EFFICIENCY OF EVAPORATIVECOOLING CHAMBERS IN TOMATO (*Lycopersicon esculentum*) STORAGE: CLIMATE CHANGE MITIGATION OPTION IN ZANZIBAR

Zuhura Ali Ameir[1], Said Suleiman Bakar[2], Jamal Kussaga[3], Rashid Suleiman[4]

[1]Department of Natural and Social Science, The State University of Zanzibar (SUZA) E-mail: mummyr2020@gmail.com.

[2]Department of Natural and social science, The State University of Zanzibar (SUZA) P.O.BOX 146 – Zanzibar Email – Sayeed.bakari@gmail.com

[3]Department of food Agroprosessing School of Engeneering and Technonogy Sokoine University of Agriculture (SUA) P.O.BOX 3006 Morogoro Tanzania, Email – rashid@sua.ac.tz

[4]Department of food Agroprosessing School of Engeneering and Technonogy Sokoine University of Agriculture (SUA) P.O.BOX 3006 Morogoro Tanzania, Email – kussaga@sua.ac.tz

The research financed by COSTECH- CST/NFASTRG/CRG/2018.012

Abstract

Tomatoes (*Lycopersicon esculentum*) are edible vegetables that encounter climate-related issues during storage. Appropriate usage of local evaporative cooling chambers (ECCs) innovative for tomato preservation is a cost-effective way to mitigate the effects of climate change. Refrigeration is quite popular, but it contains toxic greenhouse gases-emitting refrigerants, is expensive, and causes tomatoes to chill. Thus, the study intends to evaluate the effectiveness of ECCs as climate change mitigation for tomato storage. After maturation, the Roma round and Roma egg were collected in sterilized wooden bags and stored in ECCs at ambient temperatures until about noon. In ECCs the tomato sample were collected from Dunga, Nyamanzi, and Bungi. The data were analyzed using descriptive statistics. The pour- plate method was used to isolate the fungi and the bacteria. The results indicated that, pH value increased from 5.68, 7.23 and 8.64 in 1, 2 and 3 weeks, respectively, in ambient storage to 3.46, 4.26 and 5.31 at ECCs in 1, 2 and 3 weeks respectively, far more at ambient than ECCs. At Bungi, Nyamanzi and Dunga, the average temperature decrease was 20.71 °C, 20.47 °C, and 20.52 °C, respectively, while the ambient temperature was 33.61 °C, 33.66 °C, and 33.95 °C Bungi, Nyamanzi and Dunga respectively. The average relative humidity at ambient conditions and ECCs for Dunga, Bungi, and Nyamanzi were 73.4%, 71.48%, 73.55%, and 94.71%, 95.33%, and 95.19% respectively. More- over, the samples stored at ECCs have a lower percentage weight loss about 3.99% than the ambient condition which has 21.52%. The statistical analysis revealed a significant difference in microbial load in all tomato samples stored in ECCs and in ambient conditions, with a p-value < 0.05. In ambient conditions, there were more bacteria (*E.coli) was* 5.46E6CFU/g, fungi (yeast) was 6.42E6 CFU/g and mold was 5.1E6CFU/g. In ECCs the *E.coli* (3.67E6CFU/g, 4.14E6cfu/g and 3.84E6cfu/g in Bungi, Dunga and Nyamanzi respectively), yeast (4.13E6cfu/g, 3.98E6CFU/g and 4.26E6CFU/g in Bungi, Dunga and Nyamanzi respectively) and mold (3.87E6cfu/g, 3.99E6cfu/g and 4.07E6CFU/g in Bungi, Dunga and Nyamanzi respectively). When compared to ECCs, color change occurred rapidly at ambient temperatures. The total average cooling efficiency in Dunga, Bungi, and Nyamanzi was 86.98%, 86.81%, and 82.66%, respectively. Based on the study's findings, it is reasonable to assume that ECCs were effective in decreasing ambient temperature and increasing relative humidity. As a result, initiatives should be taken to increase national awareness of the efficacy of ECCs.

Keywords: Evaporative cooling chambers, climate change mitigation, Tomato, Temperature, relative humidity.

