Utilization of Plant Based Waste Materials as Alternatives to Sand in Zeer Pot Refrigerator

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Abstract-Zeer pot refrigerator has been introduced at household level in dry and hot climatic areas to preserve foods under the principal of evaporative cooling. The absorbent material of the typical zeer pot is sand. Since replacing sand with suitable absorbent material can alter the cooling efficiency of zeer pot, the present work mainly focuses on utilizing plant derived wastes as the absorbent material instead of sand to enhance the cooling efficiency. The experiment was conducted under complete randomized design with 4 treatments using absorbent materials namely sand, coir dust, saw dust and crushed corn husk together with corn hair with 3 replicates. The results showed that cooling efficiency of sand, coir dust, saw dust and crushed dried corn husk with corn hair were 69%, 58.6%, 60.8%, 22.9% respectively. It can be concluded that considering temperature drop, RH increment and cooling efficiency, saw dust and coir dust except corn husk can be used as an alternative to sand in zeer pot refrigerator.

Keywords, Evaporative cooler, Absorbent material, Cooling efficiency, Preservation

INTRODUCTION

It has been estimated that 30-40% of total fruit production and 16-41% of total vegetable production in Sri Lanka loss during different handling operations from farm gate to consumer [1]. Considerable post-harvest losses of perishables in developing countries are occurred at the consumer level because of the poor storage facilities. To reduce these post-harvest losses, several storing structures were developed from ancient time to present. Among such preservation methods, the mechanical refrigerator has introduced as the best solution to reduce these losses in storage at domestic level. Currently, selecting a refrigerant for mechanical vapor compressor refrigerators has become a major challenge of concern because most of them are not environmental friendly due to high global warming potential and high ozone depletion rate. Furthermore, the domestic refrigerator comprises with some drawbacks such as using large power by compressor, high initial cost, low efficiency due to energy wastage and may cause accidents due to presence of highly inflammable gasses [2]. However, the most inconvenient factor that affects to rural and poor people about mechanical refrigeration is epileptic power supply and low income of farmers which makes refrigeration expensive [3]. In addition, it has been observed that several fruits and vegetables such as banana, plantain, tomato etc. cannot be stored in domestic refrigerator for a long period as they are susceptible to chilling injury [4]. With these tragic effects, the attention must be drawn to develop energy efficient sustainable refrigerator which can make with the use of locally available materials. In developing countries, there is an interest in simple low-cost alternatives, many of which depend on evaporative cooling [3].

Evaporative cooler designs could be categorized according to the method of evaporation, storage chamber construction, and the absorbent medium. Some of the designs have been constructed using porous materials such that the evaporation is occurred by seeping the water from an inside of a container to outside. Here the evaporation is enhanced by drawing heat from inside cooling chamber.

This heat gradient causes a temperature reduction inside the cooling chamber. Second types of evaporative coolers are designed having a wetted pad as an absorbent media of water facilitating evaporation. The hot air masses passes through this cooling pad thus reducing the inside temperature of the storage chamber [5]. However, different designs of evaporative coolers have been reported in the literature for short-term preservation of fruits and vegetables ranges from straw packing house to some sophisticated design [6]. Among these, Zeer pot refrigerator is the most suitable evaporative cooler for rural community because it requires no special skill to operate. The people who cannot afford to buy a refrigerator could use this pot as a substitute as well.

Zeer pot is made of basic pots, sand and water. Here the evaporation is caused by convective and radiative heat transfer from the hot and dry climate of the surrounding and the cooling load from the food kept for preservation. When dry air mass passes over a wet pad through a porous wall, the water in the wet pad evaporates thus producing cool air masses. This happens because the water needs latent heat of vaporization to get evaporated [7]. As a result, heat is carried away from the center of the pot creating surface of the body much cooler. This irreversible heat and mass transfer process is influenced by the insulating material that is used [8]. Therefore, replacing sand with suitable absorbent material can alter the cooling efficiency of zeer pot.

Many types of research has been done in relation to evaporative coolers considering its design aspects and performance evaluation using various types of natural materials as cooling pads such as charcoal, jute bag, rice husk, wheat straw, coconut fiber, PVC sponge, canvas, jute curtains, hourdis clay blocks, palm leaves, hessian, cotton waste, wood wool, coconut coir, khus and stainless steel [3], [4], [8]-[11]. However, most of these materials have not been tested for zeer pot except charcoal, jute, and cotton waste. Moreover, introducing locally available plant based waste materials such as coir dust, saw dust, and dried corn cobs as alternative absorbent material may reduce the cost of wastes, save money, prevent pollution caused by reducing the need to harvest new raw materials and replace “sand” which is a limited natural resource. Therefore, the main objective of this study was to assess the suitability of locally available plant-based waste materials as an alternative to sand to improve the cooling efficiency of zeer pot.

