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EXPERIMENTAL INVESTIGATION OF EFFECTS OF ABSORBING MATERIALS ON PERFORMANCE OF CLAY POT IN POT REFRIGERATOR

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Abstract: Evaporative cooling is a well-known system to be an efficient and economical means for reducing the temperature and increasing the relative humidity in an enclosure and this effect has been extensively tried for increasing the shelf life of agricultural produce in some tropical and subtropical countries. This method is employed in pot in pot refrigerator but with problem of efficiency due to some parameters that affect it's performance. To improve the performance of it, absorbent material such as sand, jute, charcoal, jute and sand, charcoal and sawdust were used in the experiment to see how they affect the cooling rate of the zeer pot. Inner and ambient temperatures, humidity, wind speed were measured and the efficiency of each absorbent used were calculated. The results of the experiments show that the lowest temperature and highest efficiency of sand, jute, charcoal, jute and sand, coconut fibre and sawdust are 17ºC and 99.78%, 18ºC and 97.94%, 10.78ºC and 97.51%, 18ºC and 97.39%, 10ºC and 99.80%, and 12.6ºC and 99.20%, 18ºC and 97.94% respectively. From the results, coconut fibre has the lowest temperature reduction and highest efficiency, followed by charcoal and the least is Jute. Temperature difference between ambient and the inner temperature ranges between 7.4–11.2ºC, 7.4–11.4ºC, 7.4–11.3ºC, 7.4–11.2ºC, 5.4–11.1ºC and 10.6–11.0ºC for sand, jute, charcoal, jute and sand, coconut fibre and sawdust respectively.

Keywords: evaporative cooling, absorbent material, sand, jute, charcoal and sawdust

1. INTRODUCTION

Evaporative cooling is a natural process of removing heat from the body surface of both animals and plants to a comfortable level. Sensible heat is converted to latent heat through this method. This is achieved by movement of air at appropriate humidity condition to absorb water from a wet surface. As air passes over the wet surface, it absorbed moisture thereby reducing temperature of the surface. Environmental conditions affect the rate of cooling of the surface. This is the principle being used in pot-in-pot refrigeration. The process depends on air movement, temperature, humidity and the rate of heat transfer of the absorbing material used (Date, 2012).

Rural area that produces perishable goods are not connected to the national grid in Nigeria and this leads to spoilage of these produce, therefore, there is the need for a good preservative method of agricultural products. The commercial refrigerator is not easy to maintain and affordable by rural dwellers. As a result of this problem Mohammed bah Abba invented zeer pot in 1995 primarily for rural farmers to preserve their produce in Nigeria and was commercialized in 2000 as an inexpensive food storage system (Oluwasola, *et al.,* 2011).

In using zeer pot convective and radiative heat transfer from hot and dry surrounding evaporates the water in the absorbing material and pot surface and brings about cooling of space in the inner pot where food is kept. This slows both the respiratory process and activities of micro-organism which are destructive during storage of food. The irreversible heat and mass transfer is again influenced by the thermal conductivity of pot walls made of clay, sand and water in between the pots surface area of inner and outer pots.

Zeer pot is a pot-in-pot arrangement of two clay pots made out of earthenware clay.

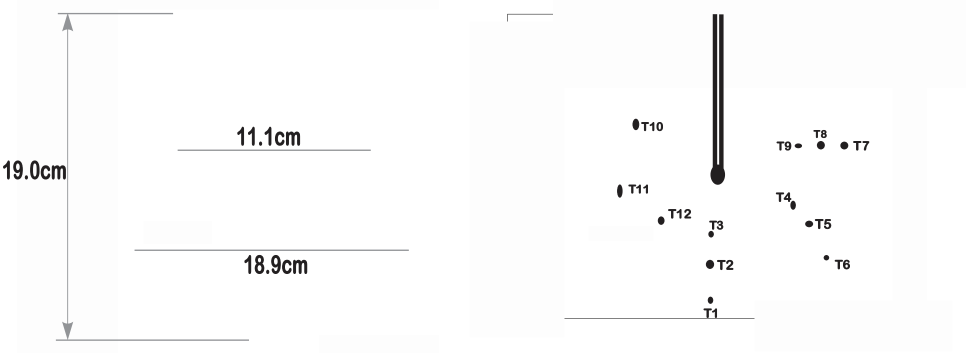
The smaller diameter pot is placed inside the pot of larger diameter and the space between them is filled with an insulative material (e.g. sand, charcoal, gunny cloth, jute etc.). Water is poured to make the insulating materials wet. The moist condition of sand between the pots is ensured. The fruits vegetables and other products to be preserved are placed inside the smaller pot. The opening of the pot is covered with a moist cloth (Date, 2012).

