Engineering and Technology Journal e-ISSN: 2456-3358
Volume 09 Issue 10 October-2024, Page No.- 5399-5405
DOI: 10.47191/etj/v9i10.21, I.F. – 8.227
© 2024, ETJ

Assessment of a Cowl-Incorporated Wind-Powered Forced-Air Evaporative Cooler for Preservation of Fruit and Vegetables

A. R. Ajewole[1], L. O. Adekoya[2]
[1, 2]Mechanical Engineering Department, Obafemi Awolowo University, Ile-Ife, Nigeria

ABSTRACT: This paper reports the performance of a cowl-incorporated wind-powered forced-air evaporative cooler for preservation of fruit and vegetables. The evaluation took place in the Department of Mechanical Engineering, Obafemi Awolowo University, Ile-Ife in October. Freshly harvested tomatoes were used in the evaluation as tomatoes were common locally and are highly perishable. The produce (2.5 kg) was kept in the cooling chamber of the evaporative cooler, and the changes in weight were observed three times daily until the produce had lost more than 7 % of its weight. The no-load cool air temperatures ranged between 27.3and 34.5ºC corresponding to ambient dry bulb temperatures 29.0and 43.9ºC respectively. The no-load cool air relative humidity ranged between 63.0 and 87.2% corresponding to ambient relative humidity of 40.8 and 79.5% respectively. The evaporative cooler no-load cooling efficiency was 66.7% while the cooling efficiency when loaded was 50.0%. The evaporative cooler was able to preserve tomatoes for 9 days losing 4.8 % weight. The evaporative cooler had the potential of effectively preserving fruit and vegetables without dependence on electricity. If used in windier and less humid regions, the average cooling efficiency of the evaporativecooler would be higher than that observed in this research.

KEYWORDS: Evaporative cooler, Cowl, Wind-powered, Fruit, Vegetable, Preservation

1.0 INTRODUCTION

Fruit and vegetables are essential food items containing vitamins and minerals which help in proper body functioning and fighting against diseases [1]. Fruits and vegetables equally contain carbohydrates and proteins needed for healthy growth [2,3]. Examples of fruit and vegetables are tomatoes, pepper, onions, African Spinach and mushroom [4]. Several diseases are caused by lack of vitamins and minerals. Such diseases include scurvy, beri-beri, rickets, anaemia, night-blindness and goiter. Thus, taking fruit and vegetables which are the major sources of vitamins and minerals becomes very essential.

Most fruit and vegetables have very low shelf lives causing economic losses. A shelf life is the period between the time a produce is harvested and the time it stops being consumable or the time it has lost appreciable nutritional quality. Low shelf lives of fresh fruit and vegetables is a major reason why such items are chemically preserved in tinned, canned, bottled or sacheted forms. The attendant effects of taking chemically-preserved fruit and vegetables is the emergence and multiplication of cancer-related health hazards which include cancer, hypersensitivity in children, thyroid tumours and brain tumours[5]. The foregoing health hazards are due to the fact that the chemicals used in preserving fruit and vegetables are casinogenic, and are therefore very detrimental to health.

Two major devices used in preserving fruit and vegetables are refrigerators and evaporative coolers. Refrigerators function based on the refrigeration cycle. They have a high cost of procurement, making them most of the times unaffordable to poor people. Besides, they are electricity-dependent, making them not to be a good option in places where there is epileptic supply of electricity. In a similarvein, fruitcannot be stored in refrigerators for a long period as they are susceptible to chilling injury [3].

As a result of the several limitations in the use of refrigerators for fruit and vegetable preservation, the use of evaporative coolers is a better option. An evaporative cooler is a device that cools a compartment as a result of the movement of air around a wet surface or wet absorbent material. Examples of absorbent materials are jute, foam, clay and palm leaf.The main objective of this paper is to ascertain the functional characteristic of the wind-powered forced-air evaporative cooler for preserving tomatoes.

