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Development of Battery Operated Evaporative Cooling System for Storing Perishables

Musliu O. Sunmonu[a,Ψ], Michael M. Odewole[b], Obafemi I. Obajemihi[c], Timothy D. Akpenpuun[d], and Mikail Jimoh[e]

[a,b,c] University of Ilorin, Department of Food Engineering, PMB 1515, Ilorin, Nigeria; E-mails: sholams2000@yahoo.co.uk; odewole2005@yahoo.com; obafemiobajemihi@gmail.com

[d, e]Department of Agricultural and Biosystems Engineering, Faculty of Engineering and Technology, University of Ilorin, P.M.B. 1515, Ilorin, Kwara State, Nigeria; E-mails: tdenen@gmail.com; mikailjimoh84@gmail.com

[Ψ] - *Corresponding Author*

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Abstract: *A study was conducted to develop a battery operated evaporative cooling structure for storing perishable fruits (pears). The structure consists of a cooling chamber made of aluminium which is inserted inside the galvanized steel interspaced with river bed sand of 7cm. The interspace soil is constantly wetted with water at room temperature to keep the soil moist condition. The other components attached are fan blades which are connected to 12 voltage battery and control by on and off switch to reduce temperature and increase relative humidity of air, electric wires and battery holder. The fan is designed in a way to suit the required operation. It consists of a stator (stationary part) and the rotor (rotary part). The fan blades are attached to the rotor which results in blowing of air due to electromagnetic induction. The capacity of the cooling chamber, amount of air moved in one revolution and fan pressure were 14,888,367mm^3, 95.5 rpm and 14.96N/m^2, respectively. Freshly harvested but matured pears were used for the experiment. The temperature and relative humidity were monitored on daily bases. The mean temperature in the storage structure and ambient were 24.93°C and 31.14°C respectively, while the mean relative humidity in the ECS and ambient were 89.5% and 61.14% respectively. Results showed that the constructed evaporative cooling structure (ECS) was able to maintain store produce at the temperature close to room temperature.*

Keywords: *Battery, Perishables, Fan, Blade, Cooling, Pears.*

1. Introduction

Losses in post-harvest of fruits and vegetables in developing countries are mostly due to the improper storage facilities. While refrigerated cool stores are the best method of preserving fruits and vegetables, they are expensive to buy and run. Consequently, in developing countries there is an interest in simple low-cost alternatives, many of which depend on evaporative cooling which is simple and does not require any external power supply (FAO, 1990). The effect of lack of adequate storage facilities for fresh fruits and vegetables after being harvested leads to the reduction in the quantity of fruit and vegetable that get to the market. This has a direct effect the distribution and consumption of the needed quantity for healthy living. Adequate storage involves proper regulation of temperature, humidity, air calculation, proper stacking pattern, regular inspection and prompt produce disposal as soon as storage life has been attained (Benzionic, 2008).

Fruits and Vegetables are vital agricultural products for human consumption worldwide. They are rich in vitamins and minerals such as carotene (provitamin A), ascorbic acid, riboflavin, iron, iodine, calcium, etc (Ihekoronye and Ngoddy, 1985). Fruits and vegetables are important sources of minerals and vitamins especially A and C. They also provide carbohydrates and protein, which are needed for normal healthy growth (Abdul, 1989; Salunkhe and Kadam, 1995; Adetuyi *et, al.,* 2008; Olusunde *et, al.,* 2009). Fruits and vegetables are of good importance in human health.

Evaporative cooling is the process by which the temperature of a substance is reduced due to the cooling effect from the evaporation of water. The conversion of sensible heat to latent heat causes a decrease in the ambient temperature as water is evaporated providing useful cooling. This cooling effect has been used on various scales from small space cooling to large industrial applications. The water evaporates into the air raising its humidity and at the same time reducing the temperature of the air (FAO, 1995). The basic principle relies on cooling by evaporation. When water evaporates it draws energy from its surroundings which produced a considerable cooling effect. Different designs of evaporative coolers have been reported in literature for the preservation of fruits and vegetables (Redulla, 1984a; Redulla ,1984b; Sanni, 1999; Acedo ,1997 ;Vakis, 1981;FAO, 1986; Roy 1989; Rusten, 1985; Alebiowu, 1985; Abdalla and Abdalla, 1995). However, none of these designs has made use of a battery that can cater for cases where there are irregular supplies of electricity.