Several researchers have worked on how to improve the performance of the Zeer pot refrigerator ranging from design improvement, testing various materials that can be used as lining material and checking the effects on water level (Prabodh, 2016, Prabodh and Thamme, 2015, Damle and Date, 2015, Olunloyo, Olunloyo and Ibiyeye, 2019, Yahaya and Akande, 2018, Shailaja, 2018 and Aniket, Shyam, Amit and Rajnikant, 2018). Results from the work of these researchers show that more work can still be done to improve the cooling efficiency of zeer pot. Hence this work study the effects of various lining materials on the performance of zeer pot

2. MATERIALS AND METHODS

The Zeer pot used in this work was made from natural earthen ware- clay due to easy availability and inexpensively to farmers. Clay was chosen because of its moldability, porosity and low thermal conductivity. The pots were of spherical shape and could contain 12 kg of the fruits or vegetables to be preserved.

The dimensions of pots used are: outer pot diameter- 0.189m, outer pot surface area- $0.0281m^2$ inner pot diameter – 0.111m, surface area of the inner pot – $0.0097m^2$ as shown in figure 1a.



(a) (b)

Figure 1: (a) Specification of the Zeer Pot used (b) Experimental set up

The efficiency of zeer pot can be calculated by using equation got from Prabodh, 2016 which is as stated:

$$\eta = \frac{T_{amb} - T_{Cold}}{T_{amb} - T_{wtb}} \tag{1}$$

where T_{amb}, T_{cold} and T_{wtb} are ambient, cold and wet bulb temperatures respectively.

3. EXPERIMENTATIONS

The preliminary investigation was done with water inside the inner pot to confirm if there will be temperature difference between the initial and final temperatures.

The experiment was set up as shown in figure 2. Direct radiation from the sun was avoided by placing the pot under the shade. The experiment was done to allow natural convection by placing the pot on a stand to allow air flow around the zeer pot. The absorbing materials used for the experiments are sand, jute, charcoal, jute and sand, coconut fibre and sawdust. Three arrangement of pot in pot were done at a time starting with wet sand, jute and charcoal, the second run was done with mixture of wet jute and sand, sawdust and coconut fibre. The experiment was repeated three times.

Figure 2: Experimental Set-up

Twelve channel temperature recorder with k-type thermocouple and mercury in glass thermometer was used for temperature measurement; hygrometer was used for humidity measurement. The readings were taking every 20 minutes for period of 12 hours. The arrangement of thermocouple sensor for temperature recording is shown in figure 1b. Ambient temperature and humidity, temperature in the pot were recorded and the results are shown in tables 1 to 6. Ambient temperature was measured by the use of thermometer, relative humidity was measured by an hygrometer, the air movement was measured by the use of anemometer and the temperature of water inside the inner pot was measured by a mercury in glass thermometer and recorded.

4. RESULTS AND DISCUSSION

The results mainly consist of variation of temperature within the Zeer pot, ambient temperature, relative humidity and wind speed with respect to time.

Table 1: Variation of Zeer Pot Temperatures, Ambient Temperature, Relative Humidity and Wind Direction with Respect to Time using Sand as the Absorbent Material

Time (min)	Relative Humidity %	Wind Speed(m/s)	Inner temp (°C)	Ambient temp(°C)	Dew Point Temp (°C)	Efficiency η (%)
0	29.80	0.00	22.00	29.40	17.870	64.18
20	30.70	0.70	20.00	29.50	18.145	83.66
40	31.00	0.20	19.00	30.10	18.667	97.09
60	29.10	0.50	18.00	29.20	17.566	96.27
80	30.20	0.70	17.00	28.10	16.976	99.78
100	31.50	0.90	19.00	29.80	18.547	88.87
120	31.60	0.90	21.00	29.90	18.646	79.08

Table 2: Variation of Zeer Pot Temperatures, Ambient Temperature, Relative Humidity and Wind Direction with Respect to Time using Jute as the Absorbent Material

Time (min)	Relative Humidity %	Wind Speed(m/s)	Inner temp (°C)	Ambient temp(°C)	Dew Point Temp (°C)	Efficiency η (%)
0	29.80	0.00	22.00	29.40	17.870	64.18
20	29.80	0.30	20.00	29.20	17.655	79.69
40	29.60	0.70	20.00	30.30	18.504	89.15
60	29.50	0.50	19.00	29.60	17.955	91.03
80	29.30	0.30	18.00	29.40	17.760	97.94
100	29.10	0.20	24.00	29.70	17.940	48.47
120	29.00	0.90	22.00	29.90	18.068	66.77

Table 3: Variation of Zeer Pot Temperatures, Ambient Temperature, Relative Humidity and Wind Direction with Respect to Time using Charcoal as the Absorbent Material

Time (min)	Relative Humidity %	Wind Speed(m/s)	Inner temp (°C)	Ambient temp(°C)	Dew Point Temp (°C)	Efficiency η (%)
0	33.30	0.40	22.00	33.00	21.415	94.95
20	32.10	0.20	20.00	31.20	19.753	97.84
40	32.00	0.20	18.00	28.90	17.965	99.68
60	31.20	0.40	17.00	27.30	16.575	96.04
80	28.70	0.50	14.70	25.30	14.565	98.74
100	26.20	0.70	12.80	23.50	12.748	99.51
120	23.10	0.70	10.78	21.20	10.509	97.47

Table 4: Variation of Zeer Pot Temperatures, Ambient Temperature, Relative Humidity and Wind Direction with Respect to Time using Combination of Jute and Sand as the Absorbent Materials.

