Scientific Journal of Engineering, and Technology (SJET)
ISSN: 3007-9519 (Online)
Volume 1 Issue 1, (2024)
https://doi.org/10.69739/sjet.v1i1.20
https://journals.stecab.com/index.php/sjet

Published by
Stecab Publishing

Research Article

Development of Evaporative Cooling System for Preservation of Tomato

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About Article

Article History

Submission: January 29, 2024
Acceptance : March 6, 2024
Publication : May 25, 2024

Keywords

Evaporative Cooler, Filling Material, Cooling Efficiency, Wheat Straw, Tef Straw, Foam, Doniya

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ABSTRACT

The portable tomato cooler was developed and evaluated for storage capacity of 50 and 200 kg having overall dimensions of 900 x 800 x 770 and 1320 x 900 x 1100 mm respectively. To evaluate its performance, different filling materials such as tef straw, wheat straw, sacks (doniya) and sponge (foam) was used. Selection of filling material was based on the cost, water holding capacity, rate of evaporation of water from filled material and easy availability. Tomato fruits were stored in an on-farm evaporative cooler for 19 days. The effect of filling materials on Physiological weight loss (PLW), inside temperature, inside relative humidity and cooling efficiency of four filling materials were studied. The weight loss varied between 8.51 to 23 % and 5.09 to 14.89 % during storage in 200 and 50 kg capacity evaporative cooler respectively. The mechanical test such as cooling efficiency for each filling material was determined and it was recorded as maximum in sponge and rages from 91 to 95 %. The maximum storage life of 19 days was found in sponge. Sponge (foam) was performed better when compared with other filling material. It was most economical filing material over the other filling materials.

Citation Style:

Nadew, A., & Nuguse, R. (2024). Development of Evaporative Cooling System for Preservation of Tomato. *Scientific Journal of Engineering, and Technology, 1*(1), 8-14. https://doi.org/10.69739/sjet.v1i1.20

1. INTRODUCTION

The total populace has been anticipated to arrive at 9.1 billion by 2050 and this will require a 70% expansion in food creation. Practically all of this development will happen in less evolved nations including Africa. Notwithstanding, Africa is experiencing 20-30% postharvest misfortunes esteemed at 4 billion bucks every year. Ethiopia has reasonable agro-environment to develop both mild and tropical natural product crops. Be that as it may, organic product creation movement is at baby stage in many pieces of the nation and both limited scope natural product makers and dealers have extremely restricted information and ability on organic product creation and postharvest taking care of training. Conventional safeguarding rehearses can't ensure assurance against disintegration of vegetable and natural products. The absence of appropriate conservation structures for leafy foods and nonappearance of capacity the executives advances frequently force the limited scale ranchers to sell their produce following harvest. Thusly, ranchers get low market costs for any overflow vegetable and natural product they might deliver. Safe conservation of products of the soil at the ranch level is critical, as it straightforwardly influences on destitution easing, food and pay security and success for the smallholder ranchers.

A large part of the post-gather loss of foods grown from the ground in emerging nations is because of the absence of legitimate storage spaces. While refrigerated cool stores are the best technique for saving foods grown from the ground however they are costly to purchase and run. Subsequently, in non-industrial nations there is an interest in basic minimal expense options, a significant number of which rely upon evaporative cooling which is straightforward and requires no outside power supply. Without suitable capacity advancements, ranchers are compelled to sell products of the soil when costs are low to keep away from post-gather misfortunes from disintegration, irritation and microbes, can't involve their reap as insurance to get to credit, and at last their food security is subverted. Consequently, food security and safe conservation at the rancher level remain forever inseparable.

The exchange additionally works no middle of the road stockpiling for conveying oversupply to acquire better costs. No cooling offices or bundling houses at any phase of product offering from ranch to customer or commodities market are at present accessible. Subsequently, dietary misfortune and postharvest rot are viewed as the difficult issues. Diminished temperature diminishes physiological, biochemical, and microbiological exercises, which are the reasons for quality crumbling (flavor, surface, variety, and nutritive worth). Evaporative cooling would be the fundamental idea utilized in low energy cooling framework and cycle cools air through the vanishing of water by utilizing water's enormous enthalpy of vaporization. The temperature of dry air could be dropped fundamentally through the stage change of fluid water to water fume.

