Experimental Comparative Analysis of Clay Pot Refrigeration Using Two Different Designs of Pots

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ABSTRACT : Refrigeration using clay pots has gained prominence in many countries today. These techniques provide refrigeration by evaporative cooling principle without consuming any electricity and are environment friendly. Off late many improvements in design and materials are being made to popularize this natural refrigeration technique. In this paper experiments are conducted on two such designs and the results compared. One of the design is the popular pot-in-pot or Zeer pot design and the second design is one in which an upper chamber is integrated with pot to store water required for evaporation, thereby eliminating the effect of thermal conductivity of sand used in Zeer Pots.

KEYWORDS - Clay pots, Evaporative cooling, Refrigeration, Thermal conductivity, Zeer Pot

1. INTRODUCTION

People in the underdeveloped countries and rural regions of developing countries face problems towards preserving fruits and vegetables. Farmers need affordable ways to preserve their produce for a few days before the goods are let into the market. Inexpensive ways to cater these needs using indigenously available materials is gaining importance. One such material which has caught people's attention is 'Clay'. Use of clay towards cooling has been in existence from a very long time. Ancient Egyptians have found to be using porous clay pots to store water. Pottery items excavated in Indus valley have also shown that many cooling characters increasing features were added in the water storing pots [1] [2].

The significant effort towards preserving food with the help of clay happened only in 1995, when Mohammed Bah Abba from Nigeria indigenously built a food preservative system from clay pots and termed it as 'Zeer Pot'. With the main intention of helping farmers in preserving their agricultural produce, the 'Zeer Pot' underwent many improvements before the commercial product rolling out in year 2000 [3].

Other such noteworthy efforts are from Mansukhbhai Prajapati, an Indian entrepreneur who developed a refrigerator out of clay to store domestic products like fruits and vegetables in 2005 [4].

Several modifications based on the 'Zeer Pot' design concept have been made and experiments carried out. One such experiment was conducted using a tin pot placed inside a larger clay pot by Kamaldeen O.S, Anugwom Uzoma et al. Results of the experiment have shown that freshness of the mangoes were preserved better in tin pot inside a clay pot but the mangoes began to react with the tin after 5 days leading to its deterioration [5].

Experiments have also shown that in 'Zeer Pots', charcoal and gunny cloth can be used as effective alternatives to sand [6].

In a Zeer pot, water is retained in the voids present in sand poured between two pots. Evaporation of this water creates a decrease in temperature of the inner pot used to store food. The cooling load of the food to be preserved coupled with convective and radiative heat transfer due to surrounding hot and dry climate causes the water to evaporate and thus brings about refrigeration effect on the inner pot. The irreversible heat and mass transfer is dependent on thermal conductivity of clay pot walls, sand present in between pots, water poured in between the pots for evaporation and surface area of inner and outer pots [7].

In this paper attempt has been made to compare the Zeer pot technique with the technique wherein an upper chamber is provided for storing water required for evaporation. This new technique eliminates the effect of thermal conductivity of sand and two clay pot walls. A brief description of two different pot designs used is provided in Section 2 followed by experimental setup details in Section 3. The results are presented and discussed in Section 4 followed by conclusion in Section 5.

2. CLAY POT DESIGNS

2.1 Zeer Pot Design

The Zeer pot design which is popularly used consists of two clay pots. The first clay pot is a large clay pot inside which the second smaller clay pot can be placed. The food that is to be preserved is placed inside the smaller inner pot. The space in between the two pots is filled with sand. The sand acts as a medium to retain water required for evaporative cooling. The water poured will fill the voids present in the sand. The outer clay pot being porous, allows water to permeate through it by hydraulic conductivity. The water thus arriving on the outer surface of the outer pot will be exposed to surrounding air. The latent heat of evaporation energy required is observed from the inner pot and thus water, by evaporating cools the inner pot area and brings about refrigeration of stored food.

