Original Research Article

A STUDY ON LOW COST POST HARVEST STORAGE TECHNIQUES TO EXTEND THE SHELF LIFE OF CITRUS FRUITS AND VEGETABLES

ABSTRACT

An attempt was made to develop low cost porous evaporative cooling storage structures for extending the shelf life of citrus fruits and vegetables at the Sylhet Agricultural University campus, Bangladesh. Clay soil, bamboo and straw were used as a wall material. Sand, clay, zeolite, rice husk and charcoal etc. were used as a pad material. But the mixture of sand and clay was found as the most efficient pad materials for lowering temperature. Porous evaporative cooling storage structure (PECSS) was developed to reduce the problems of post-harvest losses at farmer level. It is eco-friendly and no energy requirements for storage of vegetables and fruits. PECSS improves the quality and productivity of vegetables and Citrus fruits by reducing temperature, prolonging shelf life and reducing post-harvest losses respectively. The study revealed that shelf life of egg-plant (Solanum melongena) was 11 days in PECSS condition and it was 6 days in ambient condition. Therefore, weight loss was 4.07% for PECSS and 11.84% in room condition respectively. Storage life of Ladies finger (Abelmoschus esculentus) was 6 days more in PECSS condition than room condition. Weight loss was 6.62% in PECSS condition and 17.47% loss in ambient condition. In case of Malabar Spinach (Basella alba) it was 6 days for PECSS condition and 3 days for room condition and weight loss was found to be 9.48% and 16.17% respectively. The shelf life of stem amaranth (Amaranthus cruentus) was 5 days in PECSS condition and 2 days in ambient condition. Weight loss was found 7.05% at PECSS condition and 28.62% as in-room condition. By chemical analysis for fruits lemon (Citrus Limon) and orange (Citrus sinensis) found that pH and TSS were increased both ambient and PECSS condition but in PECSS condition this rate was less than ambient condition. Vitamin C, percentage juice content, citric acid values all were decrease at both condition but in PECSS condition its rate was the less ambient condition. There is scope for intensive study to improve the firmness of the porous evaporative cooling storage structure (PECSS) to reduce the storage loss of vegetables and citrus fruits for different region and its suitability for large scale design.

Keywords: *Shelf Life; Citrus Fruits; Vegetables; Porous Evaporative Cooling; Pad Materials;*

1. INTRODUCTION

Bangladesh is an agriculturally based country. According to (BBS, 2011) reported that more than 80% of the total population is engaged in agriculture and more than 50% of the population is depend agriculture for their livelihood. Bangladesh is honored with around 90 sorts of vegetables and natural products nearly all through the nation and developed throughout the entire year. The limit of normal yearly temperature is 24.8°C and least temperature is 12°C and yearly precipitation is 3876mm. Because of the profoundly momentary nature around 20-30% of all out foods grown from the ground 35% of complete vegetables creation go squander during different strides of post-harvest chain [1].

Evaporative cooling is the procedure by which the temperature of a substance is decreased because of the cooling impact from the dissipation of water. The change of reasonable warmth to dormant warmth causes a decline in the encompassing temperature as water vanished give helpful cooling. This cooling impact has been utilized on different scales from little space cooling to enormous mechanical applications [2].

In developing countries, storage has been seen to represent a more noteworthy danger to natural products since data on the capacity temperature, humidity necessities and the time allotment they can be kept without a decrease in market value is either lacking or obscure to the individuals who need the data [3]. Crumbling of natural products during capacity to a great extent relies upon temperature. One approach to expand the timeframe of realistic usability of natural products by bringing down of the temperature. Extraordinary low temperature can make harm farming produce and when the item leaves the area of controlled temperature, decay begins once more [4]. So as to keep up the nature of put away organic products, they are ordinarily kept in clammy conditions [5].

Sylhet area is privileged with abundant citrus organic products however because of absence of appropriate storage facilities post-harvest loss is additionally momentous. One approach to hinder crumbling and in this manner builds the time span citrus natural products can be put away, is by bringing down the temperature to a suitable level. On the off chance that the capacity temperature is too low the item will be harmed and furthermore when the item leaves the cold store, decaying begins again and frequently at a quicker rate. It is essential that citrus fruits are not damaged during harvest and that they are kept clean. Damaged and bruised fruits have much shorter storage lives and very poor appearance after storage [6,7] stated that keeping products at their lowest safe temperature (0°C for temperate crops or 10-12 °C for chilling sensitive crops) will increase storage life by lowering respiration rate, decreasing sensitivity to ethylene gas and reducing water loss.