In this manner, the current review would be thusly wanted to plan and foster a minimal expense, evaporative cooling framework that could be used to protect foods grown from the ground at their negligible stockpiling temperature. Hence, Effective improvement of well-working, reasonable, movable and successful evaporative protection advancements from locally accessible materials in vegetables and natural product creation region with the target of to foster evaporative cooler for leafy foods safeguarding from locally accessible materials and to assess the exhibition of the cooler on tomato

Therefore, the present study would be therefore planned to design and develop a low cost, evaporative cooling system that could be utilized to preserve fruits and vegetables at their minimal storage temperature. Therefore, Successful development of well-functioning, suitable, transportable and effective evaporative preservation technologies from locally available materials in vegetables and fruit production area with the objective of to develop evaporative cooler for fruit and vegetables preservation from locally available materials and to evaluate the performance of the cooler on tomato

2. LITERATURE REVIEW

Many previous studies show that padding materials are the main part of evaporative cooling system. Many researchers have analyzed the performance of locally; easily available and cheaply cooling pads on cooling efficiency in different countries. As result (Chinenye, 2011) were designed and constructed evaporative cooler, for the purpose of extending the shelf life of fruits and vegetables. The designs vary from the simplest to the most complicated. According to Workneh (2010), the padding houses of typical evaporative cooling facility in African rural settings are made from local materials that can be wetted with water. Saturating the walls and roofs first thing in the morning is tedious though it generates a condition for evaporative cooling of the padding house. In Uganda Odesola and Onyebuchi (2009) proposed two simple evaporative cooling chambers by using a rice shell and jute bag as the cooling pad for cooling and storage of vegetables.

Sharma and Rathi (1991) constructed evaporative cooling chamber made of an open wood frame of approximately 2 inch x 1 inch in section. The door was made by hanging one side of the frame which was covered in mesh, in and out, leaving a cavity of 1 inch which is filled with small pieces of charcoal. The cooling happens due to spraying the charcoal with water and the incoming air.

Abba (2003) developed a clay pot evaporative cooler with the same working principle as the Pot in Pot design. He used river bed sand and water to fill the space between the two pots to achieve better cooling. This storage design was introduced in Sudan, Kenya, Uganda, and Tanzania and also in Burkina Faso for food preservation.

Rajendra, *et al.*, 2015 Design, develops and test the performance evaluation on-farm evaporative cooler on fruit and vegetable and have good result and coconut coir, saw dust + gunny bag, ECC cool pad, wala sheet and gunny bag was used as padding materials.

Gunhan *et al.* (2007) evaluated the suitability of pumice stones, volcanic tuff and greenhouse shading net as alternative pad to the widely used commercial one CELdek and reported that the volcanic tuff pads can be a good alternative to the CELdek pads at 0.6 m s-1 air velocity. The maximum drop in temperature was observed 20°C as against outside temperature of 45°C and 75% RH with partal wood shavings (Jha, 2008).

Mogaji and Fapetu, 2011 evaluate an evaporative cooling system for the preservation of fresh vegetables on tomato and carrot and got acceptable result but it need power for fan.

Vala *et al.*, (2016) were carried out for four different pad materials; CELdek pad, aspen pad, coconut coir and wood savings. The study was taken to compare the local cheaply available pads with commercially pads. Average drop in temperature was 8°C and 9.75°C was observed with Celdek and wood wool respectively. While coconut coir and wood saving pads showed temperature drop of 3.5°C and 3.25°C respectively. The percentage drop in temperature with CELdek and wood wool was 40% and 43% higher as compared to wood savings and coconut coir respectively. The RH inside the storage chamber was maintained above 80% in all pads

Ahmed *et al.*, (2011) also studied the comparative performance of three padding materials; Cooling efficiency was observed higher in sliced wood pad (90%), whereas celdek pad (85%) and straw pad (76%.). celdek pad, straw pad and sliced wood pad and reported that sliced wood pad gave the more drop in temperature and relative humidity (11.77C, 40.73%) with straw pad gave least.