1.1 Contributing Factors to Deterioration in Fruit and Vegetables

Pathological, mechanical and physiological activities and evaporation of water are the main factors accountable for fruits and vegetables deterioration.

1.1.1 Pathological infection

A pathogen is defined as any small organism that can cause disease [4]. Deterioration results when they infest farm produce [6, 7].

1.1.2 Physiological activity

Ripening transforms mature plant organs into edible organs. The process is irreversible and naturally leads to deterioration and decay of the produce [7].

1.1.3 Mechanical injuries

Cracks, bruises, cuts, or abrasion could result from mishandling of fruits and vegetables leading quick deterioration and drastic reduction in their shelf lives. Olosunde [7] and Aworh*et al.* [8] discovered that mechanical damage considerably increases the rate of water loss from produce bringing about higher respiration; ethylene production rate is increased too. The level of ascorbic acid reduces and damage increases. Taste and nutritive value is altered.

1.1.4 Evaporation of water

The shelf life of any agricultural produce reduces as the rate of evaporation increases as the moisture content will normally reduce [6, 7].

2.0 EXPERIMENTAL PROCEDURE

2.1 Description of the Wind-powered Evaporative Cooler

The evaporative cooler (Plate 1) consists of a rectangular cooling chamber having a lagged wooden door and three sides of jute wall guarded with wire mesh. It has a suction cowl

LEGEND
1. Cowl
2. Cowl support
3. Duct
4. Water reservoir
5. Cooling chamber
6. Guard rope

Plate 1: The wind-powered evaporative cooler with the cooling chamber under a shed.

Connected by a vertical duct to the cooling chamber which also bears a plastic water reservoir to which are connected horizontal pipes perforated underneath. The cooling chamber also has air inlet underneath. The cowl rotates based on wind speeds. The continual rotation of the cowl forces air into the cooling chamber through the air inlet and pores in the jute wall. The air escapes into the atmosphere through the cowl. The continuous movement of air around the wet jute wall keeps the cooling chamber cooler than the ambient condition especially when the ambient humidity is low and the ambient temperature is high.

2.2 Experimental Set-up

The complete experimental set-up consists of the wind-powered evaporative cooler and the control chamber (Plate 2).The evaporative cooler was first tested at no-load, and later with a load of tomatoes. The tomatoes (2.5 kg) were weighed in a weighing balance and kept in

Plate 2: The control chamber (left) and the evaporative cooler (right) with the door opened temporarily (a) and the door closed as expected (b) during evaluation.

The cooling chamber of the evaporative cooler while the water reservoir was manually refilled with water an average of 4 times daily. A shed was created over the cooling unit to prevent the water from becoming hot as a result of the heat of the sun so as to increase the cooling efficiency of the evaporative cooler. A control chamber was placed beside the device and equal weight of freshly harvested tomatoes was kept inside it. The tomatoes were examined three times daily (8 am, 12 noon and 4 pm) for colour and weight changes. The cool air temperatures and cool air relative were also measured as well as ambient dry bulb temperatures and ambient relative humidity using a multi-function anemometer which was also used to measure the wind speeds at a hand-reach height of 1.7 m.

2.3 Determination of Percentage Weight Loss

The percentage weight loss was calculated for both the control tomatoes and the stored tomatoes using equations 3 and 4.

$$W_L = W_1 - W_2 \quad (3)$$

where,

W_L is loss in weight of the fruit or vegetables stored, (kg);

W_1 is initial weight of the fruit or vegetables stored, (kg);

W_2 is final weight of the fruit or vegetables stored, (kg).

$$L = 100W_L/W_1 \quad (4)$$

where,

L is percentage weight loss (%), and the other parameters are as earlier defined.