As indicated by a report of the National Academy of Science, Washington, DC (Anonymous, 1978) the post- harvest losses of transitory items like vegetables may be 80-100% in certain occasions. With lost around 10 - 15% in fresh weight, vegetables wilted and arrive at a condition of low market worth and purchaser acceptability. Every item took care of has its own specific temperature prerequisites. The time until cooling, temperature strength and its term should be considered. By bringing down produce temperature at the earliest opportunity after gather, for the most part inside four hours and the accompanying impacts are accomplished: breath rate is diminished, water misfortune is decreased, ethylene creation is stifled, affectability to ethylene is decreased, microbial advancement is eased back. Most verdant vegetables and 'mild' organic product including pome and citrus natural products are not chill-delicate and can be put away somewhere in the range of 0°C and 2°C for extensive stretches without noteworthy loss of visual quality. Tropical and subtropical foods grown from the ground root vegetables are chill-touchy and might be harmed at low temperatures. They are for the most part put away at 13°C or above, albeit some might be put away securely as low as 5°C whenever cooled not long after gather. Temperature should likewise be steady as changes may influence breath and attractive quality. The present conventional techniques for reaping, taking care of, bundling and putting away of vegetables can be improved with a little extra coast or impedance with the current advertising rehearses [8].

A significant part of the postharvest misfortunes of foods grown from the ground in creating nations are because of the absence of proper storerooms. Refrigerated cold stores are the best strategy for safeguarding natural products, yet they are costly. Thus, in the creating nations, for example, Bangladesh and especially in South-East Asia where most organic products are developed there is an enthusiasm for straightforward, minimal effort options, a large number of which rely upon basic evaporative cooling [9].

There is need to anticipate the misuse of new citrus foods grown from the ground during capacity by receiving a more up to date storage technique with or without vitality cooling load has been created and stretched out to the rancher fields from the view purpose of ease. Porous evaporative cooling storage structure (PECSS) is a double wall structure having space between the walls which is filled with porous water absorbing materials called pads. These pads are kept constantly wet by applying water. When unsaturated air passes through wet pad, transfer of mass and heat takes place and energy for the evaporation process comes from the air stream. Evaporative cooling is an adiabatic procedure happening at steady enthalpy. This is the most practical method for diminishing the temperature by humidifying the air. It has numerous points of interest over refrigeration framework, as it doesn't utilize refrigerant so it is agreeable to condition (decrease carbon-dioxide). It doesn't make noise as it has no moving part. It doesn't utilize power for example spares vitality. It doesn't require high introductory speculation just as operational expense is immaterial. It tends to be rapidly and effectively introduced as this basic plan. Its support is simple. It tends to be built locally accessible materials in remote zone and generally significant, it is eco-accommodating as it needn't bother with CFC.

Yet, the problem of inadequate storage facilities for fresh citrus fruits and vegetables after being harvested in Sylhet, consequence to the decrease in the quantity that gets to the market; this also has a through effect on the economic distribution and consumption of the needed quantity for human sustainability. Henceforth, the purpose of this work is to design and construct a porous evaporative cooling storage structure that will temporarily store fresh citrus fruits and vegetables to upsurge the shelf life before economical distribution, consumption and for processing. This study established that shelf life of citrus fruits and vegetables can be extended by the practice of porous evaporative cooling storage structure.

Objectives

•To compare the storability of citrus fruits and vegetables under porous evaporative cooling storage structure and the ambient temperature in this region.

•To justify the economic return of storing fruits and vegetables under this structure.

2. MATERIAL AND METHODS

2.1 Establishment of modified cooling structure

I. Location: The structure was set up in the department of agricultural construction and environmental engineering, Sylhet Agricultural University (SAU) laboratory at room temperature.

II.Wall material: clay soil, bamboo, straw.

III.Pad materials: Structure Pad is important part of PECSS. Many researchers have studied the effect of cooling pads on cooling efficiency. Used pad materials are sand, clay, zeolite, rice husk, char coal etc. Commercial pads gave good saturation efficiency, as they are specially made but they are expensive and not suitable to low income farmers and traders. Locally and easily available pads performed better with RH above 90% and maximum temperature drop of 12°C. However, performance is dependent on outside weather but saturation efficiency can further be increased by creating good porosity and air-water contact within pad. Performance of the pad material depends on outside weather, both temperature and humidity but the material having good porosity and air-water contact within the pad performed better as compared to others.

IV.Design construction: The structure consisted of a double walled soil structure with one heat insulating drip proof top. A double layered wall on all four sides around the platform was erected with soil and it was with leaving space between double wall was 5 cm. Spaced between double wall was fill up by pad materials. After the construction completed, the top opening was covered by straw materials.