MATERIAL AND METHODS

The study was carried out under statistical model; complete randomized design with 4 treatments and 3 replicates. The treatments (absorbent materials) were sand (T_1), coir dust (T_2), saw dust (T_3) and crushed corn husk together with corn hair (T_4). All absorbent materials were collected in their natural forms and subjected to air drying for 3-4 days. Corn husk and hair was oven dried at 150 °C for 1-2 hrs and crushed. Thereafter, all materials were sieved using sieve size of 1.5mm.

The zeer pot was designed by placing small clay pot in large clay pot while filling the gap between two pots using prepared absorbent material. The capacity of the inner pot and gap between 2 pots is approximately 1500 cm^3 and 3000 cm^3 respectively and other average dimensions of the made zeer pot are shown in Figure 1. Afterthat, zeer pots were placed on a stand 0.8 m above the ground. The pots were initially saturated with water as shown in Figure 2. Later, the water was continuously fed in to the absorbent material via a designed structure which has a tube with holes. The top of the zeer pots were covered with a damp jute cloth. All the zeer pots were kept in a shade environment for natural convection..

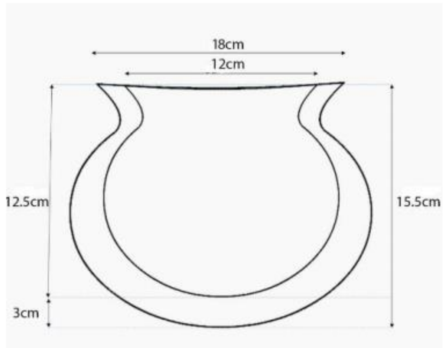

Figure 1. Average dimensions of designed zeer pot

(a) (b) (c) (d)

Figure 2: water saturated Zeer pots filled with (a) sand, (b) coir dust, (c) saw dust and (d) crushed corn husk together with corn hair

Temperature and Rlative Humidity (RH) of inside and outside (ambient) of the zeer pots were recorded using humidity temperature meter (TECPEL 322 type) under natural convention test in hourly from 08:00 hrs to 16:00 hrs for 7 days .

Furthermore, cooling efficiency was calculated using equation 1[12]. Data were analyzed using SAS software with one-way ANOVA followed by Dunnets test ($p<0.05$) for mean separation.

$$\mu = \frac{(Tout - Tin)}{(Tout - Tas)} \times 100 \qquad Equation : 1$$

Where μ is the cooling efficiency (%); T_{out} is the temperature outside the pot (°C); T_{in} is the temperature inside the pot (°C); T_{as} is the air temperature at saturation.

RESULTS AND DISCUSSION

All the treatment showed an increasing the temperature with time as ambient temperature up to 12.30-1.30 pm and then tends to decrease gradually as shown in Figure 3. Coir and saw dust showed a better performance from 8.30am to 10.30 am with a temperature reduction of 2-3 °C than sand and crushed corn husk. Maximum temperature reduction of 2.4 °C was observed in both coir and saw dust around 11.30 am. However, in the evening sand showed better performance with a maximum temperature reduction of 2.7°C (at 1.30 pm) while coir and sawdust showed less temperature drop. It was found that to achieve better temperature drop in the zeer pot, ambient environmental conditions of low relative humidity and high temperature must be prevailed [13]. Since this study was conducted under the high ambient relative humidity, a significant temperature reduction around 7 °C [8] was not observed even for the sand.

International Journal of Engineering Research and General Science Volume 5, Issue 2, March-April, 2017
ISSN 2091-2730