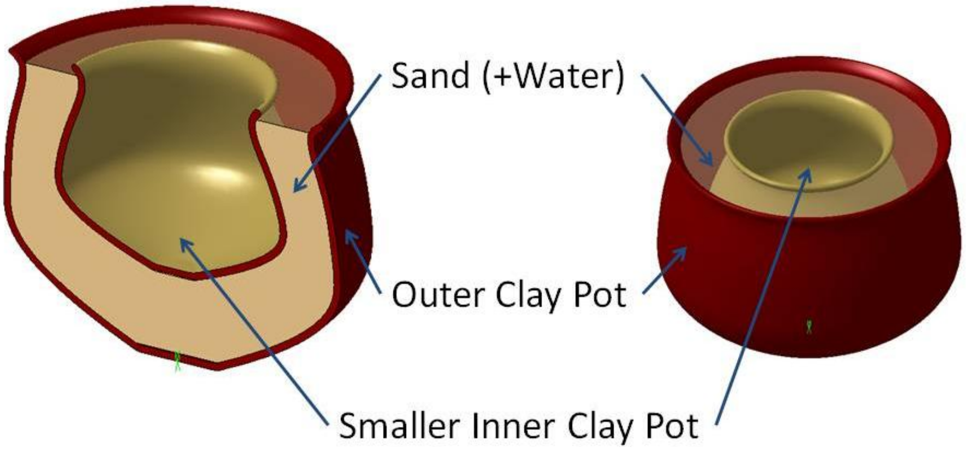

Figure 1: Zeer Pot Design with Cross Section

2.2 Pot with Upper Water Chamber Design

In this design instead of using two different clay pots, only one clay pot is used. The difference is that the water required for evaporative cooling is stored in a chamber which is integrated with the clay pot at the upper portion. The water thus stored is expected to permeate down due to gravity and pores present in clay and wet the outer surface area of the pot. The outer surface of the pot exposed to surrounding air allows the water to evaporate cools the inside space of the pot. This design consists of only one layer of clay wall between the space used for food storage and surrounding, instead of two clay wall layers and a layer of sand as seen in Zeer pot.

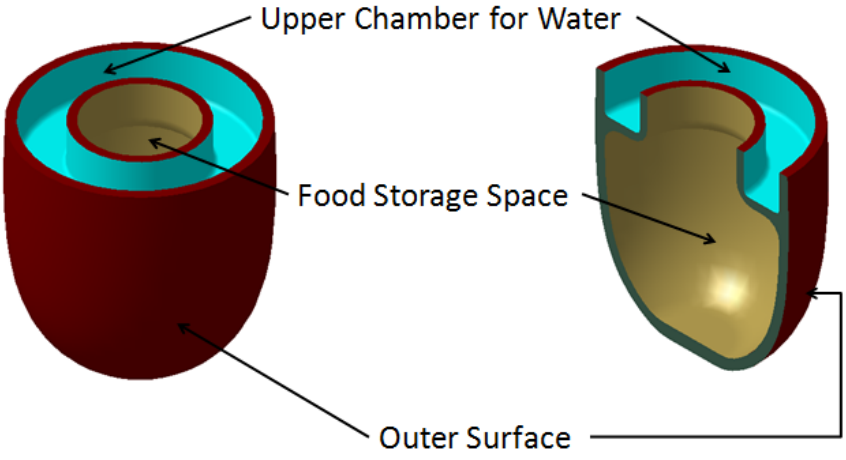

Figure 2: Pot with Upper Chamber Design with Cross Section

(a) (b)

Figure 3: (a) Zeer Pot & (b) Pot with Upper Chamber

3. EXPERIMENTAL SETUP

The experimental setup consisted of a data logger to log temperature and humidity at different intervals of time, computer remotely connected to the data logger and clay pots. The pots are kept on a stand as shown in Fig. 3 to enable flow of air all around the pot assisting in uniform evaporation and convective heat transfer. The complete apparatus is placed under shade to avoid direct radiation from sun.