Fig. 1: Developed double wall with cavity

Fig. 2: Pad materials mixing

Fig. 3: developed double wall with slightly burned

Fig. 4: Filling pad materials and-installed laboratory

Fig. 5: Finally covering the structure with straw materials

Operational method: To ensure low temperature and high RH in the storage, wetting pad materials should be done twice a day by drip system with plastic pipe and micro tubes connected to water source. It can be done manually. At initial stage water is required twice a day but certain period of time water is required, after one or two days later because pad materials remained saturated condition. After installation of all the mechanical aids the effectiveness of the structure will test whether it can lower temperature or not. RH value of the structure can predict the efficiency of the structure. Prediction can be done from the 3 days consecutive recorded values of the RH and temperature on RH/T meter. Then selective types of fruits and vegetables storage in the structure.
To validate the storage quality under the structure ambient temperature several quality tastes will be performed in laboratory such as physiological loss in weight, color, firmness (for vegetables) and pH, citric acid, vitamin c, juice content, total soluble solid (TSS), percentage of weight loss (for citrus fruits).

2.2 Method of storage

Physiological Weight Loss: The differences in weight of the fruits and vegetables stored in both the ambient and in the cooler condition for difference days are estimated. The weight loss was determined by weight balance and the percentage of weight loss was estimated using Equation (1) as given by Fabiyi, (2010).

Percentage Weight loss =original weight-new weight original weight ×100

Color Changes and Firmness: The changes in color of the fruits and vegetables were noted both in the cooler and in the encompassing condition related to the physiological weight reduction. The shading changes watched depended on the physical appearance of the foods grown from the ground Fabiyi (2010). The physical surface of the fruits and vegetables was inspected and noted. The distinction in the solidness was likewise noted in the wake of putting away the vegetables in the evaporative cooling system and in surrounding condition.

Chemical analyses: Ten healthy fruits were randomly selected prior to the experiment, after storage inside the evaporative cooing storage structure, for physiological and chemical analysis. These include

(a) Juice pH- pH concentrations in the juice were determined following extraction of juice in 50ml flux at 27°C with a digital pH meter.

(b) (Total soluble solid content (TSS)-Total soluble solid content determined by portable refractometer.

Fig. 6: Portable Refractometer

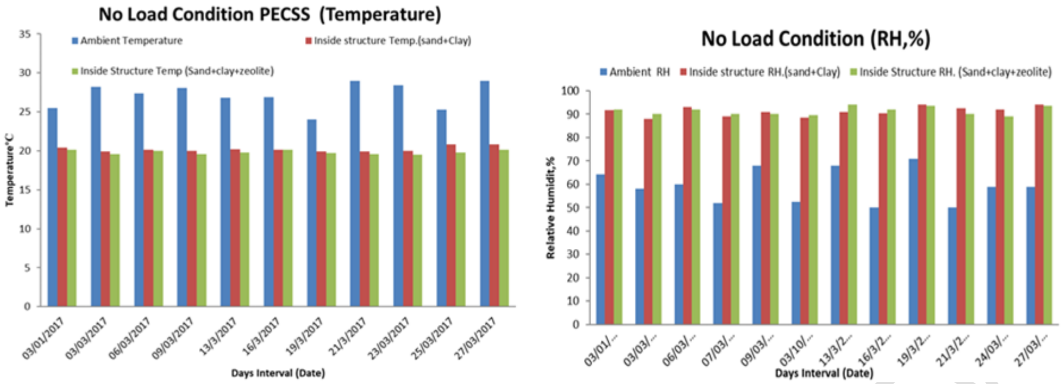
(c) Percent juice content determination: The juice contents were weighed and recorded in grams (Lacey et al. 2009; Grewal et al., 2000). The percent juice contents were calculated by using the following formula; % juice contents = juice weight ÷ fruit weight x 100

(d) Ascorbic acid (Vitamin C) content: A container of fitting volume was utilized to accumulate the arrangements recorded under the materials list. A clean eyedropper was set in every arrangement. Institutionalization of color arrangement with standard Vitamin C was finished. Utilizing an eye dropper, unequivocally 5.0 ml of standard Vitamin C arrangement was added to a 10ml graduated chamber. Volume of standard nutrient C arrangement and grouping of standard nutrient C arrangement was recorded. With an eye dropper, a couple of drops of color answer for the graduated chamber was included. The graduated chamber was shaken to blend the standard nutrient C and color blend. Keep including color arrangement until the response blend changes shading to a pink shading. The volume of the response blend toward the end point was recorded. Their activity blend into a waste receptacle then flushed the graduated chamber with around 1 ml of standard nutrient C was disposed of. The titration was rehashed. The complete volume of response blend for two titrations consents to ± 0.2 ml, if the all-out volume of response blend for two titrations doesn't consent to ± 0.2 ml, a third titration is required.

