SSRG International Journal of Agriculture & Environmental Science
ISSN: 2394-2568/ https://doi.org/10.14445/23942568/IJAES-V9I3P111

Volume 9 Issue 3, 77-88, May-June 2022

Original Article

Development of Jute Pad Zero Energy Evaporator for Improve Storability in Fresh Fruits Preservation

Ejiko Samuel Omojola[1], Filani Oreoluwa Abidemi[2], Olakolegan Oluwasayo Dorcas[3]

[1,3]Department of Mechanical Engineering, The Federal Polytechnic, Ado-Ekiti.
[2]Department of Agricultural and Bio-Environmental Engineering, The Federal Polytechnic, Ado-Ekiti.

Received: 18 April 2022 Revised: 10 June 2022 Accepted: 19 June 2022 Published: 05 July 2022

Abstract *- The preservation of fresh fruits requires the development of an evaporative cooling system for increasing the shelf life of oranges and other fruits was evaluated with the use of two different shapes of zero energy evaporators which consist of a rectangular and triangular frame with the incorporation of jute pad that is 0.06 m thickness. A water reservoir of the capacity of 21 litres is linked through a discharge pipe that supplies water to keep the cooling pad (jute) continuously wet. Studies were conducted to determine harvested orange freshness with temperature and weight compared by employing a thermometer and standard measuring scale. The data were observed daily. The result obtained from both cooling systems (rectangular and triangular shape cooling systems) revealed that the rectangular-shaped evaporative cooling system had overall advantages over the triangular shape of cooling system. The shelf life of the oranges that were examined lasted 12 to 14 days during the time the experimental work of this project was carried out. The temperature inside the evaporative cooling system (ECS) was determined, and the result was proven that the optimum temperature that can be derived inside the ECS is 31°C which corresponds with the maximum preservation temperature of fruits as prescribed by the food association organization (FAO) is 32°C. Thus, the cooling system with zero energy has a useful advantage in Nigeria's developing economy.*

Keywords *- Evaporative, Fruits, Jute Pad, Shelf life, and Storability.*

1. Introduction

Fruits are a very important food item widely consumed in Nigeria and other countries. Fruit is an important source of digestible carbohydrates, minerals, and vitamins A and C. Fruit also form an essential part of a balanced diet. In addition, it provides roughage (indigestible carbohydrates), which are essential for normal healthy digestion [1]. Refrigeration is commonly available, but it has several challenges in preserving fruits such as Mango, Banana, and Plantain. They cannot be preserved in our regular domestic refrigerator for long as they are influenced by chilling injury. Preservation methods of raw and processed fruits include storage in ventilated shed, storage at low temperatures, an evaporative coolant system, waxing, and chemical treatment. Apart from this, refrigerators costs are more than the reach of farmers with low income in rural areas.

However, the development of storage technology for fruits and other produce shows important benefits regarding extended shelf life and quality of produce. Still, lack of capital may force the farmer to ignore the use of an effective storage device, even when available and effectively managed [2, 3]. UNIDO [4] estimated that one-fifth of all manufacturing industries in developing nations and a substantial part of the raw materials were sourced from fruits between 1979 and 1980 which are processed into other forms. This further stresses the importance of fruits in developing countries' economic and industrial development, among which Nigeria is one. The major constituent of fruits is water. In their fresh form, it contains more than 80 percent water, with some varieties such as cucumber, lettuce, and melons containing about 95 percent water [5]. The principle of evaporative cooling of fruits is simple, relatively efficient, and has a low running cost. Heat in the air evaporates the water, resulting in a drop in the air temperature and an increase in relative humidity. Latent heat of evaporation enables the evaporative system to remove heat from an object, thereby reducing its temperature. This normally occurs when air that is not saturated is blown across a wet surface [6]. An active cooling system has a pad (moist material), fan, storage cabin, and water pump. The pad cooling effect depends on the atmospheric air velocity, pad thickness, and the saturation level of the pad, which is a role of the water flow rate wetting the pad and the material of construction of the pad. Apart from the general demand for the efficient operation of an evaporative cooling system, the efficiency of an active evaporative cooler depends on the rate and amount of evaporation of water from the pad [7].

Fruits are highly decomposable items that spoil within a limited time due to their decomposable and seasonal nature. They must produce maintained in seasons to ensure their constant supply throughout the year with their nutritional value still retained [8]. The major problem during storage is what happens to these produce's quality variable, especially the physical attributes such as; color, texture, and freshness, which the price sometimes depends on. The quality of fruits and vegetables may be solemnly compromised within a few hours of harvest unless the crop has been cooled on time to control the worsening [9].

Fresh fruits and vegetables' quality depends on post-harvest handling, transportation, and storage [10]. Fresh fruits and vegetables' flavors, aroma, and color are necessary for normal health [11]. Vegetables are normally regarded as necessary herbaceous plants with high moisture content in their fresh forms. They provide maximum vitamins when consumed fresh. They possess substantial quantities of vitamins A, B, C, D, E, and K, which help preserve the body against diseases and donate in no small measure to good health [12]. Temperature and relative humidity of the storage environment is important when handling fruits to increase their shelf life. Increasing the relative humidity of freshly harvested produce in the storage environment will slow the rate of water loss and other metabolic activities [13]. The destruction of these crops is caused primarily by loss of moisture, change in composition, and pathological attack. This is why vegetables are normally classified as perishable crops. After harvest, they shrivel, wither, or rot away speedily, particularly under hot tropical conditions [14].

Therefore, the safe and prolonged storage of decomposable commodities must be one of high humidity and low temperature. This will retard moisture loss, respiratory process, and activity of micro-organisms (pathogens) which are the most destructive activity during the storage of vegetable crops [15].

2. Materials and Method

The Evaporative Cooling System (ECS) development requires establishing the quantity to be preserved (assumption). The quantity will determine the volumetric capacity of the ECS. The desired temperature in the ECS to the mean external temperature will be used to establish the jute pad thickness. An external watering device for keeping the pad moist will be placed upon the frame for supply by gravity. The trays in the chambers are non-corrosive, having sufficient space for air circulation. The stored fruit samples will be monitored daily to establish the actual shelf life.