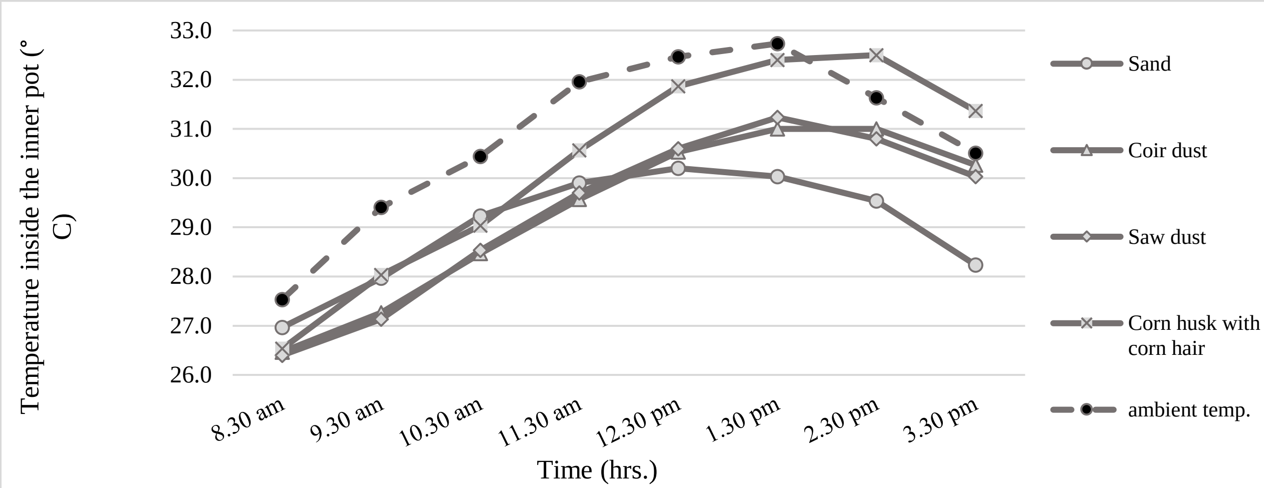

Figure 3: Change in the temperature inside the each zeer pot with respect to ambient temperature

Crushed corn husk showed a significantly lower temperature reduction at the morning compared to other treatments. Furthermore, the inside temperature of corn husk filled zeer pot was higher than ambient temperature in the evening. These results may be due to aerobic deterioration of corn husk when exposed to air as a result of aerobic microbial activity [14]. As reported by Tabacco, et al. [15] aerobic microorganisms use dry matter in silage like maize as their energy source in oxidation process. This oxidation results in the production of carbon dioxide, water and heat. Thus this release of heat and deterioration exhibited the increase of temperature and appearance of mold. Maximum temperature reduction in corn husk with corn hair was 1.4 °C observed during 9.30 – 10.30 am.

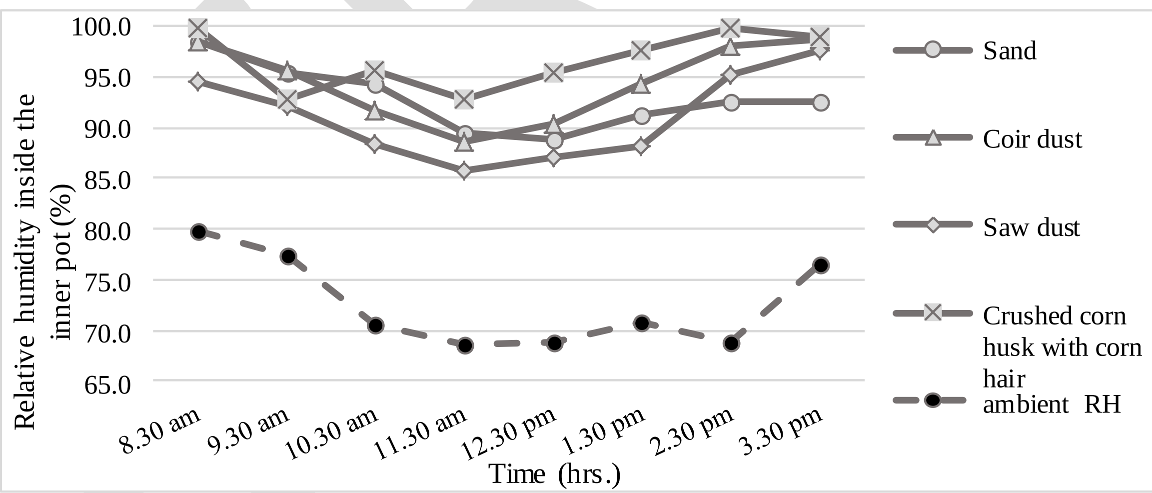

Figure 4: The relative humidity inside the each zeer pot with respect to ambient relative humidity

The relative humidity variations inside the inner pot of zeer pots with different absorbent materials are shown in figure 4. All the treatments showed a high humidity level inside the inner pot ranging from 85-100%. The crushed corn husk seemed to achieve highest humidity level between 90-95% compared to other treatments. Because of that sometimes it was observed that water has been accumulated inside the inner pots of corn husk due to condensation process with achieving dew point. Therefore, heat released during this phase change may result in increasing the temperature inside the inner pot of corn husk zeer pots. However, a 25% increase of relative humidity could be achieved in all the treatment pots.

There were no significant differences of average cooling efficiency % of saw dust and coir dust compared with sand (control) as shown in table 1**.** The average cooling efficiency of all absorbent materials except corn husk were in a range of 58%-69%. It was found that Zeer Pot with sand showed a maximum efficiency of around 78% during noon [16]. The average saturation efficiency percentage of crushed corn husk with corn hair was significantly lower than all other materials.

Table 1: Average cooling efficiency of each zeer pots

Material	**Cooling Efficiency %**
Sand	69.04 ± 5.57^{a}
Coir dust	58.60 ± 3.26^{a}
Saw dust	60.88 ± 8.20^{a}
corn husk with corn hair	22.90 ± 3.36^{b}

Values are mean ± Satandard Daviation (n=3). Means followed by the different letter are significantly different at 5% level .