3. RESULTS AND DISCUSSIONS

3.1 No load test of the evaporative cooling system

A no-load test of the PECSS was conducted to observe the effect of the evaporation that was expected to take place in PECSS shown in figure 7. The dry bulb temperature and relative humidity data determined whether the process was effective or not. This is necessary in order to determine structure efficiency before being loaded with the fruits and vegetables that will be stored within the structure. This was achieved by taking temperature difference and the relative humidity of the PECSS relative to the ambient condition. The average temperature was varied from 24°C-29°C and relative humidity was 50%-71% in ambient condition at winter season. The inside temperature of the PECSS was 19.9 to 20.8 °C and relative humidity was 88 % to 94% when sand and clay was used as a pad material and after that temperature was varied from 19.5 to 20.2℃ and relative humidity 89% to 93% when sand, clay and zeolite was used as a pad materials that was shown in Figure 7. So, the average variation in temperature was 5-9°C and relative humidity was 22-30%. Therefore, it is clear that sand and clay mixture can efficiently use for miniature structures like PECSS.

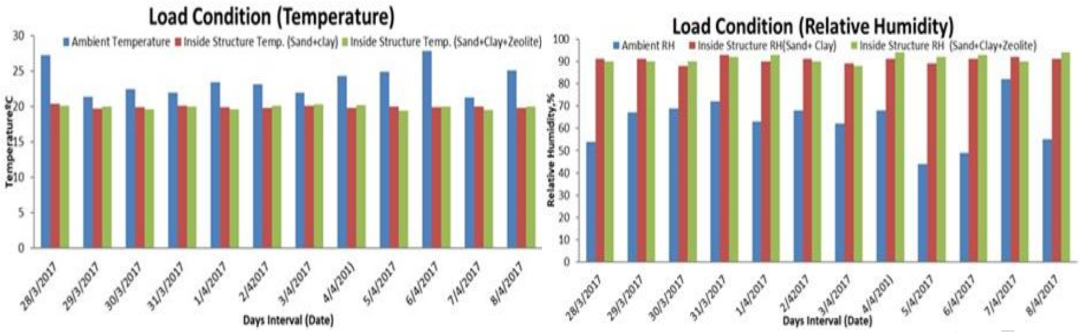


(a) (b)

Fig. 7: Comparison between (a) ambient temperature and the temperature and (b) ambient relative humidity and the relative humidity inside the porous evaporative cooling storage structure at winter.

3.2 Load test of the evaporative cooling system

The performance of evaporative cooler was evaluated from 28th March to 8th April, 2017. The average temperature inside the structure varied from 19.4°C to 20.3°C with the pad material of sand, clay and zeolite while in the ambient air temperature varied from 21.3°C to 27.8°C (Figure 8(a)). If pad material changed to a mixture of sand and clay the variation was found from 19.7°C to 20.4°C. Henceforth, relative humidity in ambient condition was 44 to 82 % in the experimental period which was varied to 73 to 93% for the pad material of sand and clay as well as slightly increased to 88 to 94% additional mixture of zeolite in pad material (Figure 8(b)). So, the average relative humidity increased inside the structure with pad material of sand and clay was 27.8% while it was 28.3% increased inside the structure with pad material of sand, clay and zeolite. It was seen that there is increment in the framework relative moistness in connection to that of the encompassing condition .It has been accounted for by ASHRAE (1982), that the necessary stockpiling relative mugginess of vegetables ranges from 85 to 90%, thus the framework relative stickiness accomplished reaches from 80.0 to 90.0% which intently concurs with that revealed by ASHRAE (1982) .The aftereffect of the normal storage temperature of orange, lemon, eggplant, women finger, red amaranth, spinach accomplished in the framework ranges from 19.4 to 20.3°C and in the meantime, the temperature of the surrounding ranges from 21.3 to 32.4°C .This suggests the distinction between the surrounding and evaporative cooling system was profoundly hugeness and in this manner the utilization of evaporative cooling framework for conservation of products of the soil can't be dismissed. In any case, high relative humidity expands the timeframe of fresh vegetable and in this way, the permeable evaporative cooling storage framework with mean 90.32% gave the higher relative stickiness than that of surrounding condition with mean 60%. Henceforth the permeable evaporative cooling stockpiling framework ought to be utilized in protection new citrus leafy foods.



(a) (b)

Fig. 8: Comparison between (a) ambient temperature and the temperature and (b) ambient relative humidity and the relative humidity inside the porous evaporative cooling storage structure

3.3 Compare Price Between Refrigeration and Porous Evaporative Cooled Storage Structure

In porous evaporative cooling storage structure construction cost was required no need operational cost like electricity or others equipment. Water was supplied daily and it can be considered if have scarcity of water nearby the source. On the other hand, refrigerator needs high initial cost and operational cost like electricity

3.4 Construction cost of porous evaporative cooled storage structure

For constructing a porous evaporative cooling storage structure labour, pad material cost, thatched shed and plastic basket included. Among them the highest 39% of this total cost were required for bricks, moderate 19% cost was required for labor and the lowest 9% of the total cost were required for bamboo. Total cost for three units of PECSS was TK. 2450. The construction cost of several materials was shown on the Figure 9.