Table 1. Sequence of Operation

S/N	MATERIALS	TOOLS	OPERATION
1	Square pipe	Mild steel	It is used for the framework of the entire cooling system.
2	Water tank	Plastic	It is a container used to store water.
3	Wire mesh	Iron	This is made up of the frame for the pad that held the cooling system and will be used where the fruits will be placed.
4	Jute pad	Fibers	This is used for the wetted pad material.
5	Hose	Rubber	This is used to round the wall of the cooling system for wetting the pad material.
6	Paint	Titanium iv oxide, calcium carbonate, and kaolin	This is used for the surface finish of the cooling system.
7	Electrode	Copper	This is used in welding two or more metals together.
8	Cutting disc	Fiberglass reinforcing net.	This is used to cut through hard, thick material.
9	Grinding disc	Fiberglass reinforcing net.	This is used for grinding and removing excess material of surface metal welds.

2.1. Design Calculations

These calculations were carried out to ensure that the ECS design achieves the aim: cross-sectional area of both shapes, the Thickness of the pad, the flow rate, nozzle diameter, coefficient of discharge and discharge volume, heat transfer analysis, and Curved surface area of the frustum. The cross-sectional areas of the rectangular and triangular ECSs shapes were determined using equations 1 and 2 as given by Lana [16] and Ejiko [17].

The cross sectional area of the two designs will be the same CSA = cross-sectional area
Therefore,
Triangle CSA = Rectangle CSA
Cross-sectional area of the rectangle

$$Area = L \times B \quad (1)$$

Where,
L= length of the shape
B= Breath of the shape
Therefore,

$$L = 0.9144mm$$
$$B = 0.6096mm$$
$$Area = L \times B$$
$$Area = 0.9144 \times 0.6096$$
$$Area = 0.5574m$$

The cross-sectional area of the triangle

$$Area = {}^{1}/_{2}\, base \times height \quad (2)$$

$$Area = {}^{1}/_{2}\, 0.9144 \times 1.2192$$
$$Area = 0.4572 \times 1.2192$$
$$Area = 0.5574m$$

The Thickness of the pad was determined using equation 3 as given by [18].

$$Q_{hg} = \frac{\Delta T}{x} \quad (3)$$

Where,
Q_{hg}= Rate of discharge (W/m^2)
ΔT = Temperature difference of thermal (℃)
x = Thickness of the insulating material (m)
ΔT =mean temperature outer – best preservation temperature

$$\Delta T = MOT - BPT$$
$$\Delta T = 32 - 5$$

$\Delta T = 27$ºC
Rate of discharge

$$Q = AV$$
$$Q = 0.56 \times 20$$
$$Q = 11.2w/m^2$$

Substitution

$$11.2 = \frac{32 - 5}{x}$$

$$x = 2.45mm$$

The flow rate, nozzle diameter, discharge coefficient, and discharge volume were determined using equations 4 and 5 as given by Lumen, [19] and equation 6 as given by [20].

$$\text{Flow rate} = Q = AV \quad (4)$$

Where,
A= cross sectional area
V= mean velocity
Nozzle diameter: Using the equation of continuity gives a somewhat different insight into the equation, which states;

$$A_1V_1 = A_2V_2$$

$$V_2 = \frac{A_1}{A_2}V_1 \quad (5)$$

Coefficient of discharge

$$cd = Ao\sqrt{2gh \div Q} \quad (6)$$

Where,
Cd= coefficient of discharge
A= Area
g= acceleration due to gravity
h=height
Q= rate of discharge
Heat transfer analysis

The heat gain by the individual insulating material of the cabinet was estimated using Fourier's law of heat conduction using equation 7 as given by [18] and air density analysis as captured by Oigbochie and Ejiko, [21].

$$Q_{hg} = \frac{kA\Delta T}{x} \quad (7)$$

Where,
Q_{hg}= Quantity of heat gained by the material (W/m^2)
A = Overall area of the material (m)
k = Thermal conductivity of the material (W/m K)
ΔT= Temperature difference of thermal (℃)
x = Thickness of the insulating material (m)
The heat gained by the square pipe for rectangular ECS is calculated as follows:

$$Q_{hgs}\frac{k_{gs}A_{gs}\Delta T_{gs}}{x_{gs}}$$

$$Q_{hgs} = \frac{1.61 \times 0.5574 \times (32.2 - 21.3)}{0.00254}$$

$$Q_{hgs} = 3851.10w/m^2$$

The heat gained by the square pipe for triangular ECS is calculated as follows:

$$Q_{hgs} = \frac{k_{gs}A_{gs}\Delta T_{gs}}{x_{gs}}$$

$$Q_{hgs} = \frac{1.61 \times 0.5574 \times (32.2 - 22.3)}{0.00254}$$

$$Q_{hgs} = 3497.79w/m^2$$

The heat gained by the jute pad for rectangular ECS is calculated as follows:

$$Q_j = \frac{k_jA_j\Delta T_j}{x_j}$$

$$Q_j = \frac{0.0004273 \times 0.5574 \times (32.2 - 21.3)}{0.06}$$

$$Q_j = 0.4326w/m^2$$

The heat gained by the jute pad for triangular ECS is calculated as follows:

$$Q_j = \frac{k_jA_j\Delta T_j}{x_j}$$

$$Q_j = \frac{0.0004273 \times 0.5574 \times (32.2 - 21.3)}{0.06}$$

$$Q_j = 0.0393w/m^2$$

The curved surface area of the frustum was determined using equations 8 to 16 as given by [22].
Diameter of bigger circular end = $345mm$