3. METHODOLOGY

3.1. Design and implementation

The actual design realization was worked out based on the literature reviewed, and the created prototype was based on previous studies for modeling of results of padding/filling material. The distance between two layers of net was 50 mm According to (Rajendra *et al.*, 2015). The fruit box and inner frame clearance was 100 mm. The space between two layers of net was filled with four filling materials: wheat straw, tef straw, sponge (foam), and sack known locally as doniya. Water distribution was accomplished by dropping water on the filled material sandwiched between two layers of mesh wire via a dripper pipe 12 mm in diameter. Two water tanks of 15 liters capacity and 43 cm height were employed as reservoirs to fulfill the requirement of water for storage. The water supply for the cooler would be powered by gravity as a drip system. The water tanks were raised to a height of 10 mm from the top of the evaporative cooler to allow for natural water circulation. The major purpose of this technology would be to keep the temperature cold enough to preserve certain fruits and vegetables.

3.2. Prototype developing consideration

The evaporative cooling innovation would be planned and created in view of the thought of the accessibility of materials locally to decrease cost of creation and upkeep; the materials for the development of the different part parts would be chosen based on the force that would be following up on them, the work they are supposed to perform and the ecological condition wherein they would work.

3.3. Description of the technology

The evaporative cooler prototype would be developed for the storage of various kg Tomato with varying diameters. The portable prototype of an evaporative tomato cooler was built for storage of 50 kg tomato with overall dimensions of 900 x 800 x 770 mm and storage capacity of 200 kg with overall dimensions of 1320 x 900 x 1100 mm. Figure 1 depicts the technology that was built and tested during the studies. The significant parts of the innovation were the Frame, water tank, padding materials, storage box and entryway. Determination and fundamental pieces of the advancements were portrayed exhaustively in Table 1.

Figure 1. Photographic view of the tomato cooler with different filling materials.

3.4. Working principle of the technology

The primary mechanism is based on evaporative cooling. Evaporative cooling is a method of lowering air temperature through the evaporation of water in the air stream. Heat from air blasted across a wet surface (pad) is used to evaporate the water, resulting in a decrease in the dry bulb temperature of air and an increase in relative humidity. It is the adiabatic conversion of sensible heat to latent heat. Thus, where the air temperature is high and the relative humidity is low, evaporative cooling is generally more efficient (Vala *et al.*, 2016). When water evaporates, it absorbs energy from its surroundings, resulting in a significant cooling impact. Evaporative cooling happens when dry air travels over a wet surface; the faster the evaporation rate, the greater the cooling. The humidity of the surrounding air influences the efficiency of an evaporative cooler. Exceptionally dry air can ingest a ton of dampness so more noteworthy cooling happens. In the outrageous instance of air that is completely soaked with water, no dissipation can happen and no cooling happens.

For the most part, an evaporative cooler is made of a permeable material that is taken care of with water. Hot dry air is drawn over the material. The water dissipates up high raising its stickiness and simultaneously lessening the temperature of the air stickiness and simultaneously lessening the temperature of the air.

Table 1. The main parts and specifications of the evaporative cooler

Items	Standard	50 kg Capacity		200 kg Capacity	
		Size	Amount	Size	Amount
Angle iron for frame	2.5*25 mm	90 cm 80 cm 60 52 cm	4 8 4 8	132 cm 90 cm 80 cm 122 cm 84 cm	4 4 4 4 8
Sheet metal for door	1.5 mm thickness	(71 * 81) cm^2	2	122 * 80 cm	2
Sheet metal for water tank sitting	1.5 mm	(37 * 27) cm^2	2	(37 * 27) cm^2	2
Angel iron for water tank stand	2.5 *25 mm	79 cm	2	114 cm	2
Round bar for door	10 mm dia	68 cm	2	101 cm	2
Round bar for water tank sitting	10 mm dia	35 cm	2	35 cm	2
Mesh wire	1 *1 cm	90*57 80*57 71*57	2 4 2	90 * 90 132 *90 80 * 90 122 *90	2 2 2 2
Sheet metal for mesh wire reinforcement	2 mm thickness	1.5 * 90 1.5 * 57 1.5 * 80	6 18 6	2 * 132 90 * 2 122 * 2 80 * 2	8 34 8 8
Plastic water tank	15 liter	15 liter	2	15 liter	2
Drip pipe	12 mm dia	175 cm	2	228 cm	2
Plastic Wheel	10 Cm dia	10 cm	2	2	10 cm
Square pipe for stand	2.5 * 25	10 cm	2	10	m