2.4 Determination of the Cooling Efficiency

The cooling efficiency for the evaporative cooler was determined by substituting the average values of the cool air temperatures, ambient air dry bulb temperatures and wet bulb temperatures in equation 5. The ambient air wet bulb temperatures were read from the psychrometric chart using the value of ambient dry bulb temperature and ambient relative humidity for each experimental run.

$$\eta_{cooling} = (T_{db} - T_s)/(T_{db} - T_{wb})*100\ \% \quad (5)$$

where,

$\eta_{cooling}$ is cooling efficiency, (%)

T_{db} is dry bulb temperature, (°C)

T_s is cool air temperature, (°C)

T_{wb} is wet-bulb temperature, (°C)

3.0 RESULTS

The evaporative cooler was tested without being loaded. Similar readings made and calculations done for no-load conditions were carried out when the evaporative cooler was loaded with tomatoes.

3.1 No-load Temperature Readings

The temperatures were measured three times daily (morning, afternoon and evening) for four days. The cool air temperatures ranged between 27.3 and 34.5°C while the corresponding ambient dry bulb temperatures ranged between 29.1 and 43.9°C (Figures 1 and 2). It was observed that the depression was high in the afternoon compared to the other periods of the day

.

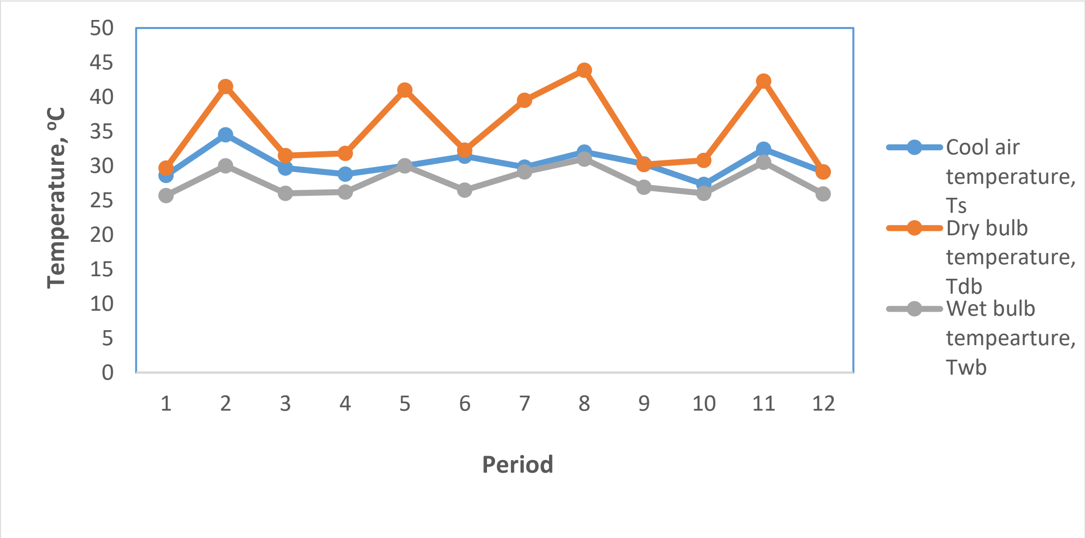

Figure 1: No-load temperature readings.

3.2 No-load Relative Humidity Readings

The relative humidity readings were made 3 times daily using a multipurpose hygrometer. The cool air relative humidity ranged between 63.0 and 87.2% while the corresponding ambient relative humidity ranged between 40.8 and 79.5% (Figure 2).