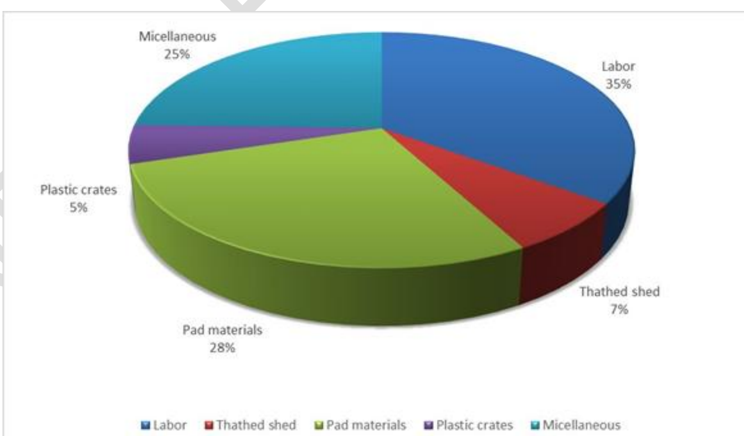


Fig. 9: Construction cost of several materials.

3.5 Physiological weight measurement of ladies' finger

The results of physiological weight loss and percentage of weight loss of ladies' finger during the experiment is shown in Table 1 below. These results revealed that the weight loss of ladies' finger in the PECSS ranged from1.0 to 1.15 g per day while that of ambient system ranges from 5 to 6 g per day while the percentage of weight loss of ladies' finger in PECSS and ambient ranged from 0.60 to 0.70% and 2.70 to 2.97% per day respectively. This means that the difference between the ambient and evaporative cooling system was highly significant and therefore the use of evaporative cooling system for preserving and improving the shelf life of ladies' finger cannot be avoided.

Table 1: Physiological weight measurement of ladies' finger

Days after storage	Initial weight both ambient condition and evaporative cooling system	Weight loss of ladies' finger in evaporative cooling system (PECS)	Percentage of weight loss in PECS, %	Weight loss of ladies' finger in ambient condition	Percentage of weight loss in ambient condition, %
2 days	200gm	197.45gm	1.27	192.23gm	3.88
4 days		195.84gm	2.08	183.13gm	8.44
6 days		192.21gm	3.9	163.68gm	18.16
8 days		190.24gm	4.88	151.59gm	24.20
11 days		187.53gm	7.73	134.65gm	32.68

3.6 Physiological weight loss of Egg-plants

Table 2 indicated the aftereffects of physiological weight reduction and level of weight reduction of brinjal during the analysis. These outcomes uncovered that the weight reduction of in the PECSS went from1.25 to 1.36 g every day while that of surrounding framework ranges from 3.5 to 3.75 g every day while the level of weight reduction of egg-plants in PECSS and encompassing extended from 0.65to 0.71% and 1.85 to 1.97% every day separately. This implies the contrast between the surrounding and PECSS was profoundly noteworthy and consequently the utilization of PECSS for protecting and improving the timeframe of realistic usability of egg-plants can't be stayed away from.

Table 2: Physiological weight loss of Egg-plants

Days after storage	Initial weight both ambient condition and evaporative cooling system	Weight loss of Egg-plants in PECSS	Percentage of weight loss in PECSS, %	Weight loss of Egg-plants in ambient condition	Percentage of weight loss in ambient condition, %
2 days	190gm	188.98gm	1.56	185.43gm	2.40
4 days		186.63gm	1.68	177.51gm	6.57
6 days		182.45gm	3.77	167.87gm	11.64
8 days		179.68gm	5.43	157.97gm	16.85
11 days		174.97gm	7.91	148.65gm	21.76

3.7 Physiological weight loss of Malabar Spinach (Basella alba)

Table 3 presented the results of physiological weight loss and percentage of weight loss of Malabar Spinach during the experiment. These results also revealed that the weight loss of Malabar spinach in the PECSS ranged from 3.4 to 3.56 g per day while that of ambient system ranges from 8.30 to 8.40g per day while the percentage of weight loss after 7 days in PECSS and ambient condition was14.58% and 34.84%.

Table 3. Physiological weight measurement of Malabar Spinach (Basella alba)

Days after storage	Initial weight both ambient condition and evaporative cooling system	Weight loss of Malabar Spinach in PECSS	Percentage of weight loss in PECSS, %	Weight loss of Malabar Spinach in ambient condition	Percentage of weight loss in ambient condition, %
2 days	170gm	165.0	2.94	158.10	7.0
4 days		157.30	7.46	140.80	17.17
6 days		148.0	12.94	128.64	24.33
7 days		145.20	14.58	110.77	34.84

3.8 Physiological weight loss of stem amaranth

Table 4. specified the aftereffects of physiological weight reduction and level of weight reduction of stem amaranth during the examination. These results revealed that the weight reduction of spinach in the PECSS went from 2.70 to 2.90g every day while that of encompassing framework ranges from 9.30 to 9.95g every day and the level of weight reduction following 7 days in PECSS and surrounding condition was10.92% and 38.72%.

