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Effect of NSPRI tin-in-pot compared with pot-in-pot evaporative cooler on the stored fruits

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Abstract

The suitability of the humidity chamber known as Evaporative Cooling System (ECS) developed by Nigerian Stored Products Research Institute as storage structures for mangoes were compared for nine days between June-July 2012. Ambient and ECS Temperature throughout the storage period ranges between 27˚C- 31˚C and 20˚C-27˚C respectively, while the corresponding relative humidity was 51%-58% and 70%-81% respectively. Color change and Weight loss were observed as a physical change to determine effect of each selected ECS on the stored mangoes. There is significant range of ripening in tin-in-pot which led to early deterioration of the stored mangoes. Pot –in-pot affects the freshness of the stored mangoes. The overall effectiveness of the tested ECS shows that tin-in-pot is better for the storage of mangoes since for five days it retains the freshness of the stored mangoes but cannot be used for long due to its natural reaction with the stored fruits. Recommendations were suggested in this paper for better modification of ECS in any future related project.

Keywords: *Evaporation, cooling system, Relative humidity, Storage Period, Mango*

1 Introduction

An evaporative cooler which can also be referred to as swamp cooler, desert cooler and wet air cooler is a device that cools through the evaporation of water. This device works by employing water's large enthalpy of vaporization. The temperature of dried air can be dropped significantly through the phase transition of liquid water to water vapor(evaporation), which can cool air using much less energy than refrigeration. In extremely dry climate, evaporation cooling of air has the added benefit of conditioning the air with more moisture for the comfort of the building occupants. Unlike closed cycle refrigeration, evaporation cooling requires a water source and must continually consume water to operate (Wikipedia). This is employed for the storage of fruits and vegetables since the environment for safe and prolonged storage of perishable commodities (fruits) must therefore be one of high humidity and low temperature [13]. The essence of storage of fruits and vegetables is therefore an uttermost importance since it adds a considerable amount of nutrients to the diet of humans. Many researchers had substantially worked on different evaporation coolers but this work is to study the effect of tin-in-pot compared to pot-in-pot coolers to see how physically they affect the stored fruits.

1.1 Statement of problem

The consumption of fruits and vegetables is important because the nutrients contained in them can be used in the treatment of CDR (Cardio vascular disease) and cancer. A Nigeria researcher showed that at the national level, 24.8% of children lower than 5 suffered from subclinical vitamin A deficiency while 4.7% were vitamin A deficient, making a total of 29.5% who suffered from clinically deficiency [11]. The lack of adequate storage facilities for fruits and vegetables after harvest leads to the reduction in the quantity of fruits that get to market which also has a direct effect on the distribution and consumption of the needed quantity for healthy living.

2 Objectives

i. The main objective of this work is to ascertain the effect of tin-in-pot compared to pot-in-pot evaporative coolers and suggest different material to be used for modification if there is need be.
ii. Specific objective is to evaluate the two set of (tin-in-pot and pot-in-pot) evaporative coolers with the storability of mango fruits.

3 Literature review

3.1 History of evaporative cooler

Evaporation cooling is a phenomenon in which evaporation of a liquid typically into surrounding air cools an object or liquid in contact with it. Evaporation cooling occurs when air that is not humid passes over a wet surface; the faster the rate of evaporation the greater the cooling effect. In 1800bc the New England textiles factory began to use the evaporative cooling systems to cool their mills [8]. Bamboo cooler were constructed with bricks with hessian cloth which were used to wrap the bricks. Also charcoal coolers were produced together with the almirah cooler. [6] described some type of evaporative cooling that was being used in New Delhi, Indian in which a wetted mat with fan was used to cool a local restaurant. The concept of water-cooling a roof has a long history but it is estimated that less than 60 million square feet of roof have ever been water cooled [9]. It was also reported that if only a small amount of water is placed on the roof, the evaporation is highly accelerated as compared to would be if the roof surface was flooded [4].