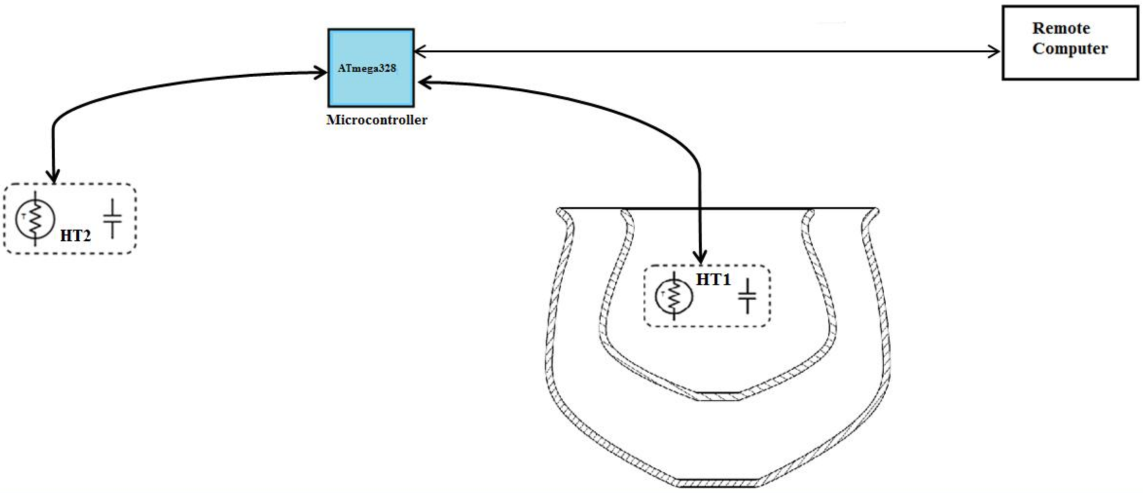

Figure 4: Experimental Arrangement [6]

The data logger consists of an ATmega328 microcontroller connected to two Humidity and Temperature measuring sensors. The sensors AM2302/RHT03, consists of a thermistor to sense the temperature and a polymer capacitor for humidity. Operational ranges of the sensors are 0 to 100% Relative Humidity and -40ºC to 80ºC Temperature. Accuracy is ±2 % for humidity and less than ±0.5ºC for temperature. One sensor (HT1) was placed inside the pot where food is to be preserved and the other sensor (HT2) was placed outside to record ambient temperature and humidity values. Both the sensors were calibrated with respect to each other in order to obtain accurate difference in temperature and humidity between the two locations.

The microcontroller was connected to the remote computer and programmed to record data for every 3 seconds and log directly to the excel sheet on the computer. The readings were recorded from 7:10 to 21:30 hrs.

The wet bulb temperature was calculated using the formula [8]:

$$T_w = T_a*\mathrm{atan}(0.151977*(RH_a+8.313659)^{1/2} + \mathrm{atan}(T_a+RH_a) - \mathrm{atan}(RH_a - 1.676331) + 0.00391838*RH_a^{3/2} *\mathrm{atan}(0.023101*RH_a) - 4.686035 \qquad (1)$$

Where T_w is the wet bulb temperature in ºC, RH_a is the Relative Humidity of air around pot in % and T_a is the temperature of ambient air in ºC measured by sensor.

The efficiency is calculated from the formula [9]:

$$\eta = (T_a - T_i) / (T_a - T_w) *100 \qquad (2)$$

Where T_i is the temperature at food storage space in pot measured in ºC and η is the efficiency in %.

4. RESULTS AND DISCUSSIONS

The results consist of variation in ambient air temperature and storage space temperature through the day and variation of efficiency.