Table 4. Physiological weight measurement of stem amaranth

Days after storage	Initial weight both ambient condition and evaporative cooling system	Weight loss of stem amaranth in PECSS	Percentage of weight loss in PECSS, %	Weight loss of stem amaranth in ambient condition	Percentage of weight loss in ambient condition, %
2days	180gm	174.16	3.24	160.23	10.98
4days		168.69	6.28	126.93	29.49
6days		165.98	7.78	116.48	35.26
7days		160.34	10.92	110.34	38.72

3.9 Weight loss during storage in PECSS

The weight of fresh citrus fruits in the PECSS and ambient storage significantly differed over the course of the experiment that was showed in the Figure 10.

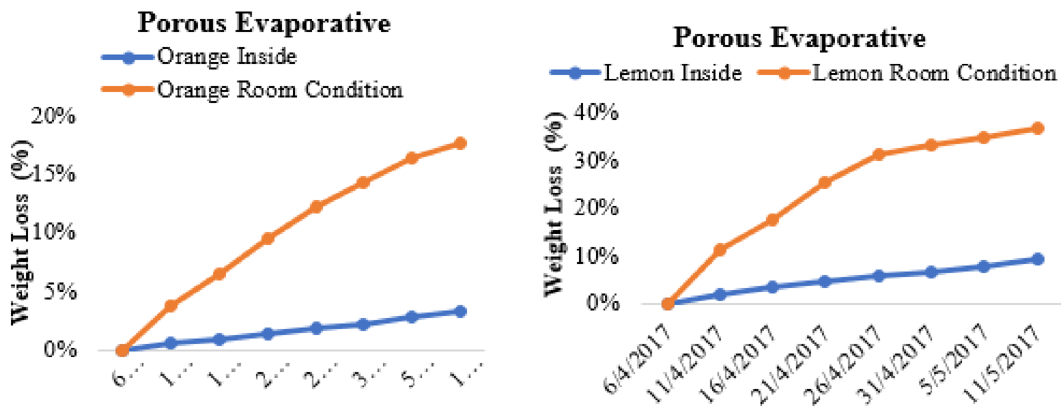


Fig. 10: Graphical representation of Weight loss percentage of (a) Orange/Citrus reticulate and (b) Lemon (Pate lebu)/Citrus limon in PECSS.

It controlled the weight loss of 8 % in PECSS in contrast to ambient condition for orange and 21% for Lemon

3.10 Changes in pH value: There was a significant difference in the value of lemon fruits either in the evaporative cooling chamber or in ambient storage. An increase in pH value was observed in the ambient storage after 6 days and thereafter it increased significantly as well as in the evaporative cooling chamber.

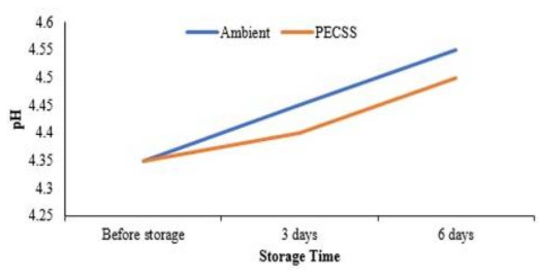


Fig. 11: PH value of orange

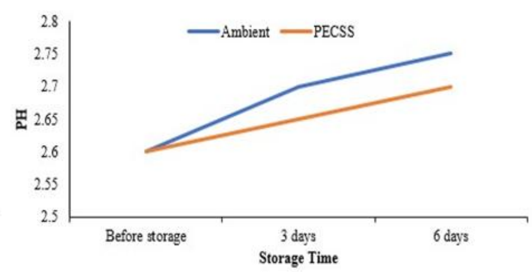
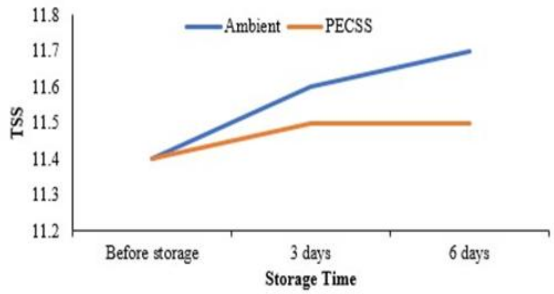


Fig. 12: PH value of lemon

3.11 Changes in TSS value: A gradual increase in total soluble contents was observed in all samples during storage, which could be attributed to water loss. This result may have been related to the persistent consumption of sugars and organic acids for lime tissue metabolism, rather than the solute concentration effects, during long term storage. Ambient storage time shows significant difference in soluble solid contents even in initial stages.