3.2 Advances in evaporative cooling technology:

(17) developed a cheap cool store in Kenya with the help of local grass for storage of vegetables. He kept the roof and walls wet by dripping water from the top of the roof. Evaporative cooling which rely on wind pressure to force through wet pads, have also been designed and constructed especially in some developing countries like India and Nigeria [7]. Construction of various evaporative cooling systems was done by [6] using available materials as absorbent (pads). Materials used include canvas, jute curtains and hordes clay blocks. Also a mechanical fan was introduced to some of the coolers constructed. The pipe line works at the top of the hexagonal frame supplied water constantly to wet the pad which is made of jute fiber. Wind pressure forced the air through the wetted jute pad. Limitation of this design is that efficiency of the evaporative cooler depends on wind velocity [7]. [12] in their study on storage of tomatoes in evaporative cooler environment reported that a drop of 8.2˚C from ambient condition of 32˚C while the relative humidity increased 36.6% over an ambient 60.4%. They further reported that storage life unpacked fresh tomatoes in evaporative cooler environment as 11days from the 4days storage life under ambient condition while in combination with sealed but perforated polyethylene bags; it was 18days and 13 days respectively. [13] also did research on the performance evaluation of absorbent material in evaporation cooling for the storage of fruits and vegetables. Three materials were selected as pad materials: jute, hessian and cotton waste. The design implemented a centrifugal fan, high density polystyrene plastic plywood used as covering for the walls and basement and the top and the main body frame was made of thick wood. The performance criteria included the cooling efficiency, amount of heat load removed and the quality assessment of the stored products. The result showed that the jute material had the overall advantage over the other materials. The cooling efficiency could be increased if the two sides were padded. [15] did research comparative study on storage of fruits and vegetables in ambient. An evaporative cool chamber was constructed with the help of baked bricks and riverbed sand. It was recorded that weight loss of fruits and vegetable kept inside the chamber was lower than those stored outside the chamber. The fruits and vegetables were fresh up to 3 to 5 days more inside the chamber than the outside.

3.3. Factors affecting the shelf life of fruits and vegetables

The various factors that can affect the shelf life of fruits and vegetables which will lead to their deterioration. These include:

i. Ambient condition
ii. Variety and stage of ripening

<u>Ambient condition:</u> The environmental condition has a great influence on the shelf life of fruits and vegetables and the factors can be sub-divided into temperature and relative humidity.

Temperature: This can be defined as the degree of hotness and coldness of material. Temperature has a great influence on the shelf life of agricultural products. [7] found that all produce are subjected to damage when exposed to extreme temperature which will lead to increase in their level of respiration. Also it was further disclosed that agricultural products vary in their temperature tolerance. [16] suggested that deterioration of fresh commodities can result from physiological breakdown due to natural ripening process, water loss, temperature injury, physical damage or invasion by microorganisms. All of these factors can interact and all are influenced by temperature. He further said that exposure to alternating cold and warm temperature may result in moisture accumulation on the surface of commodities (sweating) which may enhance decay development. Relative humidity: This is the measurement of the amount of water vapor in the as a percentage of the maximum quality that air is capable of holding at a specific temperature. Mathematically it can be represented by R.H = actual vapor density/saturated vapor density. Relative humidity can also be mathematically represented as $\Phi = E_w/E^*_w$ where E_w = partial pressure of water vapor and E^*_w = saturated vapor pressure.

$E^*_w = (1.0007+3.46 \times 10^{-6}p)(6.1121)e^{(17.502T/240.97+T)}$

Where T is the dry bulb temperature and p is absolute pressure (mbar).

The relative humidity has a great effect on the deterioration of fruits and vegetables because it has a direct relationship with moisture content in the atmosphere which determines whether the shelf life will not be exceeded. [3] said that the relative humidity of the storage unit directly influences water loss in produce. [16] also said water loss means salable weight loss and reduced profit.

3.4 Variety and stage of ripening

Post harvest operation does not stop fruit and vegetable from respiring which if not controlled will lead to over-ripening of the fruits and leads to early deterioration depending on the stage the fruits are handled which in practice varies from mature green to fully ripened. The commodities have different storage conditions [13].

3.5 Factors accountable for deterioration of fruits and vegetables

I. Physiological activities. During post-harvest operation, the fruits and vegetables still continue their normal physiological activities. [13] disclosed that ripening transforms a physiological nature but inedible plant organ into a visually attractive and edible organ which marks the complete development of a fruit and commencement of senescence and it is normally and irreversible event. Major change which do make up fruit ripening are seed maturation, abscission, production of volatile compounds, development of wax on skin and changes in colour, respiration rate, rate of ethylene production, tissue permeability, composition of pectin and carbohydrates, organic and protein [14].