$$\text{Radius} = r1 = \frac{345}{2}mm \quad (8)$$

Diameter of smaller circular end = $295mm$
Radius = $r2 = \frac{295}{2}mm$

Now,
Height of frustum = Total height of bucket − Height of cylinder

$$= 291 - 116 = 175mm$$

1. Slant height of frustum (l) = $\sqrt{h^2 + (r1 - r2)^2}$ (9)

$$= \sqrt{175^2 + \left(\frac{345}{2} - \frac{295}{2}\right)^2}$$

$$= 176.77mm$$

2. Curved surface area of the frustum = $ƛ(r1 + r2)l$ (10)

$$= ƛ \times 176.77\left(\frac{345}{2} - \frac{295}{2}\right)$$

$$= 13885.28mm$$

3. Area of the circular base

A base is a circle with a radius = $r2 = \frac{295}{2}$

Area of circular base = $ƛr2^2$ (11)

$$= ƛ \times \left(\frac{295}{2}\right)^2$$

$$= ƛ \times (147.5)^2$$

$$= 21756.25 \times 3.142$$

$$= 68358.14mm$$

4. Curved surface area of the cylinder

Radius of cylinder = $r2 = \frac{295}{2}$

Height of cylinder = $116mm$

The curved surface area of the cylinder = $2ƛrh$ (12)= $2 \times ƛ \times \left(\frac{295}{2}\right) \times 116$

$$= 2 \times 3.142 \times 147.5 \times 116$$

$$= 107519.24mm$$

5. Volume of water in bucket =volume of the frustum

$$= \frac{1}{3}ƛh(r1^2 + r2^2 + r2r2) \qquad (13)$$

$$= \frac{1}{3} \times \frac{22}{7} \times 175\left(\left(\frac{345}{2}\right)^2 + \left(\frac{295}{2}\right)^2 + \frac{345}{2} \times \frac{295}{2}\right)$$

$$= \frac{22}{7} \times \frac{175}{3}((172.5)^2 + (147.5)^2 + 172.5 \times 147.5)$$

$$= \frac{22}{7} \times \frac{175}{3}(29756.25 + 21756..25 + 25443.75)$$

$$= \frac{22}{7} \times \frac{175}{3}(76956.25)$$

$$= \frac{14104798.02}{1000} litres$$

$$= 14104.79 litres$$

6. $L^2 = H^2 + (R - r)^2$ (14)

$$176.7^2 = (291)^2 + (172.5 - r)^2$$

$$31222.89 = 84681 + (172.5 - r)^2$$

$$53458.11 = (172.5 - r)^2$$

Taking square root on both sides,

$$231.2 = 172.5 - r$$

$$r = 59.2$$

TSA of frustum

$TSA = ƛL(R + r) + ƛ(R^2 + r^2)$ (15)

$$TSA = ƛ(176.7)(172.5 + 59.2) + ƛ(172.5^2 + 59.2^2)$$

$$TSA = ƛ(176.7) \times 231.7 + ƛ(29756.25 + 3504.64)$$

$$TSA = ƛ40941.39 + ƛ(33260.89)$$

$$TSA = 74202.28ƛ$$

CSA of frustum

$CSA = ƛL(R + r)$ (16)

$CSA = ƛ(176.7)(172.5 + 59.2)$

$$CSA = ƛ(176.7)(231.7)$$

$$CSA = 40941.39ƛ$$

2.2. Construction Methods of the Evaporator Cooling System

This study constructed an evaporative cooling system of 20 kg storage capacity, suitable for preserving fresh fruit. The evaporative cooling system consists of the cabinet and the transmitting medium [cooling pad]. It is rectangular and triangular-shaped with a total storage space of 0.02m^3. The frame is made of square pipe and internally insulated with a cooling pad of 0.025m [jute materials] and a water pump with a discharge capacity of 3.5l/min. A water reservoir capacity of 0.05m^3 is linked to the top cooling system through a hose supplying water to keep the cooling pad continuously wet. The net was placed at the internal and external walls of the evaporator. The basic principle relies on cooling by evaporator; when the system is set in operation, the dry air from the surrounding pass over the wet surface [cooling pad] and soaked water away from the cooling pad. When water evaporates, it draws energy from its surroundings [storage chamber] which produces a considerable cooling effect in the cooling chamber. The isometric view of the developed evaporative cooling system is shown in Figures 1 to 3.

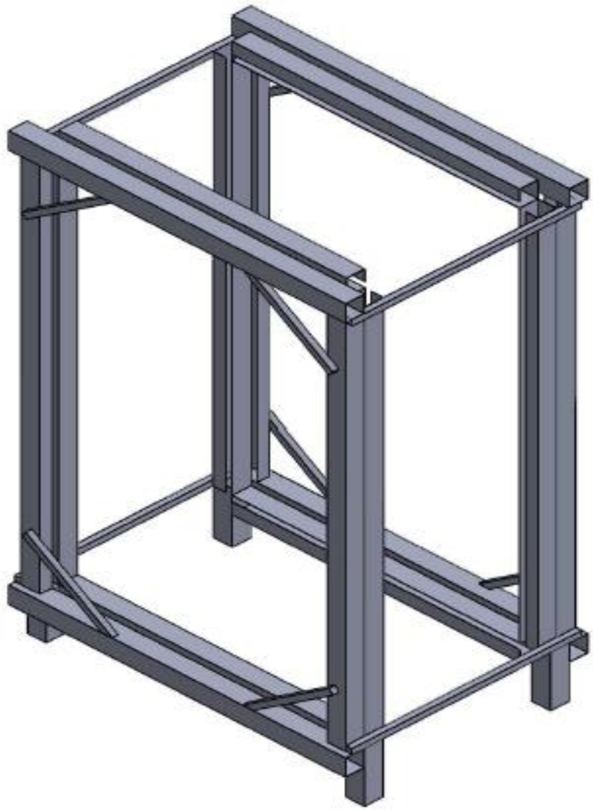

Fig. 1 A schematic diagram of a rectangular shape of an evaporative cooling system.