3.5. Selection of Filling Matewrial

The efficiency of an active evaporative cooler is determined by the rate and amount of water evaporation from the filling material as part of the basic requirements. This is determined by the air velocity, the thickness of the filling material, and the degree of saturation of the filling material, which is determined by the water flow rate that wets the filling material (transmission media). As a result, the filler material will be chosen based on locally available materials such as wheat and tef straw, sponge or foam, and doniya sacks.

3.6. Performance Evaluation

The performance evaluation of the fruit and vegetables storage/ preservation would be made on the basis of the following parameters; according to Rajendra *et al.*, (2015).

- • Cooling Efficiency

$$\eta = \frac{Td - Tc}{Td - Tw} x100 \quad (1)$$

Where: Td and Tw are the dry and wet bulb temperature of the ambient air and Tc is the dry bulb temperature of the cooled air in ^{0}C

- • Per Cent Loss in Weight (PLW)

$$PLW = \frac{W_1 - W_2}{W_1} x100 \quad (2)$$

Where, W1: Weight of sample before storage
W2: Weight of sample after storage

3.7. Experimental Design and Data Analysis

To register the cooling execution of the cooler, an exceptional cooling chamber having 50 and 200 kg storage limit four each would be planned and created. The models would be assessed regarding the cooling proficiency, percent misfortune in weight and cooling execution. An information examination would be performed utilizing statistix 8 programming. Impacts would be viewed as huge in every factual estimation ($P \leq 5$).

4. RESULTS AND DISCUSSION

4.1. Effect of padding Materials on Physiological weight loss during storage

The impact of padding materials on physiological loss in weight (PLW) of tomato was seen as measurably critical in all filling materials utilized for evaporative cooler on tomato.

The weight reduction showed variety from 8.51 to 23 % and 5.09 to 14.89 % during capacity in 200 and 50 kg limit evaporative cooler separately. The weight reduction viewed as least (5.09 and 8.51 %) in the event of tomato put away in wipe cushioning on nineteenth day of capacity in 50 and 200 kg limit evaporative cooler while it was greatest (21.6 %) if there should arise an occurrence of organic products put away at room temperature on sixth day of capacity. The impact of filling materials on physiological loss in weight was plotted in Figure 2. Comparable patterns were accounted for by (Rajendra *et al.*, 2015) for sapota put away in evaporative cooler. It was seen from the information that the expansion in physiological loss in weight was at quicker rate in tomato put away at room temperature followed by Duniya (sack) and wheat straw filling materials separately. Among all cushioning materials, spoange/froth showed least weight reduction. The expansion in weight reduction with capacity period might be because of decrease in dampness content on breath. The pace of breath could have diminished because of low temperature. Comparable outcomes were accounted for by (Roy & buddy, 1991) for capacity of mango in evaporative cooler and (Taye & Fapetu, 2011).