II. Pathological infection. Pathogens are one of the major causes of deterioration of fruits and vegetables when they destroy and make it not pleasing to the sight. [3] disclosed that crops destined for storage should be as free as possible from skin breaks, bruises, spots, rots, decay and other deterioration. [13] also said that insects and pests can cause considerable damage of fruits and vegetables through either complete removal of the fruits or feeding on them. Thus causing skin breaks which may facilitate entry of decay organism.

III. Mechanical Injuries. The injuries that are visible on fruits and vegetables are caused by mishandling or other cause which leads to cracks, bruises, cuts or abrasion which makes the produce not attractive and also less remarkable. [1] disclosed that impact bruising of tomatoes results in higher respiration and ethylene production rates, increased damage and lower levels of titer table and ascorbic acid which can alter taste and nutritive value. [13] also disclosed that mechanical damage can also accelerate the rate of water loss from produce, bruising damages the surface organization of the tissue and allows a much greater flow of gaseous material through the damaged area.

IV. EVAPORATION OF WATER. Evaporative loss from the surface of fruits and vegetables has an effect on the quality of the produce. The higher the rate of evaporation, the lower the moisture content and shelf life of the agricultural produce. [13] further said that weight loss results from moisture loss via evaporation of water from the tissues when the fruits and vegetables are attempting to be in equilibrium with the environment which is usually at lower water activities.

4 Material and method

4.1 Development of NSPRI evaporative cooling system

The domestic type of evaporative cooling systems used here were designed and constructed by Nigerian Stored Products Research Institute (NSPRI) by [2]. This comprises of two types.

i. Pot-in-pot ECS. A small clay pot with bottom surrounded with polyethylene was kept inside a bigger clay pot and the inter space is filled with river-bed sand which was made moist always by adding water twice a day; in the morning and evening time. The pot had a wooden cover.

ii. Tin-in-pot ECS. The small clay pot used in (i) above was replaced with an empty kerosene tin (18liters) with one end removed and the back painted with aluminum paint to prevent rusting. A suitable cover was provided and the sand at the inter-space kept moist by applying water twice a day as described above.

4.2 Procurement of Mango fruits and experimental design

Freshly harvested mango fruits (matured green) were plucked at the NSPRI premises and labeled each for easy identification. The mangoes were weighed one after the other before putting them into the evaporative cooling systems. Two set of pot-in-pot and tin-in-pot evaporative cooling systems were used to ensure accuracy. The set of ECS with the weighed mango fruits inside were kept in a cool place to ensure adequate humidity of the chambers. A control was kept in the floor of ventilated shed beside the evaporative coolers.

Three parameters were taken on daily bases which include weight loss, color change and decay. Weight loss was determined using a digital weighing balance, color change was determined by sensory evaluation (sight) and decay was determined by counting the number of mangoes found to be over 50% rotten. Temperature and relative humidity of each ECS replicate were also monitored. This study was conducted for 9 days and results were obtained.

5 Results

5.1 General results after the experiment

A. The effects of nine days storage of mangoes with pot-in-pot and tin-in-pot ECS are shown in the tables below respectively. The rate of ripening of the stored mangoes in tin-in-pot ECS is faster compared with that of pot-in-pot ECS. This was determined by color and texture changes and leads to early generation of spot on stored mangoes as shown on the table (1) and (2)

Table 1: Rate of ripening of Mangoes in Pot-in-Pot ECS

	MANGO LABEL	DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9
POT-IN-POT	A	MG	MG	GY	GY	GY	YG	YG	FY	FY
	B	MG	MG	GY	GY	GY	GY	YG	FY	FY
	C	MG	MG	GY	GY	GY	YG	YG	FY	FY
	D	MG	MG	GY	GY	GY	YG	YG	FY	FY
	E	MG	MG	GY	GY	GY	GY	YG	FY	FY
	F	MG	MG	GY	GY	GY	YG	YG	FY	FY
	G	MG	MG	GY	GY	GY	YG	YG	FY	FY
	H	MG	MG	GY	GY	GY	GY	YG	FY	FY
	I	MG	MG	GY	GY	GY	YG	YG	FY	FY
	J	MG	MG	GY	GY	GY	GY	YG	FY	FY