DOI: 10.7176/JETP/15-1-01

Publication date: February 28th 2025

1. INTRODUCTION

The tomato (*Lycopersicon esculentum*) is one of the most popular vegetables in the developed world (Deribe *et al.,* 2016). Tomatoes are high in lycopene, carotenoids, and other nutrients such vitamins and minerals (Pathare *et al.,* 2021). Global tomato output has grown by 43% in the last 30 years due to growing demand, averaging 1.3 million metric tons per year (Luzi-Kihupi *et al.,* 2015). Most of this increase occurred in Italy (for paste production), Greece, and France (Luzi-Kihupi *et al.,* 2015). Tanzania's contribution to global tomato production is estimated at 463,964t in 2021 growing average annual rate of 5.86% (Bilaro *et al.,* 2022). The World production of tomato was 186.82 million tonnes from an area of 5.05million hectares with a productivity of 36.98 tonnes/hectares during the year 2020 *(Pal et al.,* 2023). China is the leader in tomato production at global level with a 34.72% share (64.87 million tonnes) in total production (Pal *et al.,* 2023). The world's second largest tomato grower is India, which accounts for 11.01% of global output (20.57 million tonnes) (FAO 2022). In India in 2020-21, tomato area, output, and productivity were estimated 845 thousand hectares, 21181 thousand tonnes, and 25.07 tonnes/ha (Pal *et al.,* 2023). Tomatoes are a valuable cash crop for the country's smallholder farmers (Mutayoba *et al.,* 2018). The annual vegetable output yield in Zanzibar is roughly 10,500 tons, supplying less than 20% of national demand (Mutayoba *et al.,* 2018). As a result, Zanzibar imports around 80% of its vegetables and 20% of its fruits (Abdalla, 2021). Tomato fruit has a climacteric lifespan of 2 to 3 weeks and substantial post-harvest losses (PHL) of 20-50%, necessitating prompt chilling after harvesting to prevent the ripening process and retain freshness (Sibanda & Workneh, 2019). The absence of suitable storage facilities accounts for a large portion of the post-harvest loss of fruits and vegetables in underdeveloped nations. While refrigerated cold shops are the greatest way to preserve fruits and vegetables, they are costly to purchase and operate (Mutayoba *et al.,* 2018). As a result, there is a growing interest in low-cost solutions in poor nations, many of which rely on evaporative cooling, which is simple and does not require any external power source. Reduced PHL levels are critical for increasing market participation, tomato producer welfare, and food supply (Sibanda & Workneh, 2019). Appropriate postharvest measures for fresh tomato fruit are necessary to prevent deterioration, with optimal circumstances of low temperature ranging from 10°C to 15°C and high relative humidity (RH) ranging from 85-95% (Sibanda & Workneh, 2019). Temperature has a significant impact on the deterioration of fruits and vegetables during storage. Room/air temperatures have a direct impact on vegetable respiration and metabolic rates (Islam *et al.,* 2013). Taking into consideration rising demand and weather changes, suitable storage conditions and facilities are crucial for ensuring tomato supply throughout the year and increasing incomes of resource-poor smallholder farmers (Freddy, 2014). Although cold storage is thought to be the greatest option for preserving fruits and vegetables, it involves a significant upfront cost (Liberty *et al.,* 2013). Furthermore, in rural areas, it may not be suited for on-farm storage (Liberty *et al.,* 2013). As a result, in developing nations, low-cost alternative and simple-to-use technologies such as evaporative cooling chambers would be an option for smallholder farmers in rural areas, many of whom rely on evaporative cooling, which is simple and does not require an external power source (Lal Basediya *et al.,* 2013). Despite the fact that Evaporative Cooling Chambers (ECC) have been built and are being utilized by smallholder vegetable producers in three Zanzibar districts: urban west (Nyamanzi), south (Bungi), and central (Dunga), their usefulness has yet to be determined. The purpose of this study is to evaluate the effectiveness ECC used by farmers in Zanzibar.

2. MATERIALS AND METHOD

2.1 Study area

The research was conducted in three districts including: urban west (Nyamanzi), south (Bungi), and central (Dunga). The laboratory analyses were done at the Sokoine University of Agriculture (SUA) in Morogoro.