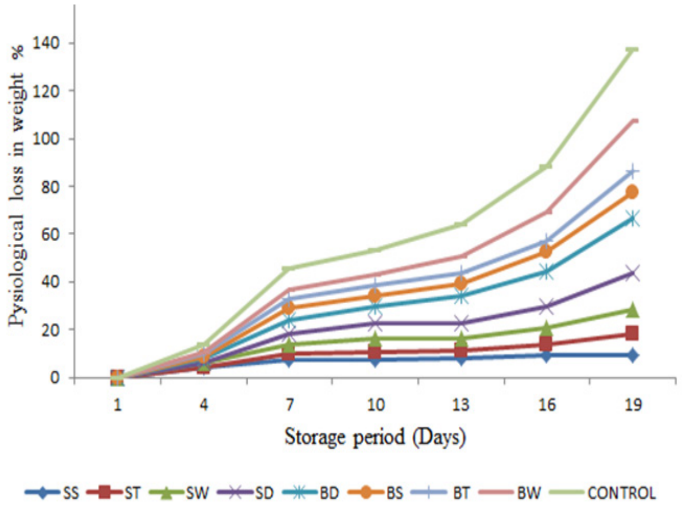

Figure 2. Effect of padding materials on PLW in evaporative Cooler

4.2. Effect of padding Materials on Temperature inside evaporative cooling technologies during storage

All padding materials had a statistically significant effect on the temperature of the evaporative cooler. Fig. 3 depicts the results on the effect of cushioning materials on temperature. Throughout the storage period, the average temperature for all filler materials ranges from 17.5 to 25.30 °C. When the room temperature was 26 to 31 degrees Celsius, a minimum temperature of 17.5 to 20 degrees Celsius was obtained in the sponge. The sponge cooler produced a greater temperature reduction (8.5 to 11 °C).

Doniya cool pad had the lowest temperature reduction, followed by wheat straw and tef straw cooling pads. Mule (2009) found a similar trend in the internal temperature of the evaporative cooler for sapota fruit preservation. (Jha, 2008) observed a temperature drop of 200 degrees Celsius for stored potatoes in a cool chamber during the summer.

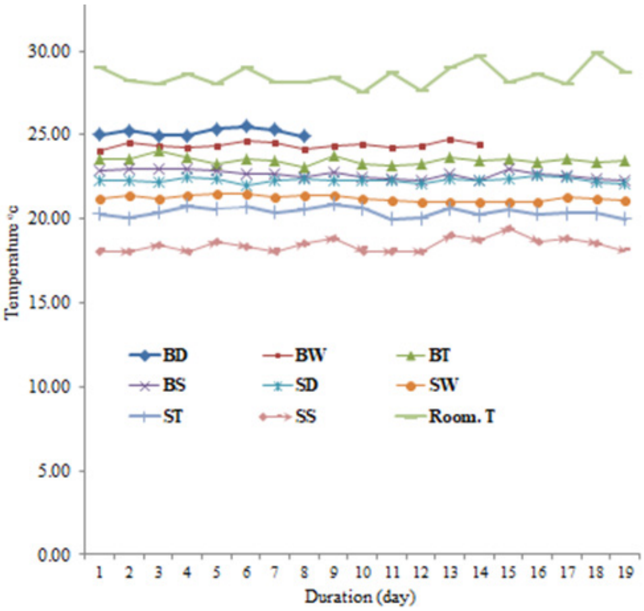

Figure 3. Effect of padding materials on Temperature in evaporative Cooler during storage period

4.3. Effect of padding Materials on humidity inside evaporative cooling technologies during storage

The effect of padding materials on relative humidity was found statistically significant in all padding materials. Relative humidity observed at atmospheric condition was 57 to 60 % during storage. The data on effect of padding materials on inside relative humidity of evaporative cooler was plotted in Figure 4. Inside relative humidity recorded for all of the padding material was ranging from 64.67 to 97.67 %. Minimum relative humidity was recorded in Duniya/sacks cool pad of evaporative cooler as compared to other. Whereas, maximum relative humidity (97.67 %) was recorded in sponge cooling pad followed by tef straw and wheat straw of evaporative cooler respectively. Same trend of inside relative humidity in the evaporative cooler have been reported by (Mule, 2009; Rajendra *et al.*, 2015) for sapota fruit storage.

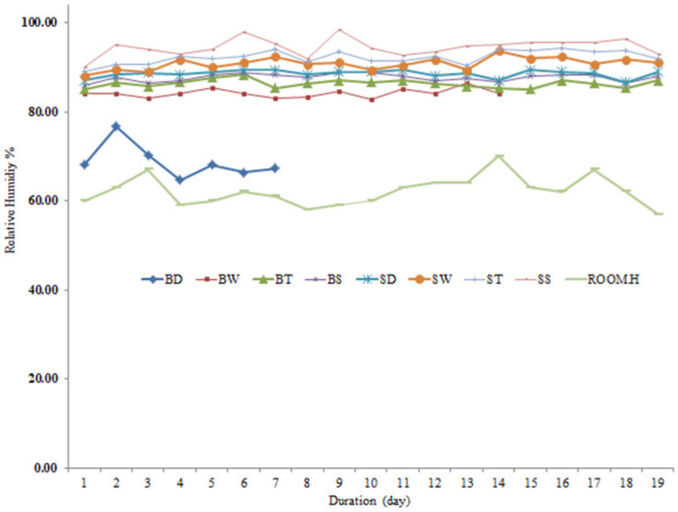

Figure 4. Effect of padding materials on humidity in evaporative Cooler during storage period