Apart from the epileptic power supply and low income of farmers in the rural areas to purchase a

refrigerator, there is need to develop a battery operated evaporative cooling structure for fruits and vegetables in order to reduce the spoilage of agricultural materials.

2 Materials and Methods

2.1 Material Selection

The knowledge of the properties of materials and the way they behave under load is necessary. Example of this characteristic may include strength, stiffness, flexibility, durability, weight, resistance of heat and welding, ability to cast or hardening, machine ability, electrical conductivity, resistance to corrosion, availabilities of materials from local market, protection of food etc.

2.2 Convenient and Automatic Features

The control switch for starting the device as well as the stopping lever should be placed at convenient location and within the reach of the operator. Cases of replacement of worn or damage part easy access to these operation of a machine in term of maintenance and consistent functioning at full capacity were considered.

2.3 Noise requirement

The design eliminates noise and vibration as much as possible. The use of soft materials that can absorb vibration and enable the device to operate without vibrating was considered.

2.4 Capacity of the Cooling Chamber

Each cooling chamber has diameter of 270mm (inner cylinder), 390 mm (outer cylinder) and height of 260 mm (inner cylinder) and 320mm (outer cylinder). The capacities of the cooling chamber were mathematically determined by

$V = \pi r^2 h$ ..... (1)

Where r is the radius of inner cylinder and d is diameter. Hence,

r = d/2

= 270/2 = 135mm π = 3.142

V = 3.142 x 135^2 x 260 = 14,888 mm^3

2.5 Amount of Air Moved in One Revolution

Q = Swept Area of the blade x Velocity

Q = $\pi D^2/4$ * *Velocity*, with assumed velocity of 1*m/s*

..... (2)

And *D* is the diameter of fan blade.

The diameter of the fan blade is 200mm (0.2m)

Radius (r) = D/2 = 0.2/2 = 0.1mm

$$Q = \frac{3.142 \times 0.2^2}{4} X\ 1 = 0.0314\ m^3/s$$

But, Velocity V= r x $\frac{\pi}{30 \times n}$ ..... (3)

Where r is the radius of fan blade, n is the velocity in revolution per minute.

$$n = \frac{30 \times V}{\pi r} = \frac{30 \times 1}{3.142 \times 0.1}$$

n = 95.5 rpm

2.6 Fan Pressure

The fan pressure is determined by the relation;

$P = K \rho n^2$ ..... (4)

Where n is the fan speed (rpm)

D is the diameter of fan (m) and *P* is the air density (kg/m^3)

Where *K* is the constant of proportionality (dimensionless) and is given by;

$$K = \frac{Q}{pnD^3} = \frac{0.03142}{1000 \times 95.5 \times 0.2^3} = 4.1 \times 10^{-5}$$

Recall fan pressure

(P) = K ρ n^2D^2 = 4.1×10^{-5} x 1000 x 95.5^2 x 0.2^2

= $14.96 N/m^2$

2.7 Description of Battery Operated Evaporative Cooling Structure (ECS)

The cooling chambers was made with cylindrical aluminum sheet inserted inside another cylindrical galvanized steel and inter spaced with clay as lagging material. The soil is constantly wet with water at room temperature to keep the soil in moist condition that six blades were constructed inside the cooling chamber with plastic material. Figure 1 show the isometric view of the battery-operated evaporative cooling structure. The orthographic projection and exploded view of the battery-operated evaporative cooling structure are shown in Figures 2 and 3, respectively.