2.2 The design of evaporative cooling chambers

The three ECCs were constructed by using locally available materials. The double walls was built by using burnt bricks (Birhanu and Belay, 2023). Then clean sand was filled with sand (Sairi *et al.,* 2020). The ECCs was shaded by using dried coconut leaves to prevent sunshine and rain. Then water was sprinkled or poured in the sand to ensure cooling in the chamber. As the water evaporated in the sand, the cooling effect wass induced in the stored produce. As a shown in Plate 2.1

Plate 1.1: Structure of Evaporative Cooling chamber technology in storage of tomato

2.3 Cooling principle of evaporative cooling chambers

The basic principle relies on cooling by evaporation. When water evaporates, it draws energy from its surroundings which produces a considerable cooling effect. Evaporative cooling occurs when air, that is not too humid, passes over a wet surface; the faster the rate of evaporation the greater the cooling. The efficiency of an evaporative cooler depends on the humidity of the surrounding air. Very dry air can absorb a lot of moisture so greater cooling occurs. In the extreme case of air that is totally saturated with water, no evaporation can take place and no cooling occurs.

2.4 Collection of samples

Two samples weighing 5 kilograms each were collected from two varieties Roma round and Roma egg (plate 2.2). The samples were collected from farmers around the area and immediately placed into the cooling chambers. Then 0.05kg samples were with drawn each week for three consecutive weeks (i.e. 21 days). After sampling, the samples placed into a sterile plastic container. The samples cannot be transported to the laboratory within one hour; they must be maintained in a refrigerator under ideal conditions of low temperature ranging from 10°C to 15°C in accordance with sample storage requirements. The sterilized plastic container was put in transport ice bags labeled with a biohazard warning. A transport ice bag was put on the floor below the front passenger seat in the boat during the trip from Zanzibar to Morogoro at the Sokoine University of Argiculture (SUA) laboratory for microbial analysis.

Plate 1.2: Roma round and Roma egg tomato

2.5 Microbiological analyses

Microbiological parameters studied included the growth of bacteria and fungi, including *E. coli*, yeast, and mold, as well as TVC and pH levels.

2.5.1 Sample preparation

The tomato fruit samples were sterilized using distilled water, according to Wang et al., (2009). The remaining sections were then placed in sterile sample trays after being cut into quarters with sterile blades. The same sample's mixed quarters were carefully homogenized into a puree while using sterile gloves to minimize operator contamination. The samples were then assessed and analyzed for microorganisms.

2.5.2 Media Preparation

Culture media used were pour plate method, Potato Dextrose Agar (PDA) and MacConkey agar. The media were all prepared according to the manufacturer's instructions. Pour plate method is the laboratory techniques which was used for isolating and counting viable microorganism like bacteria and fungi in a liquid sample that is added with molten argar for inoculation their colony forming unit. In generally this technique counts the total number of colony forming unit on the surface of solid medium. In pour plate method, the sample was added to the Petri dish, then poured to the molten agar. Then the media is allow to solidify before being incubated at 37 °C to grow and reproduced. Then the number of isolated colonies were counted after incubation.

2.5.2 Isolation of E. coli

Pour plate technique was used to inoculate E. coli whereby MacConkey agar was employed as the inoculation culture under ISO 7251:2005.

2.5.2 Isolation of Yeast and Molds

Both yeast and mold were inoculated in line with ISO 21527-1:2008 by utilizing Potato Dextrose Agar using the pour plate technique.

2.5.4 Determination of Total Viable count (Total Bacteria Count)

Using a sterile pipette for each diluent, 0.1ml of each 24 samples dilution was transferred and disseminated over plate count (PC) agar to determine the total viable counts which were expressed as units per gram (cfu/g) of samples (Barth *et al.,* 2009).

2.5.5 Determination of pH value

The pH was measured directly by using a pH meter (pH meter 3305, Japan) whereby the sample was homogenized (UMNI MIXER HOMOGINIZER SNMX21177).

