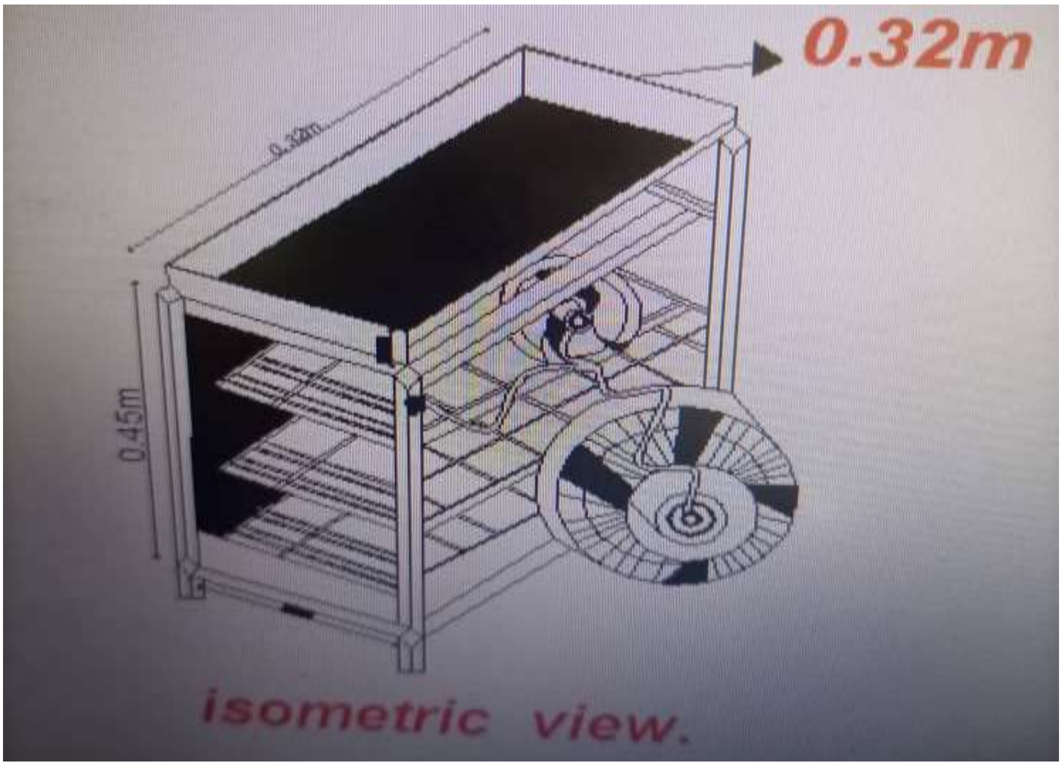

Figure 1 **Isometric view of the evaporative cooling system**

Figure 2a **Colouration change of stored tomato in the cooler**

Figure 2b Colouration change of stored tomato under ambient condition

Figure 3a Firmness and growth of moulds of stored tomato under the ambient condition

Figure 3b Firmness and growth of moulds of stored tomato in the cooler