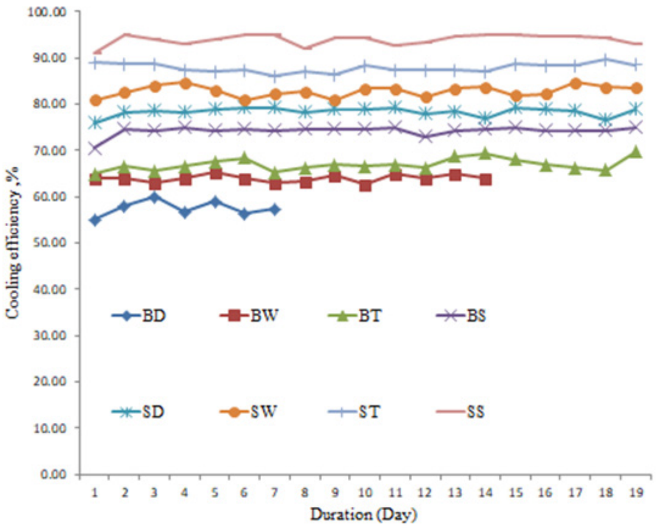

Figure 5. Effect of padding materials on cooling efficiency in evaporative Cooler during storage period

4.4. Effect of Padding Materials on Cooling Efficiency

The effect of padding materials on cooling efficiency was found statistically significant in all padding materials. The data on effect of padding materials on cooling efficiency of evaporative cooler was plotted in Figure 5. Maximum cooling efficiency was recorded in sponge cooling pad followed tef straw and wheat straw cooling pad respectively. The highest cooling efficiency (94.67 %) was recorded in sponge cooling padding. Minimum cooling efficiency was observed in the doniya/sacks cooling pad. Cooling efficiency of the doniya/sacks cooling pad was ranging from 55 to 59.67 %. Similar results were reported by (Thakral *et al.*, 2000) for perishable products stored in evaporative cooling system and (William *et al.*, 2009) for absorbent material stored in evaporative cooling.

5. CONCLUSIONS

Based on the results the following conclusions could be drawn:

- The percent weight loss (PLW) varied between 5.09 to 23 %. Maximum weight loss was found in the doniya/sacks cooling pad whereas minimum (5.09 %) was found in sponge cooling pad of 50 kg storing capacity. The PLW was found increased with increase in storage period for all the padding materials.
- The maximum total storage life of 19 days was found in case of tomato stored in all cooler within the acceptable range except in sack and wheat straw cooler 200 kg capacity cooler. Whereas, minimum storage life of 6days found in control sample followed by 9 and 14 days in Duniya/sacks and wheat straw cooling pad respectively in 200 kg capacity of cooler.
- Minimum inside temperature of 18.10 0C was recorded in sponge cooling pad among all padding materials when average room temperature was 28.48 0C. The average temperature drop of 9.08 to 10.38 0C was found in case of sponge cooling pad throughout the storage period in 50 kg.
- Maximum inside relative humidity of 95% was recorded in sponge cooling pad among all padding materials when average room relative humidity was 62.16 %.
- Highest cooling efficiency of 93 % was recorded in sponge cooling pad evaporative cooler followed by tef straw cooling pad 90 %.
- Sponge cooling pad with a 50 kg capacity proved to be the best for increasing the shelf life (up to 14 days) of tomatoes amongst all other padding materials.
- Sponge cooling pad was found to be the most economical filling material amongst all others, followed by tef straw

Acknowledgment

The authors thank the Asela Agricultural Engineering Research Center and Oromia Agricultural Research Institution for coordinating the facility and financing the project.

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