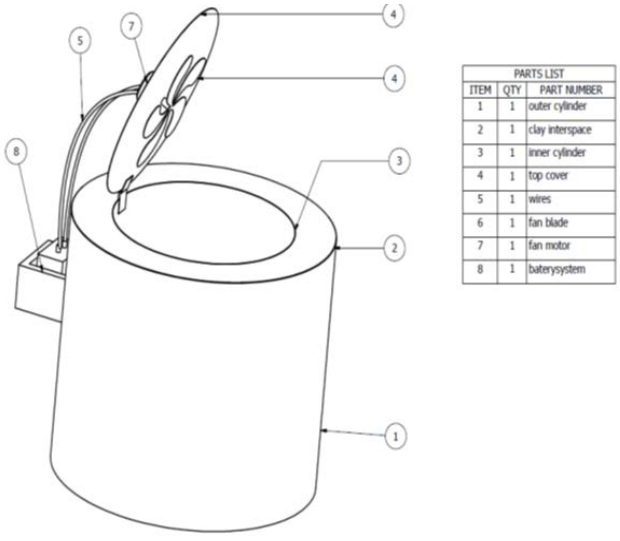


Figure 1. Isometric View of Battery-operated Evaporative Cooling Structure

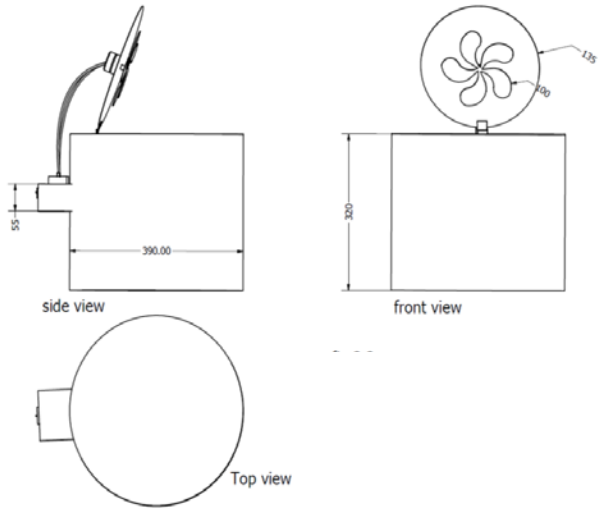
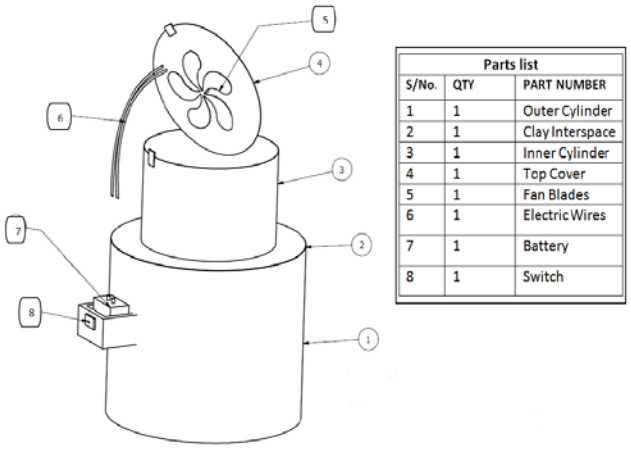


Figure 2. Orthographic Projection of Battery-operated Cooling Structure



Parts list		
S/No.	QTY	PART NUMBER
1	1	Outer Cylinder
2	1	Clay Interspace
3	1	Inner Cylinder
4	1	Top Cover
5	1	Fan Blades
6	1	Electric Wires
7	1	Battery
8	1	Switch

Figure 3. Exploded view of battery operated evaporative cooling structure

The fan is designed to suit the required operation. It consists of stator (stationary part) and the rotor (rotary part). Stator is a part which contains pairs of slotted cores that is made up of thin section of soft iron. The cores are wounded with insulated copper wire to form one or more pairs of definite magnetic pole. This stator winding is connected to direct current source to form an electromagnet and the rotor is inserted in stator. The north pole of the stator will induce the north pole at the upper portion of the rotor while south pole of the stator will induce the south pole at the lower portion of rotor. The fan blades are attached to the rotor which results in blowing of air due to electromagnetic induction.