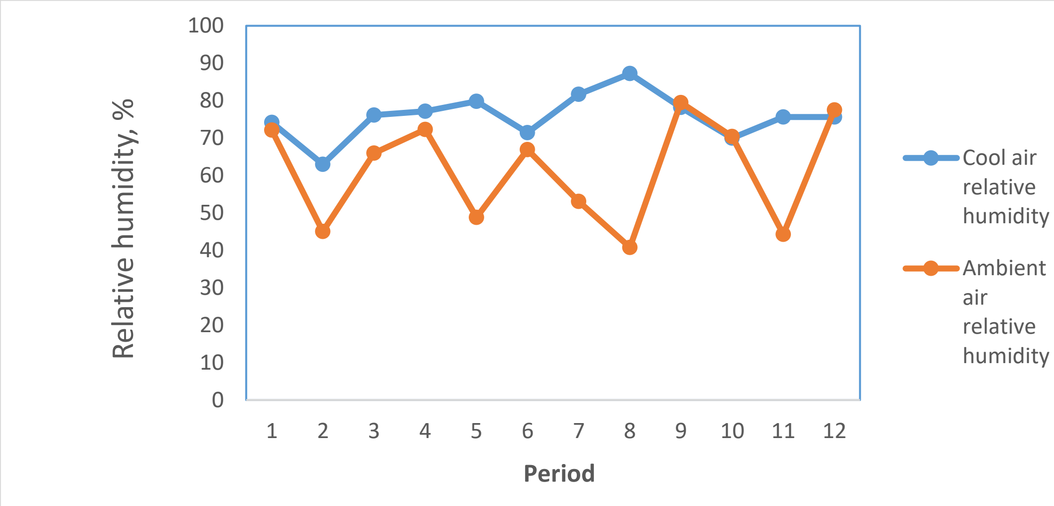

Figure 2: No-load relative humidity readings.

3.3 No-load Cooling Efficiency

The no-load cooling efficiency was calculated for each experimental run. The cooling efficiency values fluctuated with a maximum value of 100% (Figure 3). In the experimental run 9, the no-load cooling efficiency was a negative value resulting from the value of T_s being higher than that of T_{db}. The foregoing condition must have been due to high ambient air relative humidity. The average ambient dry bulb temperature (35.3°C), cool air temperature (30.3°C) and ambient wet bulb temperature (27.8°C) were used in computing the average no-load cooling efficiency as 66.7 %.

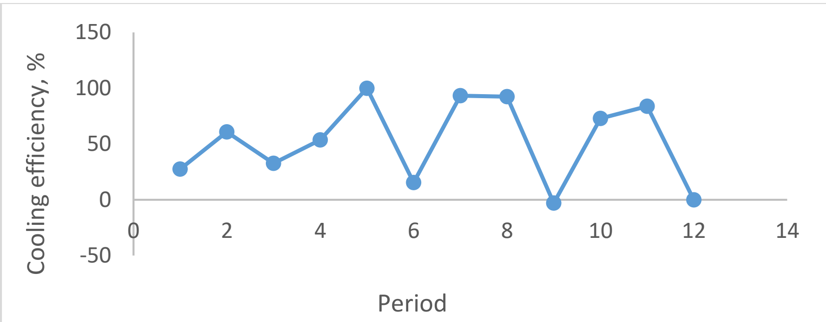

Figure 3: No-load cooling efficiency.

3.4 Temperatures when Loaded

The cool air temperatures ranged between 25.1 and 35.9°C while the corresponding ambient dry bulb temperatures ranged between 24.9 and 51.2°C (Figure 4).