Time (min)	Relative Humidity %	Wind Speed(m/s)	Inner temp (°C)	Ambient temp(°C)	Dew Point Temp (°C)	Efficiency η (%)
0	29.80	0.00	22.0	29.40	17.870	64.18
20	29.70	0.30	18.0	29.20	17.700	97.39
40	29.50	0.70	18.0	29.10	17.580	96.35
60	29.50	0.80	20.0	29.30	17.730	80.38
80	29.30	0.70	22.0	30.20	18.360	69.26
100	29.00	1.00	22.00	30.00	18.143	67.47
120	28.20	1.20	21.00	29.00	17.216	67.89

Table 5: Variation of Zeer Pot Temperatures, Ambient Temperature, Relative Humidity and Wind Direction with Respect to Time using coconut fibre as the Absorbent Material.

Time (min)	Relative Humidity %	Wind Speed(m/s)	Inner temp (°C)	Ambient temp(°C)	Dew Point Temp (°C)	Efficiency η (%)
0	32.00	0.40	22.00	27.40	16.813	51.01
20	31.80	0.20	20.00	26.50	16.083	62.40
40	33.10	0.30	18.00	26.50	16.335	83.62
60	32.60	0.40	16.00	26.00	15.853	98.94
80	28.10	0.60	14.00	24.60	13.926	99.31
100	24.10	0.50	12.00	23.10	11.978	99.80
120	21.10	0.70	10.00	20.80	9.852	98.65

Table 6: Variation of Zeer Pot Temperatures, Ambient Temperature, Relative Humidity and Wind Direction with Respect to Time using sawdust as the Absorbent Material.

Time (min)	Relative Humidity %	Wind Speed(m/s)	Inner temp (°C)	Ambient temp(°C)	Dew Point Temp (°C)	Efficiency η (%)
0	32.00	0.00	22.00	33.00	21.113	92.67
20	32.10	0.80	20.20	31.10	19.676	95.41
40	31.50	0.30	18.20	29.10	18.012	98.30
60	29.50	0.50	16.50	27.30	16.226	97.52
80	27.20	0.70	14.23	25.10	14.118	98.98
100	25.10	0.60	12.26	23.00	12.173	99.20
120	25.00	0.70	12.16	22.80	12.010	98.61

Tables 1-6 show variation of relative humidity, wind speed, inner temperature, ambient temperature, dew point temperature and efficiency for different lining materials in between the pots i.e sand, jute, charcoal, jute and sand, coconut fibre and sawdust. Temperature difference between ambient and the inner temperature ranges between 7.4–11.2°C, 7.4–11.4°C, 7.4–11.3°C, 7.4–11.2°C, 5.4–11.1°C and 10.6–11.0°C for sand, jute, charcoal, jute and sand, coconut fibre and sawdust respectively. The results of the experiment show that sand has temperature and efficiency of 17°C and 99.78%, jute has temperature and efficiency of 18°C and 97.94%, charcoal has temperature and efficiency of 10.78°C and 99.51%, jute and sand has temperature and efficiency of 18°C and 97.39%, coconut fibre has temperature and efficiency of 10°C and 99.80%, and sawdust has temperature and efficiency of 12.6°C and 99.20%. The average inner temperature from the least to the highest are 16°C, 16.47°C, 16.51°C, 19.43°C, 20.43°C and 20.71°C for coconut fibre, charcoal, sawdust, sand, jute & sand and jute respectively. All the results show that all the lining materials used could reduce the inner temperature appreciably. However, coconut fibre that has the highest efficiency, reduced the temperature better that the rest lining material, followed by charcoal and the least is jute.

5. CONCLUSION

In this paper, effects of different absorbent materials on the heat reduction and efficiency of the zeer pot were conducted. The inner and ambient temperature, wind speed and humidity were measured every 20 minutes during the experiment that lasted for 120 minutes. The results of the experiment show that sand has temperature and efficiency of 17°C and 99.78%, jute has temperature and efficiency of 18°C and 97.94%, charcoal has temperature and efficiency of 10.78°C and 99.51%, jute and sand has temperature and efficiency of 18°C and 97.39%, coconut fibre has temperature and efficiency of 10°C and 99.80%, and sawdust has temperature and efficiency of 12.6°C and 99.20%. From the results, coconut fibre has the lowest temperature reduction and highest efficiency, followed by charcoal and the least is Jute.

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