A slot which is of the same size as the motor of was made to give room for inserting the motor of the fan and attached to the cover of the aluminum with the use of bolt and nut. The wire from the source of electricity (Battery 12v) was run to the main switch (single step control) and the wire of thickness 1 mm from the fan motor met at main switch. The circuit was closed and the current flow led to rotation of the fan blade inside the Battery operated evaporative cooling structure. This served as a cooling aid to the pear inside the cooling chamber in addition to cooling resulted from evaporation of water from the wet surface (moist riverbed sand) by air that is not too humid.

3. Results and Discussions

Table 1 shows the summary statistics of temperature and relative humidity of the storage conditions. The results show that, the temperature in the evaporative cooling structure is lower than that obtained from the ambient for stored pears while the relative humidity was observed to be higher in Evaporative Cooling Structure. This is in line with the finding of Samuel et al. (2013).

Table 1. Summary Statistics of the Temperature and Relative Humidity

		AMBIENT CONDITION		ECS CONDITION	
Storage Condition		Temperature (^{0}C)	Relative Humidity (%)	Temperature (^{0}C)	Relative Humidity (%)
Ambient	Mean	30.33	61.67	28.33	79.33
	SD	0.58	2.89	0.58	0.58
ECS	Mean	25.00	65.00	26.00	80.00
	SD	1.00	5.00	0.00	1.00
Ambient	Mean	32.00	61.00	23.67	80.67
	SD	1.00	1.73	0.58	1.53
ECS	Mean	29.67	64.67	24.00	81.00
	SD	0.58	4.04	1.00	1.00
Ambient	Mean	31.00	60.67	23.67	79.00
	SD	1.00	1.15	0.58	0.00
ECS	Mean	30.67	62.67	23.33	78.67
	SD	1.15	2.52	0.58	0.58

Table 1. Summary Statistics of the Temperature and Relative Humidity *(continued)*

Storage Condition		AMBIENT CONDITION		ECS CONDITION	
		Temperature (^{0}C)	Relative Humidity (%)	Temperature (^{0}C)	Relative Humidity (%)
Ambient	Mean	31.33	64.33	22.67	80.00
	SD	0.58	2.31	0.58	1.00
ECS	Mean	30.67	63.00	23.67	81.33
	SD	1.15	1.00	0.58	3.21
Ambient	Mean	31.00	65.00	22.33	79.33
	SD	1.00	1.73	0.58	2.31
ECS	Mean	32.67	60.67	24.33	81.00
	SD	1.53	1.15	1.53	1.00
Ambient	Mean	30.67	64.00	23.67	79.00
	SD	1.15	1.73	0.58	0.00
ECS	Mean	32.00	63.33	24.33	76.67
	SD	1.00	4.16	0.58	2.31
Ambient	Mean	31.33	61.67	23.67	74.00
	SD	1.53	2.89	0.58	0.00
ECS	Mean	31.00	63.67	24.33	73.00
	SD	1.00	1.53	0.58	0.00

Figure 4 shows the overview of the storage conditions as determined by temperature and relative humidity. The relative humidity of the ECS appears to be stable along the storage days and was higher compared to the relative humidity of the ambient. This may imply that the ECS improved or increased the relative humidity of the storage environment by at least 20% on the average. A significant difference in temperature (10°C) was observed between the Evaporative Cooling Structure and ambient. Generally, it can be concluded that ECS increases the relative humidity and decreases the temperature of the storage environment (Acedo, 1997).