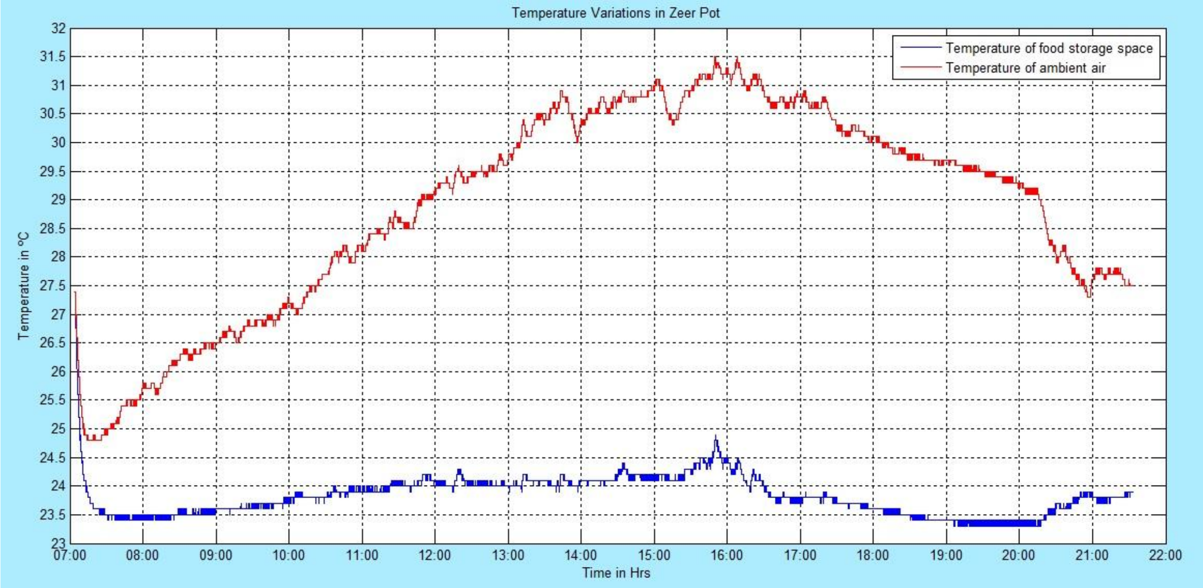

Figure 5: Temperature Variations in Zeer Pot

Plot of temperature variations in Zeer Pot design is as shown in Fig. 5. The ambient temperature is at its highest around 16:00 Hrs in noon at 31.5ºC. The storage space temperature seems to be increasing marginally as the day progresses but after reaching a highest value of around 24.9ºC in noon it keeps decreasing with the advent of evening. The minimum temperature reached is 23.3ºC. The mean temperature is 24.1 ºC and the variation being only ± 0.8 ºC. The Zeer Pot design thus shows a stable temperature at its storage space despite the ambient temperature variation being ± 3.35 ºC around a mean value of 28.15ºC.

Plot of temperature variations in Upper Chamber pot design is shown in Fig. 6. The ambient temperature increases as the day progress and measures a maximum of 30.9ºC at around 15:00 hrs in noon. After that it again decreases. Initially the temperature in the storage space is more than that of surrounding but as the day progresses and system stabilizes, the temperature comes below the ambient temperature. The maximum temperature of the storage space is around 26.6ºC and the variation is ± 1.45ºC around a mean temperature of

25.15ºC. The ambient temperature is observed to be having a variation of ±3.25 ºC around a mean value of 27.65ºC.