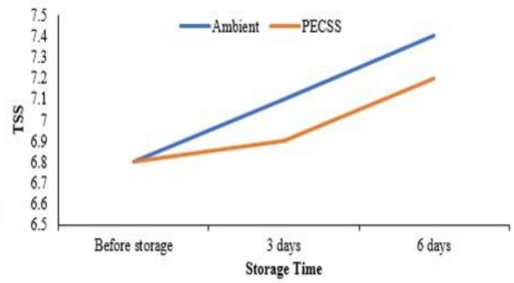
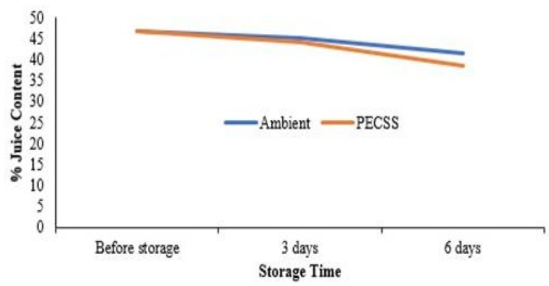


Fig. 13: TSS value of orange

Fig. 14: TSS of lemon

3.12 Changes of percentage juice content: Juice content decreased in PECSS slowly over day than in ambient condition is shown in Fig: 15 and Fig: 16



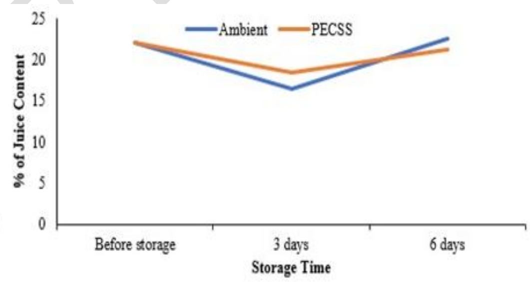
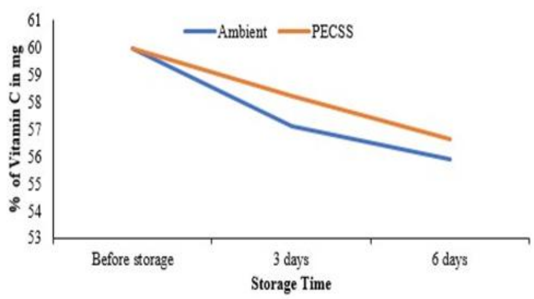


Fig: 15: Juice Content of Orange

Fig. 16: Juice content of lemon

3.13 Changes of Vitamin C: Over a period of time it was observed that vitamin c is gradually decreased both ambient and PECSS but in ambient condition vitamin c is decreased more than in PECSS is shown in Fig: 17 and Fig: 18.



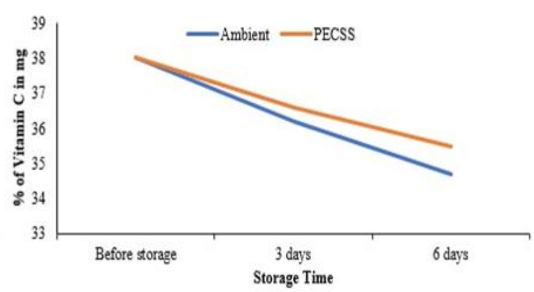


Fig. 17: Vitamin c in orange

Fig. 18: Vitamin c in lemon

3.14 Changes in citric acid: It was observed that citrus acid is continuously diminished both ambient and PECSS however in encompassing condition citrus acid is diminished more than in PECSS is shown in Fig: 19 and Fig: 20.

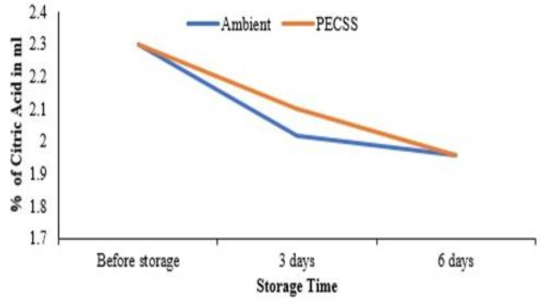


Fig. 19: Citric acid in orange

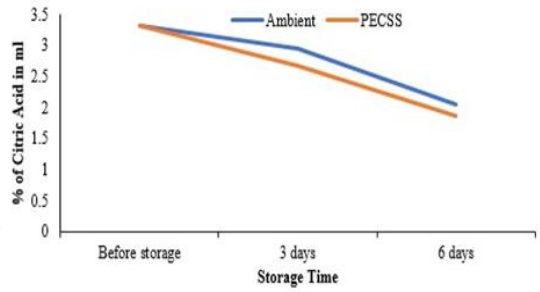


Fig. 20: Citric acid in lemon

3.15 Effect of storage system on color and firmness of Egg-plants (Solanum melongena)

Egg-plants were stored in the PECSS and outside the chamber. The changes in color as the storage progressed were observed. The color of the egg-plants in outside chamber and Porous evaporative cooled chamber storage gradually changing with time. From below Fig: 21-24. it was observed that the color and firmness were remain unchanged 11 days in PECSS whereas color and firmness were remained pure 6 days in ambient condition. In PECSS shelf life were increased 5 days compared with ambient storage system.