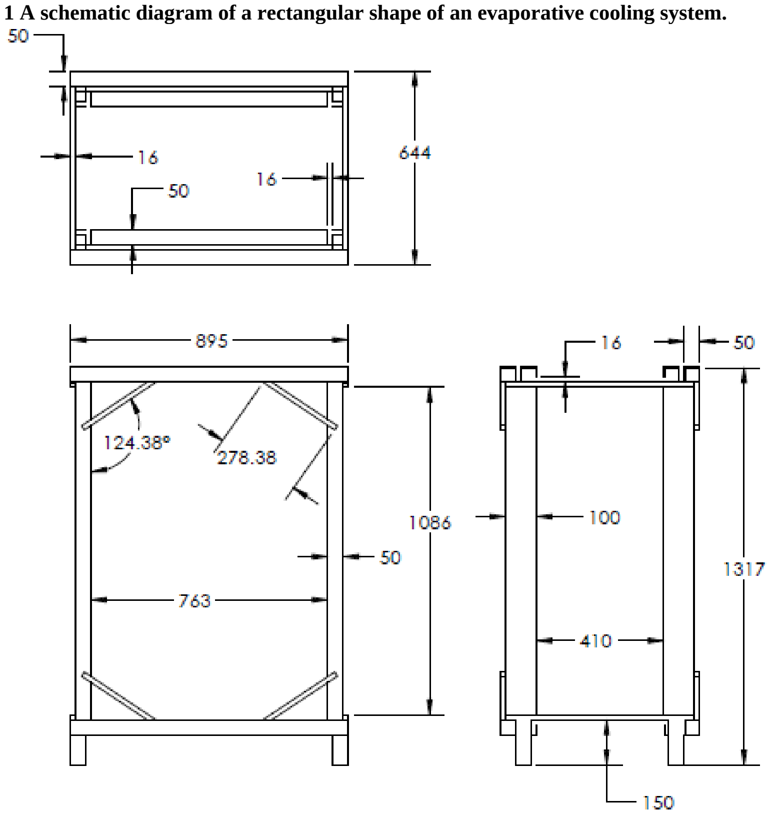

Fig. 2 Rectangular Shape ECS Frame Orthographic View.

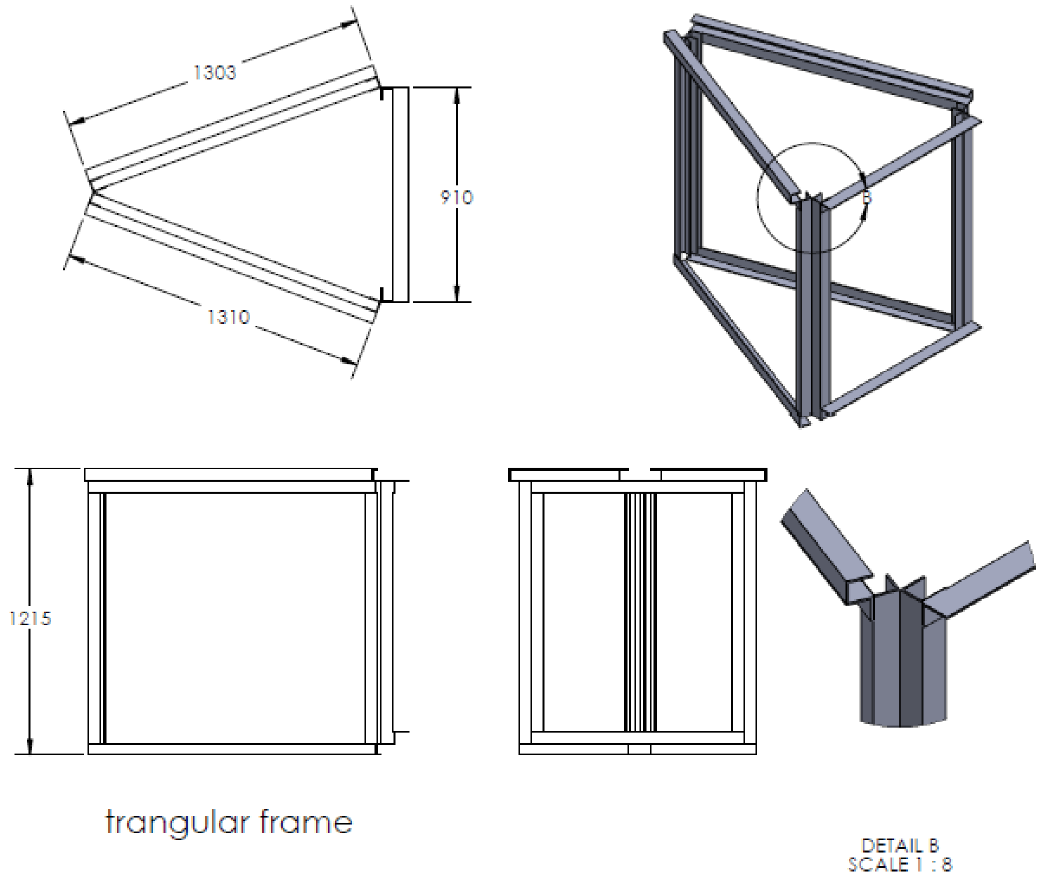

Fig. 3 Triangular Shape ECS Frame Orthographic View.

Plate 1a. Construction of a rectangle ECS

Plate 1b. Construction of a triangular ECS

Plate 2a. Outside View Rectangular ECS

Plate 2b. Outside View Triangular ECS

Samples Analysis

Plate 3a. Rectangular ECS Samples

Plate 3b. Triangular ECS Samples

Plate 4. Golden Mettler Weighing Balance

Plate 5. Measurement of Oranges Samples

Plate 6. Inner View Rectangular ECS

Plate 7. Water Pocket Thermometer

According to the design of the ECS, it has a storage capacity of 50 kg, is easy to maintain, and is mobile, and the trays are also detachable from all sides. It maintained the natural taste of fruits after preservation compared to the refrigerated cooling system, which reduces the natural taste after freezing. Using this system will help reduce the spoilage of fruits and vegetables where there is no electricity to power refrigerating system.