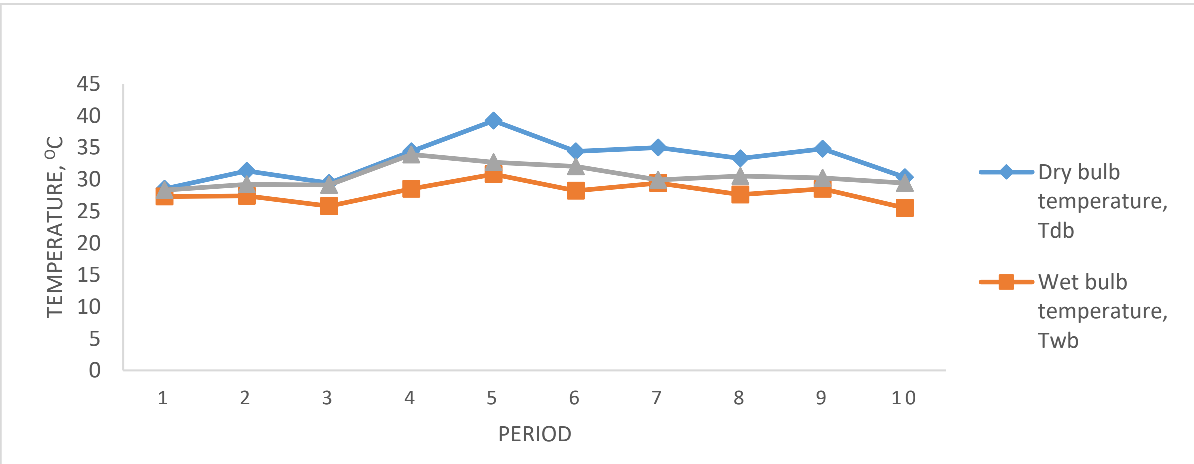

Figure 4: Temperatures when loaded.

3.5 Relative Humidity when Loaded

The cool air relative humidity ranged between 63.9 and 81.4% while the corresponding ambient relative humidity ranged between 33.9 and 82.0 ºC (Figure 5).

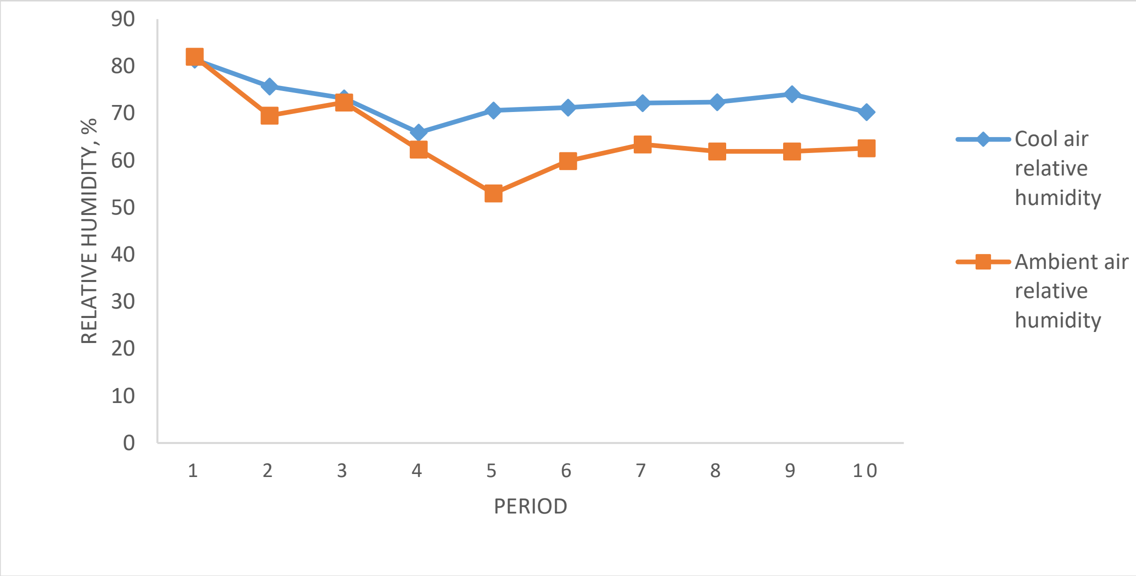

Figure 5: Relative humidity when loaded.

3.6 Efficiency when Loaded

As in the case of no-load conditions, the cooling efficiency when the evaporative cooler was loaded fluctuated With a maximum value of 91.07 % (Figure 6). The average ambient air dry bulb temperature (31.1 ºC), cool air temperature (30.5 ºC) and ambient air wet bulb temperature (27.9 ºC) resulted in an average cooling efficiency of 50.0 %.