3.16 Color changes of Egg-plants brinjal in porous evaporative cooling storage system (PECSS):

Fig. 21: before storage

Fig: 22: after 7 days

Fig: 23: after 11 days

Fig: 24: after 14 days

3.17 Color changes of Egg-plants in ambient condition

Fig. 25: before storage

Fig. 26: after 3 days

Fig. 27: after 6 days

Fig. 28: after 8 days

3.18 Effect of storage system on color and firmness of ladies' finger (Abelmoschus esculentus)

The color and firmness changes of ladies' finger were observed and noted in Figures bellow. The colors were marginally changed from greenish to yellowish following 8 days yet not being disintegrated in PECSS While in surrounding condition shading and solidness were changed from greenish to yellowish following 5 days and weakened inside 7 days. In PECSS timeframe of realistic usability were expanded 6 days than the ambient condition

3.19 Color changes of ladies' finger in porous evaporative cooling system (PECSS)

Fig. 29: before storage

Fig. 30: after 5 days

Fig. 31: after 8 days

Fig. 32: after 11 days

3.20 Color changes of ladies-finger in ambient condition

Fig. 33: before storage

Fig: 34: after 5days

Fig: 35: after 6 days

Fig. 36: after 8 days

3.21 Effect of storage system on color and firmness of malabar spinach (basella alba)

From below figures predicted that greenish to yellowish color were happened after 5 days but not being fully deteriorated in pecss however in ambient condition color and firmness were altered from greenish to yellowish after 2 days and fully deteriorated within 4 days. Shelf life were increased 3 days compared with ambient storage system during the pecss.

3.22 Color changes of Malabar Spinach (Basella alba) in PECSS

Fig. 37: before storage

Fig. 38: after 3 days

Fig .39: after 5 days

Fig. 40: after 7 days

3.23 Color changes of Molabar spinach (Basella alba) in ambient condition

Fig. 41: before storage

Fig. 42: after 2 days

Fig. 43: after 4 days

Fig. 44: after 5 days

3.24 Effect of storage system on color and firmness of Stem amaranth (*Amaranthus cruentus)*

Stem amaranth color and firmness changes were detected and showed in figures below. The color and firmness were changed after 4 days and fully deteriorated within 6 days in PECSS. Although in ambient condition color and firmness were changed following 2 days and completely disintegrated inside 3days. In PECSS timeframe of realistic usability were expanded 2 days.

3.25 Color changes of steam amaranth leaf in PECSS

Fig: 45: before storage

Fig. 46: after 4 days

Fig. 47: After 6 days

Fig. 48: After 7 days

3.26 Changes of steam amaranth leaf in ambient system

Fig. 49: before storage **Fig. 50: after 2 days**

Fig. 51: after 3 days **Fig. 52: after 5 days**

4. CONCLUSION

The Porous Evaporative Cooling Storage Structure (PECSS) can maintain relatively low inside temperature and high relative humidity as compared with ambient temperature and relative humidity due to the porosity and evaporative mechanism of pad material. By this experiment it is observed that in PECSS temperature reduced about 5-9°C.In contrast the relative humidity was increased about 90% in average inside the PECSS which was about 60% in average for ambient condition. Mixture of sand and clay can be efficiently used as the pad material of this types of structures. The average weight loss of ladies' finger (Abelmoschus esculentus) both in ambient and PECSS was 17.472% and 6.62% respectively. Similarly, for egg-plant (Solanum melongena) both in ambient and PECSS was 11.844 % and 4.07% respectively. On an average the marketable quality and shelf life of these types of vegetables can be increased about 5 days. In case of leafy vegetables like Malabar Spinach (Basella alba) and stem amaranth (Amaranthus cruentus) the shelf life can be increased up to 3 days by using PECSS. The citrus fruits such as lemon (Citrus Limon) and orange (Citrus sinensis) pH was increased both ambient and structure but in PECSS its range was less than ambient. Citrus can be stored in PECSS for prolonging shelf life with marketable quality because of less change was found in TSS, Citric acid and Vitamin C. This structure is fragile in nature. So, an intensive research can improve its firmness in large scale design. If anyone want to made this structure with large size, it will be needed to half burning then full burning because full burning has more possibility to cracking and this problem faced in this research. Due to the power shortage and high expense in conventional cold storage or refrigeration system this types of low cost PECSS is an emerging technique to adopt for reducing the post-harvest losses of fruits and vegetables for low income farmers in Bangladesh.

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