3. Results and Discussion

The performance of the evaporative cooling system with the load to be cooled was evaluated daily at an interval of 24 hrs for 14 days. During these periods of evaluating the performance of the evaporator, the temperature kept decreasing with the rate of air and water flowing within the evaporator compartment and, after that, maintaining an appreciable constant low-temperature value of about 21.3°C. However, the maximum temperature for the cooling of fruits is 32°C. Thus, the evaporative cooling system temperature was consistently lower than the ambient air temperature during the hottest time of the day when insulation was appreciable, and cooling was needed inside the evaporative cooling chamber. The frame structure of the ECS, as shown in Fig 1 to 3, is such that it can accommodate 20 kg of oranges for 10 kg per layer. The design is such that the lagging cooling pad (jute) can easily be pulled out and placed back easily by sliding. The performance of the evaporative cooling system was evaluated within the interval of 24 hrs for 14 days, and the method used to compare the temperature of both evaporative cooling systems with the use of a thermometer and the weight was also compared using a standard measuring scale which helps to determine the effectiveness of both shapes.

Table 2. Weight of the Oranges in Kilogram

Sample No	Day 1 (kg)	Day 2 (kg)	Day 3 (kg)	Day 4 (kg)	Day 5 (kg)	Day 6 (kg)	Day 7 (kg)	Day 8 (kg)	Day 9 (kg)	Day 10 (kg)	Day11 (kg)	Day12 (kg	Day13 (kg)	Day14 (kg)
A1	6.1078	5.8192	5.8132	5.7101	5.6411	5.5476	5.4706	5.4066	5.3428	5.0427	4.8628	4.5433	4.1546	3.8905
A2	6.4585	5.7413	5.7043	5.6436	5.5786	5.5002	5.4339	5.3759	5.3269	5.0265	4.8356	4.5825	4.1517	3.8468
B1	7.224	6.0656	6.0199	5.8822	5.8074	5.686	5.1516	5.0889	4.9806	4.6048	4.4614	4.1203	3.7832	3.4604
B2	6.4289	5.7746	5.7661	5.6586	5.582	5.4001	5.3228	5.2776	5.2017	4.9014	4.8018	4.4116	4.0014	3.7017

A1 represents the upper tray in the rectangular Evaporative Cooling System

A2 represents the lower tray in the rectangular Evaporative Cooling System

B1 represents the upper tray in the triangular Evaporative Cooling System

B2 represents the lower tray in the triangular Evaporative Cooling System

According to Table 2, the weighing of the oranges is to determine the effectiveness of the evaporative cooling system; during the process of weighing the oranges which were done at an interval of 24 hrs for 14 days, it was observed that the oranges were reducing in weight, at maximum 1kg per day and by minimum 0.2 kg per day. A solid proof, as shown in this table, is that this evaporative cooling system can also be used to maintain the weight of fruits for longer shelf life. Rapid Reduction of the weight of fruits can result in early spoilage of the fruits.

Table 3. Ambient daily temperature for both cooling system and the outer temperature for the system at the loaded condition with oranges for 9 days.

Temperature (ºC)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
Rectangle (ºC)	28.1	26.2	23.1	31.4	25.2	22.8	21.6	21.3	25.8	25.3	22.9	21.7	21.4	25.9
Triangle (ºC)	29.1	27.2	25.4	31.5	25.0	26.9	23.7	22.3	23.9	25.1	26.8	23.8	22.4	23.8
Outer (ºC)	32.2	32.2	33.4	33.2	31.3	30.7	33.7	29.7	32.9	31.4	30.8	33.8	29.8	32.8
Main outer(ºC)	32.8	32.7	33.7	33.5	31.6	31.5	34.7	30.3	33.5	31.7	31.6	34.8	30.4	33.8

Table 3 shows that heat is one of the major media that helps fruits get ripe or mature, which also determines the fruit's harvesting time. It is still one of the major media that affects the shelf life of fruits. When the temperature of an environment is more than 32°C, fruits tend to get spoiled and sourer on time. According to the temperature table, it has been proven and determined that the temperature in the evaporative cooling system cannot be more than 21°C to 31.5°C, whereby the weight of fruits can easily be maintained, and the fruits can also be preserved for longer shelf life. The temperature inside the evaporative cooling systems rose to 31.4°C and 31.5°C, respectively, on the fourth day, serving as the maximum temperature for the ECS. And the minimum temperature was also recorded on the 8th day, which was 21.3°C and 22.3°C, respectively. The change in temperature results from the relative humidity outside noted as the outer temperature. If the temperature outside is very high, this can also affect the temperature inside the ECS. The ECS system must be kept in a cool place where there is cool air, this will help to regulate the temperature of the ECS to be under control, and the temperature change will not be far from each other the relative humidity. The water inside the bucket also must not be too warm, which can affect the temperature inside the ECS. The process of cooling can always be achieved when there is cool air entering the ECS and cool water flowing into the cooling pad (jute).

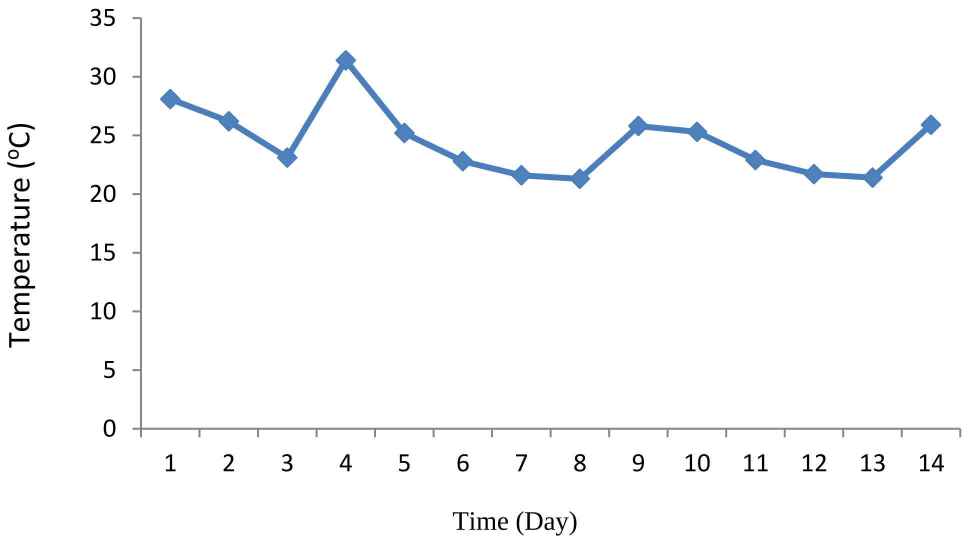

Fig. 4 Experimental and model results at a temperature range between (21.3 and 31.4)ºC for oranges in rectangular ECS

The temperature of the rectangular evaporative cooling system, as shown in figure 4.1, continually decreased until the fourth day, when there was a low water flow rate on the cooling pad (jute). The temperature increased drastically until the water was well regulated again. From the fifth to the eighth day, the temperature was at a steady rate. On the ninth day, the temperature increased slightly due to a high increase in the outer temperature.