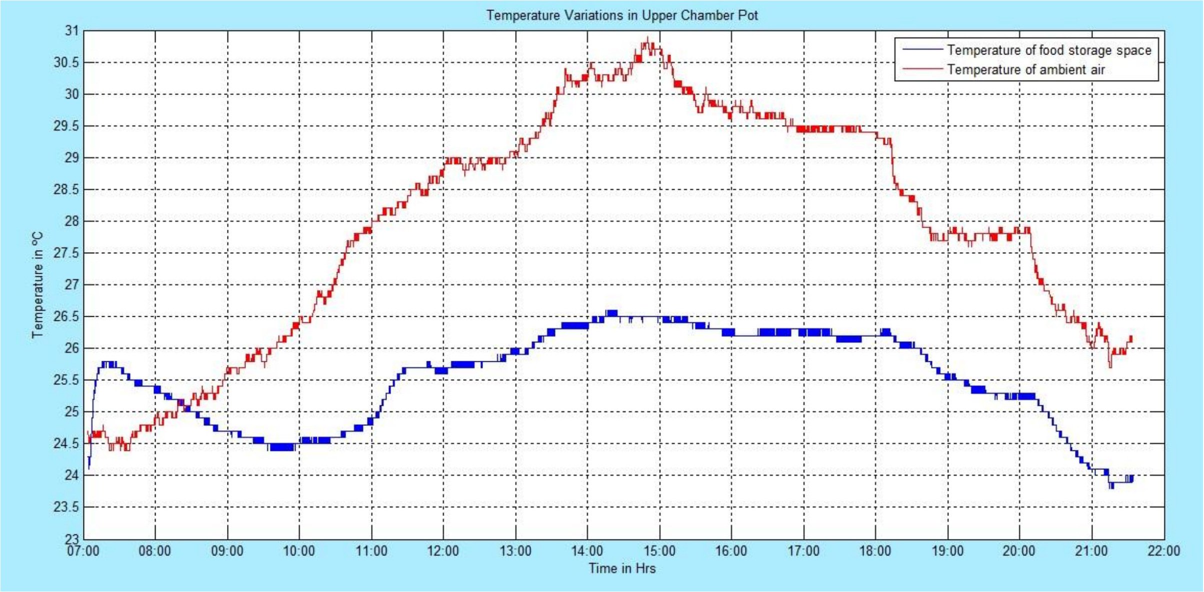

Figure 6: Temperature Variations in Upper Chamber Pot design

From the ambient temperature and relative humidity readings from the sensors, the wet bulb temperature (T_w) is calculated from equation (1). The efficiency (η) in equation (2) is thus calculated and plotted as shown in Fig. 7. For convenience, the efficiencies are plotted from 9:00 hrs instead of 7:00 hrs since the upper chamber pot design is found to be stable after 9:00 hrs during experimentation.