Table 2: Rate of ripening of Mangoes in Tin-in-Pot ECS

	MANGO LABEL	DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9
TIN-IN-POT	K	MG	MG	GY	GY	YG	FY	FY	FY	YWS
	L	MG	GY	GY	GY	YG	FY	FY	FY	YWS
	M	MG	MG	GY	GY	YG	FY	FY	FY	FY
	N	MG	MG	GY	GY	YG	FY	FY	FY	YWS
	O	MG	GY	GY	GY	YG	YG	FY	FY	FY
	P	MG	MG	GY	YG	YG	YG	FY	FY	FY
	Q	MG	MG	GY	YG	YG	FY	FY	FY	YWS
	R	MG	GY	GY	GY	YG	FY	FY	YWS	YWS
	S	MG	GY	GY	GY	YG	YG	FY	YWS	YWS
	T	MG	GY	GY	YG	YG	FY	FY	FY	FY

NOTE: MG = matured green
GY = green yellow (this is used when green is observed more than yellow)
YG = yellow green (this is used when yellow is observed more than green)
FY = full yellow
YWS = yellow with spot

B. The temperature and relative humidity measured in tin-in-pot is considerably better than that of pot-in-pot in morning and during the night time but observed lower in the afternoon when there is hot condition. See the table (3) and (4) below

Table 3: Inner temperature and relative humidity of pot-in-pot tin-in-pot ECS

	DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9
POT-IN-POT	26.5˚C	25.5˚C	24.5˚C	26.0˚C	23.5˚C	26.0˚C	24.5˚C	26.0˚C	27.0˚C
	70%	70%	71%	70%	72%	70%	71%	70%	69%
TIN-IN-POT	24˚C	23.5˚C	20.0˚C	24.5˚C	20˚C	24˚C	22˚C	23˚C	25.5˚C
	80%	80.5%	82%	80%	82%	80%	81%	81%	80%

Table 4: shows ambient temperature and relative humidity was taken as follows

DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9
30.60˚C	30.0˚C	29.1˚C	30.5˚C	27.2˚C	30.2˚C	29.4˚C	30.5˚C	31.0˚C
58%	53%	60%	53%	61%	54%	60%	53%	51%

C. Weight loss in tin-in-pot is observed lower than that of pot-in-pot. See table below

Table 5: Weight loss of Mangoes taken each day in Pot-in-Pot

	MANGO LABEL	DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9
POT-IN-POT	A	128.50	127.91	127.42	126.96	126.35	126.19	126.07	125.54	125.23
	B	121.40	120.67	120.16	119.79	119.45	118.98	118.89	118.40	117.90
	C	104.60	104.03	103.62	103.10	102.82	102.39	102.28	101.72	101.45
	D	115.20	114.65	114.09	113.56	113.15	112.58	112.23	109.97	109.32
	E	153.86	152.84	152.29	151.79	151.44	150.94	150.71	150.10	149.85
	F	115.42	114.53	114.14	113.59	113.52	112.95	112.69	112.15	111.65
	G	136.60	135.33	134.74	134.13	133.88	133.02	132.16	130.82	130.34
	H	129.51	128.49	127.98	127.45	127.17	126.65	126.44	125.89	125.35
	I	112.25	111.53	111.22	110.85	110.69	110.28	109.89	109.19	108.32
	J	116.26	115.56	115.19	114.76	114.63	114.30	113.98	113.55	113.85

Table 6: Weight loss of Mangoes taken each day in Tin-in-Pot

	MANGO LABEL	DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9
TIN-IN-POT	K	120.50	119.23	118.42	117.67	117.05	116.22	115.24	114.29	113.90
	L	88.63	87.90	87.24	86.78	86.15	85.66	85.13	84.55	83.38
	M	120.53	119.90	119.30	118.87	118.53	118.04	117.56	116.92	115.02
	N	91.33	90.37	89.75	89.13	88.67	88.26	87.64	86.98	86.01
	O	102.61	101.53	100.82	100.08	99.35	98.73	97.79	95.65	94.64
	P	82.91	82.30	81.72	81.33	80.79	80.28	79.61	78.55	77.45
	Q	111.85	110.44	109.79	109.12	108.49	107.83	107.23	106.37	105.50
	R	116.24	115.11	113.79	112.98	112.14	111.24	110.19	108.77	107.95
	S	109.26	108.46	107.63	107.09	106.51	105.73	104.26	102.73	101.32
	T	96.86	96.04	95.26	94.87	94.17	93.58	92.95	91.85	90.75