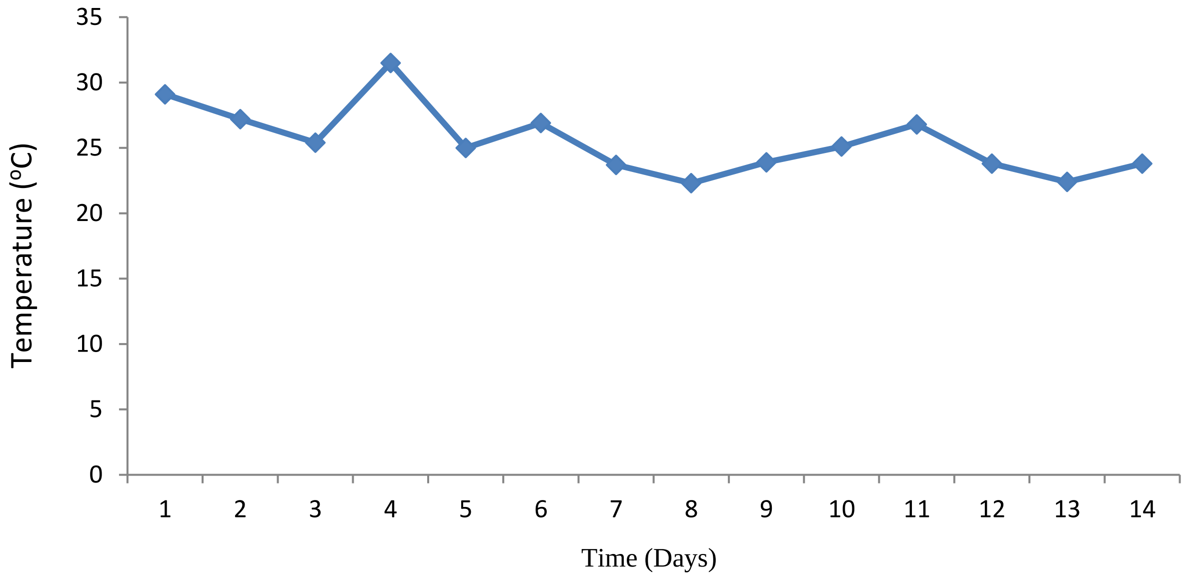

Fig. 5 Experimental and model results at a temperature range between (22.3 and 31.5) ºC for oranges in triangular ECS.

The temperature of the triangular evaporative cooling system, as shown in Figure 5, is also similar to the rectangular shape. The difference between both ECS is very small. The temperature of the triangular shape also increased drastically on the fourth day due to a low flow rate of water that dropped on the cooling pad (jute). The temperature of every other day of the experiment was relative to each other and was well maintained. The triangular ECS temperature was also on a steady rate in which the temperature of each day was not far from each other.

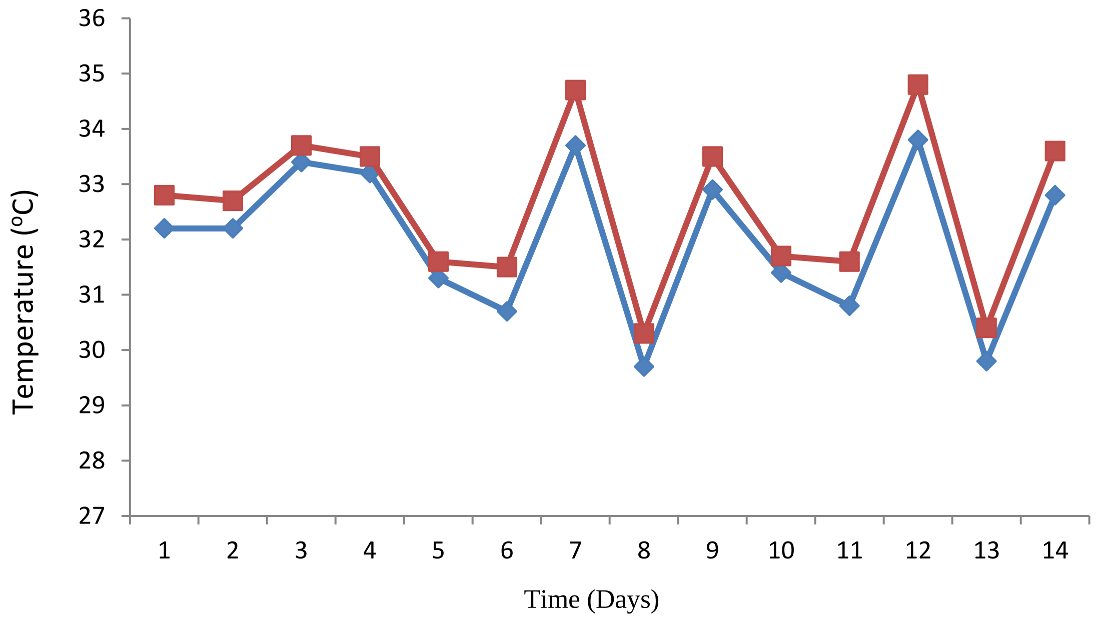

Fig. 6 Experimental and model results at a temperature range between (29.7 to 33.7)ºC and (30.3 to 34.8)ºC for both shapes of the ECS's outer and main outer temperature.