4 CONCLUSION

It can be concluded that the zeer pots with saw dust and coir dust had similar inside temperature variation as sand with a temperature drop of 2-3 °C under the ambient temperature range of 27-33°C and RH range of 65%-85%.Considering temperature drop, RH increment and cooling efficiency of zeer pots with saw dust and coir dust, they can be used as an alternative to sand in zeer pot refrigerator. The zeer pot with crushed corn husk and corn hair was not suitable to preserve foods because of lower temperature and even generating heat due to microorganism activities compared with other absorbent materials. If all zeer pots keep under hot and dry ambient air conditions, cooling efficiency would be improved significantly for better performances.

REFERENCES:

[1]FAO, 2006. Postharvest Management of Fruits and Vegetables in the Asia-Pacific Region.

[2]Barua, P.P.B., Sarma, D., Sharma, J.K., Rahman, M., Boruah, A. and Gogoi, H., "Feasibility Study of Sustainable Sweat Evaporative," International Journal of Engineering Trends and Technology, 12(8), pp.414–420, 2014.

[3]Liberty, J.T., Agidi, G. and Okonkwo, W.I., "Predicting Storability of Fruits and Vegetables in Passive Evaporative Cooling Structures," International Journal of Scientific Engineering and Technology, 3(5), pp.518–523, 2014.

[4]Olosunde, W.A., Igbeka, J.C. and Olurin, T.O., "Performance Evaluation of Absorbent Materials in Evaporative Cooling System for the Storage of Fruits and Vegetables," International Journal of Food Engineering, 5(3), pp.1–15, 2009.

[5]Liberty, J.T., Ugwuishiwu, B.O., Pukuma, S. a. and Odo, C.E., "Principles and Application of Evaporative Cooling Systems for Fruits and Vegetables Preservation, "International Journal of Current Engineering and Technology, 3(3), pp.1000–1006, 2013.

[6]Kamorudeen, A.O., Ismaila, O.A., Mudasiru, A.A., Teslim, A.A. and Kareem Mutui, O., "Development of an Ambient Control Method for Tomatoes Preservation," The International institute for Science, Technology and Education, pp. 1-11, 2013.

[7]Chinenye, N.M., Manuwa, S.I., Olukunle, O.J. and Oluwalana, I.B., "Development of an active evaporative cooling system for short-term storage of fruits and vegetable in a tropical climate, “Agricultural Engineering International: CIGR Journal, 15(4), pp.307–313, 2013.

[8]Dutt, P.S. and Gowda, T., "Experimental Study of Alternatives to Sand in Zeer Pot Refrigeration Technique," International of Modern Engineering Research, 5(5), pp.1–7, 2015.

[9]Abdalla A.M, Abdalla K.N, A.-H.H.., Utilization of date palm leaves and fibers as wetted pads in evaporative coolers. AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA, 26(April), pp.52–54, 1995.

[10]Khond, V., "Experimental investigation of desert cooler performance using four different cooling pad materials," American Journal of Scientific and Industrial Research, 2(3), pp.418–421, 2011.

[11]Vala, K. V, Saiyed, F. and Joshi, D.C., "Evaporative Cooled Storage Structures : An Indian Scenario," Trends in Post-Harvest Technology, 2(3), pp.22–32, 2014.

[12]Elmsaad, E. and Omran, A., 2015. Evaluating the Effect of New Local Materials of Evaporative Cooling Pads. American -Eurasian Journal of Agricultural & Environmental Science, 15(1), pp.78–84

[13]Basediya, A., Samuel, D.V.K. and Beera, V., "Evaporative cooling system for storage of fruits and vegetables - a review," Journal of Food Science and Technology, 50(June), pp.429–442, 2013.

[14]Gerlach, K., Roß, F., Weiß, K., Büscher, W. and Südekum, K.H., "Changes in maize silage fermentation products during aerobic deterioration and effects on dry matter intake by goats," Agricultural and Food Science, 22(1), pp.168–181, 2013.

[15]Tabacco, E., Piano, S., Cavallarin, L., Bernardes, T.F. and Borreani, G.,"Clostridia spore formation during aerobic deterioration of maize and sorghum silages as influenced by Lactobacillus buchneri and Lactobacillus plantarum inoculants, "Journal of Applied Microbiology, 107(5), pp.1632–1641, 2009.

[16]Prabodh Sai Dutt R, Experimental Comparative Analysis of Clay Pot Refrigeration Using Two Different Designs of Pots, “ International Journal of Latest Research in Engineering and Technology (IJLRET)”,ISSN: 2454-5031,(2)2, PP 30-35, February 2016