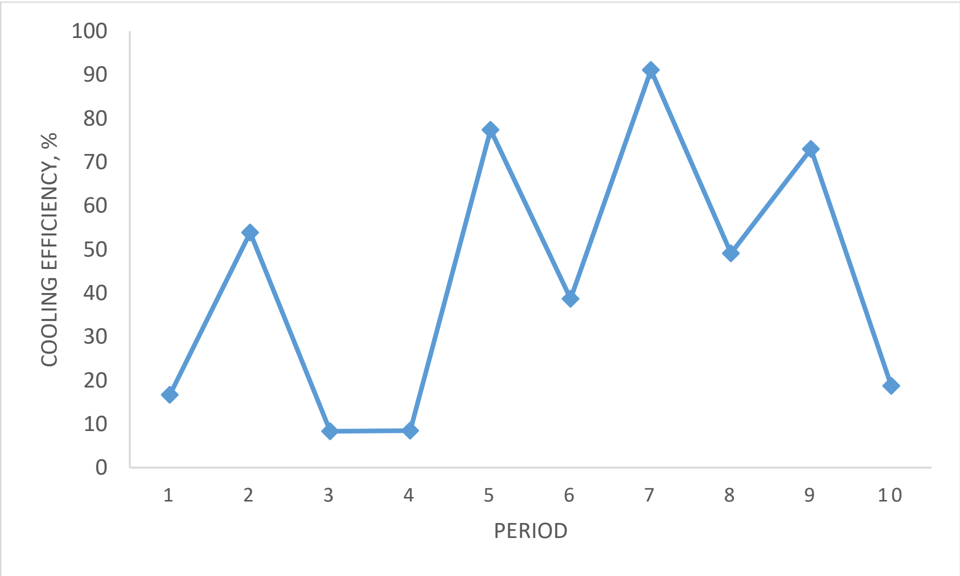

Figure 6: Cooling efficiency when loaded.

3.7Assessment of the Quality of the Tomatoes

The tomatoes stored were observed for colour change, firmness and weight changes.The tomatoes (red in colour) were already ripe before the commencement of the experiment. There was no significant change in colour throughout the experimentation.On the ninth day, the tomatoes in the evaporative cooler had lost 4.8 % weight while the control tomatoes had lost 11.2 % weight necessitating ending the experiment on the tenth day. On the tenth day, the tomatoes in the cooling chamber that were yet to bring out water were separated and found to be 36 % by weight which boiled down to the fact that 54 % had started bringing out water. According to Thompson [9], the maximum percentage water loss of tomatoes before becoming unsaleable is 7 %. Therefore, stopping the experiment on the tenth day was justified as at that time the tomatoes in the evaporative cooler had lost 9.2 % of their weight while the control tomatoes had lost 19.2 %. It is worthy of note that weight changes in tomatoes are due to loss of water. Plate 3 shows the conditions of the tomatoes in the evaporative cooler and the control chamber on the tenth day. Figure 7 is the percentage weight loss in the tomatoes in the wind-powered forced-air evaporative cooler and the control chamber.

(a)

(b)

Plate 3: Conditions of the tomatoes on the tenth day: (a) inside the cooling chamber; (b) inside the control chamber.