The outer and main outer temperatures, as shown in Figure 6, are inconsistent due to the time the readings were taken each day. It was observed that the highest temperature relating to humidity could be recorded between 12 pm to 3 pm. At this same time, the air circulating the ECS can also increase in temperature, increasing the temperature of the ECS. At this period, the water flowing around the ECS must be cool and flow at a steady rate

.

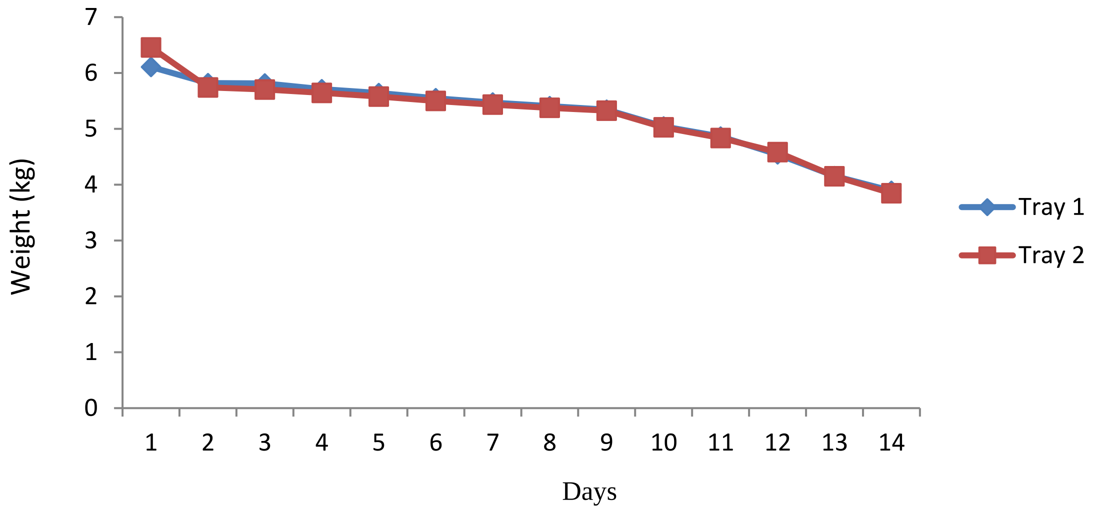

Fig. 7 Physiological weight losses of the tested samples (Oranges) of Rectangular ECS.

Forty-Five oranges were dropped into each tray of the ECS; according to 4, the lower tray had more weight than the upper tray, but before the end of the experiment, the weight of both trays was mostly equivalent to each other, which shows that the lower tray was more conservative and effective in terms of temperature conditioning. The weight loss of the oranges in rectangular ECS depicts well-preserved oranges because of their longer shelf life compared to the triangular ECS due to the low steady rate of weight loss in the system.

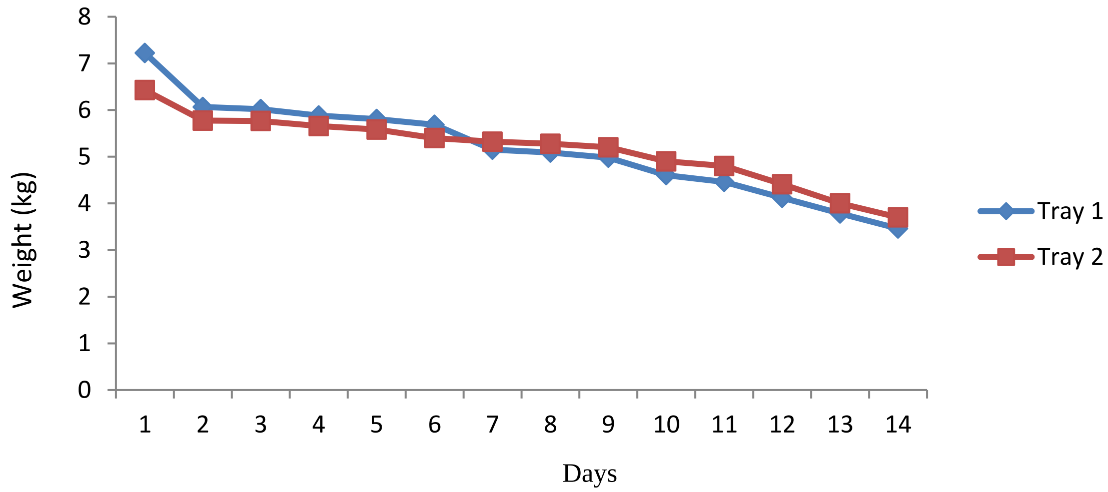

Fig. 8 Physiological weight losses of the tested samples (Oranges) of Triangular ECS

Figure 8 shows that the lower tray is more conservative than the upper tray in the triangular ECS. Forty-five oranges were dropped inside each of the trays. The oranges in the upper tray had the highest weight than the lower tray. But in the process of days and time, the first tray deceased rapidly, resulting from the upper tray being close to the outer temperature that comes directly from the sun. The Triangular ECS can effectively preserve fruits when there is enough flow of water running into the cooling pad (jute), enough cool air entering into the ECS, and a relative humidity running at a constant lower temperature. The experiment has been carried out, and the shelf life of oranges was determined, which ranges from 12 to 14 days (two-week maximum), while the outer sample lasted for 8 days.

3.1. Discussion

During the evaluation process, it was observed that the weight of the oranges kept decreasing, and the weight loss in the triangular shape was more than that of the rectangular. It was observed that cooler temperatures could be maintained in the rectangular ECS compared to the triangular shape. The rectangular shape is more effective when compared to the triangular shape. The experimental result of the ECS shows that this system can be well predicted and recommended if there is the availability of water and air, which can be used as the major coolant for this project work, the cooling pad (jute) can retain its moist for 5 – 7 hours under a cool condition before it starts getting dry without the flow of water. The water in the bucket has to be constantly regulated to keep the inner temperature of the ECS lower and steady. If the temperature of the ECS is constantly lower, that will help the shelf life of the fruits to be longer and suitable for human consumption. The ECS needs to be well covered by the cooling pad (jute) without leaving out any space that can result in lost air in the ECS system. Because if the system is exposed to outer temperature, the temperature inside tends to be equivalent to the outer temperature, which can result in temperature loss in the ECS. For a longer shelf life of any fruits or vegetables that will be preserved, such fruits or vegetables must still be fresh. Fruits that have been on the ground for days would have lost some nutrients due to humidity, resulting in early spoilage of such fruits or vegetables.