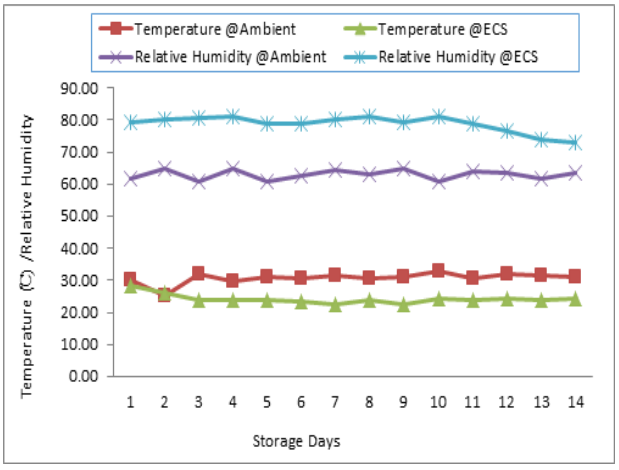


Figure 4. Chart Showing Variations in Temperature and Relative Humidity Ambient and ECS.

The temperature and relative humidity of the ECS and Ambient shows variations which might be a function of the direct effect of the storage structure. These may imply that the nutritional qualities of stored pear fruits under these varied storage condition are not the same.

4. Conclusions and Recommendations

It can be concluded at the end of this research that the constructed evaporative cooling structure (ECS) was able to maintain store produce at the temperature close to room temperature. From the result obtained, the average temperature of ECS is 24.93°C and relative humidity is 89.50%, while the ambient temperature is 31.14°C and relative humidity is 63.14%. It is however recommended that different size of fan blades of the ECS should be designed and the effect of cooling rate should be considered in further research.

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Authors' Biographical Notes:

Musliu Olushola Sunmonu *holds B.Eng., M.Eng and PhD degrees in Agricultural Engineering with specialty in Food Processing and storage. He is currently Senior Lecturer in the Department of Food Engineering, University of Ilorin. His research interests are in the area of design and development of post-harvest technologies and modelling of post-harvest systems. Dr. Sunmonu is a member of the following professional bodies: American Society of Agricultural and Biological Engineers (ASABE), Council for the Regulation of Engineering in Nigeria (COREN), Nigerian Society of Engineers (NSE) and Nigerian Institution of Agricultural Engineers (NIAE). Some of his completed projects already commissioned are a milk silo with agitator and cooling unit for milk storage, collapsible drum dryer and movable cabinet dryers among others.*

Michael Mayokun Odewole *is Lecturer of the Department of Food Engineering, University of Ilorin, Ilorin, Nigeria. He obtained his Bachelor of Engineering (B.Eng.) and Master of Engineering (M.Eng.) degrees in Agricultural and Biosystems Engineering with specialisation in Crop/Food Processing and Storage Engineering. Currently, he is pursuing Ph.D in the Department of Agricultural and Environmental Engineering, Federal University of Technology Akure, Nigeria. Mr. Odewole has over twenty-five (25) publications in his area of specialisation. He is a member of the following professional bodies: American Society of Agricultural and Biological Engineers (ASABE), Council for the Regulation of Engineering in Nigeria (COREN), Nigerian Society of Engineers (NSE) and Nigerian Institution of Agricultural Engineers (NIAE).*

Obafemi Ibitayo Obajemihi *holds B.Eng. and M.Eng degrees in Agricultural and Bioresources Engineering. He specialises in the area of post-harvest technology and food engineering, and currently a PhD researcher in the department of Agricultural and Biosystems Engineering, University of Ilorin, Nigeria. Mr. Obajemihi has keen interest in Modelling and optimisation of drying process conditions for high quality food products. He is presently serving as a Lecturer/ Researcher in the Department of Food and Bioprocess Engineering, University of Ilorin. He is registered engineer and member of the Nigerian Society of Engineers (NSE) and the American Society of Agricultural and Biological Engineers (ASABE).*

Timothy Denen Akpenpuun *holds B.Sc and M.Sc degrees in Agricultural and Environmental Engineering with specialisation in Farm Structures and Environmental Control. Akpenpuun teaches at the Department of Agricultural and Biosystems Engineering, Faculty of Engineering and Technology, University of Ilorin, Ilorin. His areas of research interests are controlled environment agriculture (CEA) and Agro-Meteorology.*

Mikail Jimoh *holds B.Eng. in Agricultural and Biosystems Engineering from University of Ilorin with specialisation in Farm Structures.*

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