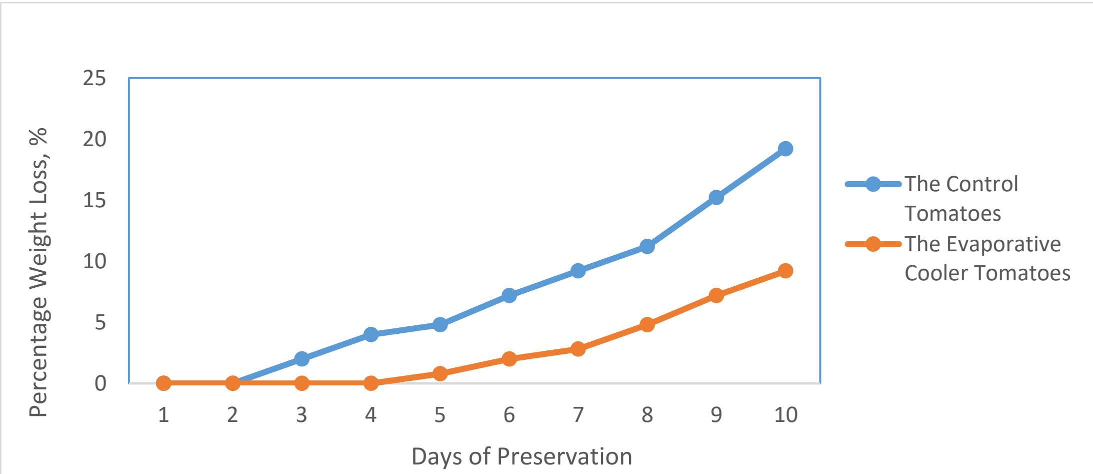

Figure 7: Percentage weight loss in the tomatoes in the control chamber and those in the evaporative cooler.

The changes in the weights of the control tomatoes and the tomatoes in the evaporative cooler show that control tomatoes lost weight faster than the tomatoes in the evaporative cooler. Before the fifth day, the control tomatoes had lost more than 7 % of their weight while by the ninth day the tomatoes in the evaporative cooler had lost up to 7 % of their weight. In other words, the shelf life of the control tomatoes was 5 days while the shelf life of the tomatoes in the evaporative cooler was 9 days.

4.0 CONCLUSIONS

The study examined the performance of a wind-powered forced-air evaporative cooler having a suction cowl. Results from the experiment show that the evaporative cooler was able to preserve tomatoes for 9 days without appreciable loss in weight while the control tomatoes lasted for 5 days, signifying that the evaporative cooler was able to reduce weight loss in the tomatoes betterthan in the ambient conditions. The device has the potential to perform better if operated in a windier and less humid region.

ACKNOWLEDGEMENTS

The authors wish to appreciate the following people for their contributions to the success of the research: B. S. Ogundele, BankoleOluyaire, Fadele, Okanlawon, A. O. Koya, S. A. Adio, T. Olasunkanmi, Mr. Olomide, D. B. Aderinoye, BusayoAdeboye, Amujoyegbe, Ojerinde Joshua, Agboola Oluwagbemi and Tosin Oloruntoba.

REFERENCES

1. A.I. Ihekoronye, P.O. Ngoddy, Tropical fruits and vegetables. Integrated Food Science and Technology for Tropics, Macmillan Publ. Ltd, London and Basing Stroke, (1985) 293-311.
2. D.K. Salunkhe, S.S. Kadam,Handbook of Fruit Science and Technology, Dekker, New York, 1995.
3. W.A. Olosunde, J.C. Igbeka, T.O. Olurin, Performance evaluation of absorbent materials in evaporative cooling systems for the storage of fruits and vegetables. International Journal of Food Engineering, 5 (2009)3.
4. Cambridge University Press, Cambridge Advanced Learner's Dictionary, third ed., Cambridge University Press, Cambridge, 2008.
5. K. Vera, What are dangers of preservatives? www.livestrong.com/article/29302-dangers-preservatives, 2014 (accessed 08-09-2015).
6. A.O. Fabiyi, Design, construction and testing of an evaporative cooling facility for storing vegetables, Agricultural Science Department, University of Agriculture, Abeokuta (2010), Unpublished.
7. W.A. Olosunde, Performance evaluation of absorbent materials in the evaporative cooling system for the storage of fruits and vegetables, M.Sc. thesis, Department of Agricultural Engineering, University of Ibadan, Ibadan (2006).
8. O.C. Aworh, A.O. Olorunda, I.A. Akhuemonkhan, Effects of post-harvest handling on quality attributes of tomatoes in the Nigerian marketing system, Food Chemistry, 10 (1988)225-230.
9. A.K. Thompson, Postharvest technology of fruits and vegetables. Blackwell Science Ltd., Oxford, UK, pp. 410. 1996