During preservation, some Precautionary Measures to be taken; it is very important always to check and observe the fruits that have been kept in the ECS because some fruits tend to spoil easily, so to keep other fruits from being affected. Spoilt fruits must be isolated from the good fruits to maintain good storability. To help the shelf life of the fruits also, a well-covered ECS will disallow insects to perch on the fruits inside the ECS. There should be a little distance between the ECS stand and the ground level, at least two (2) meters above the ground level. The ECS systems also need to be well painted in and out to avoid metal corrosion due to the intensity of water dropping on the cooling pad (jute). Neat water ought to be poured into the bucket to avoid the pipe's holes getting blocked. The holes on the pipe must let water out always so that the flow rate of water can circulate and be regulated accordingly.

4. Conclusion

The fruit preservation carried out on the evaporative cooling system shows that the two ECS constructions are good and effective for preserving fruits and vegetables, but the rectangular shape is preferable. Also, using water and air as a source of energy yielded a good and measurable result, alleviating the problem encountered with the early spoilage of the preservation of fruits and inadequate power supply.

5. Recommendation

The evaporative cooling system can be improved by placing a tray under the frame to collect and recycle water. A shade should be built for the ECS to avoid direct heat from the sun. The design should be structured to accommodate varieties of fruits and vegetables at a temperature range below 32°C.

References

[1] Salunke D. K & Kadam S. S, “Handbook of Fruit Science and Technology,” *NewYork: Dekker*, 1995.

[2] A. O. Filani, S. O. Ejiko, O. D.Olakolegan O.D. and O. C. Adeosun, "Effect of Storage Length on Gari Attribute", *A Paper Presented at the 12th Engineering Forum, School of Engineering, The Federal Polytechnic, Ado-Ekiti*, The Polytechnic Conference Centre, Ado-Ekiti, Ekiti State, pp. 241 – 252, 2019.

[3] NSPR, “Storage of Fruits And Vegetables”, *Nigeria Stored Product Research Institute Bull*, vol. 5, no. 2, pp. 33-37, 1990.

[4] UNIDO, “Appropriate Industrial Technology for Food Storage Technology,” United Nations, New York, 1979.

[5] L. A. Sanni, “Development of an Evaporative Cooling Storage System for Vegetable Crop. M.Sc. Project Report,” *Department of Agricultural Engineering, Obafemi Awolowo University*, Ile-Ife, Nigeria, 1999.

[6] ”Food Association Organisation (FAO),” *FAO Production Yearbook*, FAO, Rome, vol. 34, 1983.

[7] A. U. Dzivama, "Performance Evaluation of an Active Cooling System for the Storage of Fruits and Vegetables,” *Ph.D. Thesis, Department of Agricultural Engineering*, University of Ibadan, Ibadan. pp. 11-23, 2000.

[8] CFNEU, “Communities Food and Extension Unit", D-II/183, Kidwai Nagar (West), N. Delhi, 2003, [Online]. Available: http://wed.nic.in/us5.htm.

[9] P. Jeffries & M. J. Jeger, “The Biological Control of Postharvest Diseases of Fruit Biocontrol,” 1990.

[10] J. Haidar & T. Demisse, “Malnutrition and Xerophthagma in Rural Communities of Ethiopia,” *East Afr. Med. J.*, vol. 10, pp. 590-593, 1999.

[11] R. B. Duckworth, “Fruits and Vegetables,” *Pergamon Press, Oxford*, pp. 135, 1979.

[12] E. M. Peter, “Vegetable Virtues: Nutritional Values," 1997, [Online]. Available: https://www.angnr.umd.edu/howard/mg/advege.htm.

[13] N. Katsoulas, A. Baille & C. Kittas, “Effect of Misting on Transpiration and Conductance of a Greenhouse Rose Canopy,” *Agricultural And Forest Meteorology*, vol. 106, pp. 233-247, 2001.

[14] V. I. D. Ndirika & C. N. Asota, “An Evaporative Cooling System for Rural Storage of Fresh Tomato,” *Journal of Agricultural Engineering and Technology*, vol. 2, no. 4, pp. 56-66, 1994.

[15] H. J. Barre, L. L. Sammet & G. L. Nelson G.L, “Environmental and Functional Engineering of Agricultural Buildings,” *Van Nostrand Reinhold Company*, New York, 1988.

[16] B. S. Lana, “How to Calculate a Cross-Sectional Area,” 2020, [Online]. Available: https://sciencing.com

[17] S. O. Ejiko, E. G. Adubi, and R. A. Adewuyi, "Hydroelectric Power Plant Design: A Case Study of Agric Livestock Investigation Centre Dam In Erinfun, Ekiti State", *Adeleke University Journal of Engineering and Technology* (AUJET), vol. 2, no. 3, pp. 61-79, 2020.

[18] T. S. Mogaji & O. P. Fapetu, “Development of an Evaporative Cooling System for the Preservation of Fresh Vegetables,” *African Journal of Food Science,* vol. 5, no. 4, pp. 255 – 266, 2011.

[19] Lumen, “Flow Rate and Its Relation,” 2022, [Online]. Available: https://course.lumenlearning.com/physics/chapter/12-1-flow-rate-and-its-relation-to-velocity.

[20] Physic, “Relationship of Discharge and Minor Loss Coeffiecient,” 2017, [Online]. Available: http://www.physicsforum.com

[21] D. Oigbochie D. and S. O. Ejiko, "Design and Performance Evaluation of 0.2 Tonne Maize Dual Layer Solar Dryer", *International Advanced Research Journal in Science, Engineering and Technology,* vol. 7, no. 5, pp. 53-60, 2020. Doi: 10.17148/Iarjset.2020.7508

[22] K. Manan, “Frustum of the Surface Area,” 2013, [Online]. Available: https://www.cuemath.com