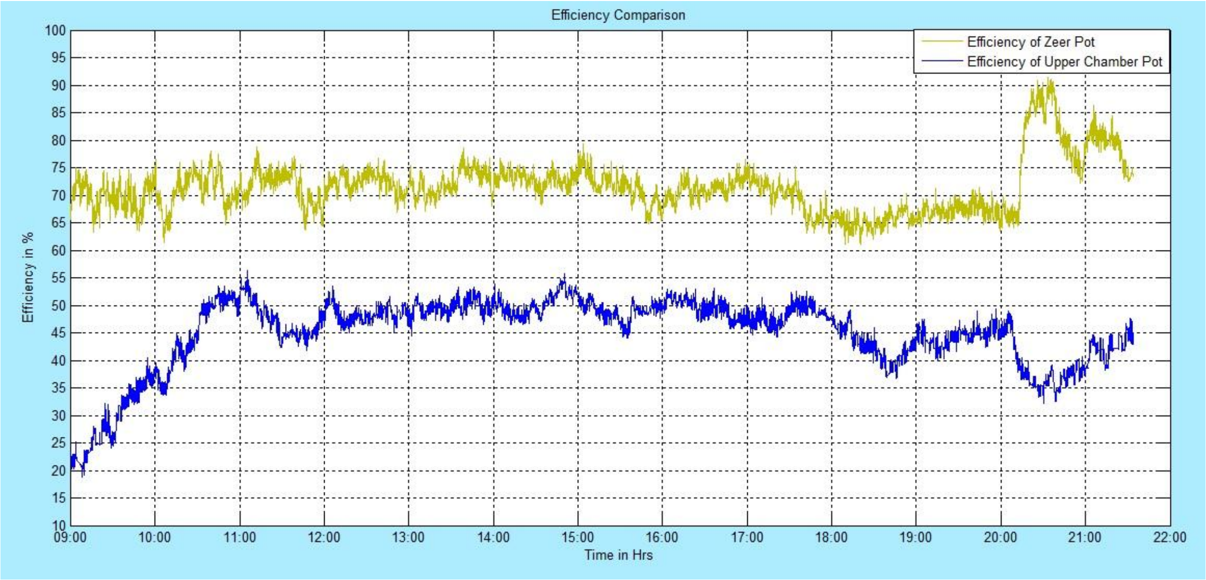

Figure 7: Comparison of Efficiency Variations

During night and early morning, generally the ambient temperature will be low and thus efforts required to preserve foods are minimum. It is only during the day time that maximum efforts are required and thus concentrating on the readings obtained during noon, the Zeer Pot design shows a maximum efficiency of around 78% and the Upper Chamber Pot shows around 56%.

All the experiment results thus show that the existing Zeer Pot design is better than the Upper Chamber Pot design. The Upper Chamber Pot design is a good alternative to Zeer Pot and capable of preserving food, though not as long as in Zeer Pot. In this experiment both the pots are made from the same composition of clay. Hence permeability and porosity will be same. Increasing the permeability of clay by adding sand and other additives might increase the efficiency of the pot.

5. CONCLUSION

In this paper experiments were conducted on the popular Zeer Pot design refrigeration technique and it was compared with a new design having upper chamber to store water required for evaporation. The results obtained were compared and it was found that the Zeer Pot provided better cooling than the new design.

The Upper Chamber Pot is also capable of providing sufficient decrease in temperature required for refrigeration of food. But provisions still remain in improvising the design and material. Increasing the clay permeability and porosity provides one of the prospective areas of improvement to increase the efficiency of both the designs.

Thus, this paper provides an insight towards ways of improving refrigeration using only clay as the raw material. Refrigeration of these types will prove immensely beneficial to the rural masses and to people living in the under developed countries. Also as there is no requirement of electricity to run the system, extensive usage of these sorts of refrigeration systems helps in providing greener environment too.

REFERENCES

[1] Zhiyin Duan, Changhong Zhan, Xingxing Zhang, Mahmud Mustafa, Xudong Zhao, Behrang Alimohammadisagvand, Ala Hasan, Indirect evaporative cooling: Past, present and future potentials, *Renewable and Sustainable Energy Reviews*, 2012, 6823 – 6850.

[2] George Dales, Jonathan Mark Kenoyer, Leslie Alcock, Excavations at Mohenjo Daro, Pakistan: The Pottery, *UPenn Museum of Archaeology*, 1986.

[3] Oluwasola, Oluwemimo, Pot-in-pot Enterprise: Fridge for the Poor, *GIM Case Study No. B080. New York*, United Nations Development Programme, 2011.

[4] *Fifth National Biennial Grassroots Technological Innovation and Traditional Knowledge Awards*, 2009, 43-48.

[5] Kamaldeen O. S, Anugwom Uzoma, Olyemi F.F and Awagu E.F, Effect of NSPRI tin-in-pot compared with pot-in-pot evaporative cooler on the stored fruits, *International Journal of Engineering and Technology, 2 (1)*, 2013, 63-69.

[6] Prabodh Sai Dutt R, Thamme Gowda C.S, Experimental Study of Alternatives to Sand in Zeer Pot Refrigeration Technique, *International Journal of Modern Engineering Research , 5(5),* 2015, 1- 7.

[7] A.W.Date, Heat and Mass transfer analysis of a clay-pot refrigerator, *International Journal of Heat and Mass Transfer, 55,* 2012, 3977-3983.

[8] Roland Stull, Wet-Bulb Temperature from Relative Humidity and Air Temperature, *Journal of Applied Meteorology and Climatology, 50(11),* 2011, 2267-2269.

[9] William Adebisi Olosunde, J.C. Igbeka, Taiwo Olufemi Olurin, Performance Evaluation of Absorbent Materials in Evaporative Cooling System for the Storage of Fruits andVegetables, *International Journal of Food Engineering,* 5(3), 2009.