5.2 Discussion as regard the above results

A. It implies that there is natural reaction between the tin and the stored mangoes which causes natural ripening process. There might be an oxidation reaction (liquid from the fruits reacting with the tin) or temperature fluctuation. [16] suggested that deterioration of fresh commodities can result from physiological breakdown due to natural ripening process, water loss, temperature injury, physical damage or invasion by microorganisms.

B. This implies that tin as a good heat conductor transfers heat to the inner part which in turn increase the inner temperature thereby reduce the inner relative humidity during afternoon when there is heat but in the morning and night the overall cooling effect is much better than pot-in-pot ECS because of its better transfer of cooling effect. [8] disclosed that the faster the surrounding air moves over fresh produce , the quicker the water is lost. Air movement through produce is essential to remove the heat respiration but the rate of movement must be kept as low as possible.

C. This might be attributed to the fact that low temperature and high relative humidity is obtainable within its cooling chamber for longer period of time (morning and night). This makes it the better storage device if not for the early ripening which leads to spot and rotten of mangoes earlier than pot-in-pot.

6 Conclusion

The results obtained from this work show that NSPRI tin-in-pot ECS is very effective as a storage device but cannot be used for longer period as pot-in-pot when used for fruits because of its natural reaction with the fruit acidity. One major beauty of tin-in-pot ECS is that it retains fruit freshness better than pot-in-pot.

7 Recommendations

To ensure better effectiveness, the following recommendations were suggested

i. Other non-ferrous metals can be worked upon to select the best that has no or low negative effect on the stored fruits. Stainless steel is suggested and expected to put in trial for subsequent design.

ii. Since it was discovered during the experiment that the cooler the airflow needed for evaporation in the system the better the cooling effect, it therefore recommended that apart from putting the ECS under shed one can also develop a means of artificial production of cool air for the evaporation process in the system this will surely make ECS more effective.

iii. A better water source should be developed for convenient watering of the ECS. It is suggested that one can incorporate perforated piping system to a main water source see the figure 1 below:

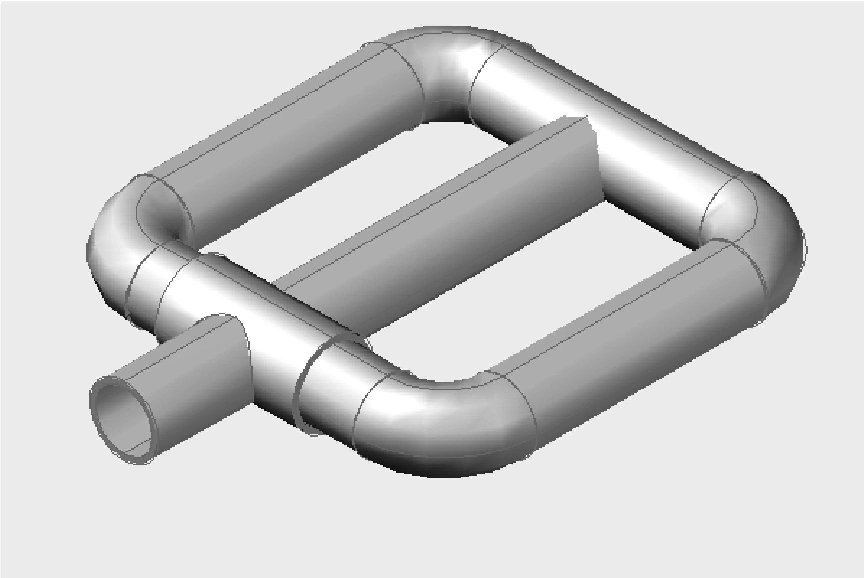

Fig.1 proposed piping system for water supply in the modified evaporative cooler

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