Plate 1.3: pH samples analysis reading and preparation for samples

2.6 Qualities analysis

The qualities analyzed were physiological loss in weight, change in color, and environmental parameters like temperature, relative humidity, and evaporative cooling efficiency, which were tested during the experimental investigation as follows.

2.6.1 Post harvest loss (PHL)

Weight loss in tomatoes were observed during the study beginning on the first day (zero day) and progressing through three, six, nine, twelve, fifteen, eighteen, and twenty-one days, and was recorded and measured after three days using a digital electronic balance, according to each variety and the amount stored.

Workneh et al. (2011a) provided the methodologies for calculating Post harvest loss

$$PHW\ (\%) = \frac{W_1 - W_2}{W_1} \times 100\%$$

Where;

PHL= Post harvest loss, %

W_1 = *Weight of tomato fruit before storage, g*

W_2 = *Weight of tomato fruit after storage, g.*

2.6.2 Color change

The color changes of the tomatoes were studied in both variables using the observation technique from the first day up to day twenty-one across all the ECCs as well as ambient conditions. According to Fabiyi (2010), the color variations observed were caused by the physical characteristics of the tomatoes.

2.6.3 Evaporative cooling efficiency

A psychrometer was a device for measuring air humidity, by measuring the temperature difference between a dry thermometer bulb and a wet thermometer bulb that has lost some moisture due to evaporation at the same time. Inside and outside the ECCs between 12:00 a.m. and 2:00 p.m, one thermometer's bulb was kept wet, causing it to record a lower temperature than the dry-bulb thermometer due to evaporation cooling. Drier air absorbs more moisture from the bulb, which causes it to cool down faster.

The technique provided by Sibanda and Workneh (2020) was used to compute the cooling efficiency (η) of the ECCs.

The equation can be displayed below.

$$\eta = \frac{(Tdb - Ts)}{(Tdb - Tw)} x100\%$$

Where, Tdb = dry bulb temperature in °C, Tw = Wet bulb temperature in °C, Ts = Storage temperature in °C

2.7 Statistical analysis

Microsoft Excel 2010 and Statistical Package for Social Science (SPSS) version 20 was used to perform the F-test analysis in order to analyze the variation of more than two variables during observation of tomato samples. At a p-value less than 0.05, a level of confidence of 95% was determined for all data.

3. RESULT AND DISCUSSION

3.1 Temperature and relative humidity

Perishables' shelf life is largely influenced both temperature and relative humidity. Evaporative cooler storages enhanced relative humidity while lowering interior storage temperature as compared to the control. The low temperature inside the evaporative cooling chambers was maintain by utilizing the passive evaporative cooling method. The findings shown in the figures 1.1

TEMPERATURE IN (°C)							RELATIVE HUMIDITY IN (%)					
DAYS	DUNGA		BUNGI		NYAMANZI		DUNGA		BUNGI		NYAMANZI	
	ECCs	*AMB*	*ECCs*	*AMB*	*ECCs*	*AMB*	*ECCs*	*AMB*	*ECCs*	*AMB*	*ECCs*	*AMB*
1.	21	35	20	34	20	35	96	69	97	69	95	76
2.	22	34	22	33	20	34	96	68	98	69	97	77
3.	20	33	21	35	22	33	98	71	97	72	98	75
4.	20	35	20	35	21	35	91	74	95	76	93	77
5.	21	36	22	34	19	34	99	77	93	77	99	80
6.	19	35	20	35	20	35	98	76	96	67	96	81
7.	23	29	21	31	22	30	95	60	97	67	97	77
8.	19	31	21	33	21	33	97	76	94	71	96	75
9.	20	32	20	34	20	34	94	70	92	75	95	65
10.	21	34	22	34	20	32	95	68	94	69	96	69
11.	20	35	21	33	22	33	97	75	98	79	95	81
12.	22	33	19	35	20	34	98	68	96	77	98	79
13.	21	34	21	31	21	35	95	79	96	77	92	77
14.	19	34	20	30	20	31	88	68	87	78	93	72
15.	20	35	20	33	20	33	87	67	88	76	97	71
16.	21	35	20	34	20	35	96	69	97	69	95	76
17.	22	34	22	33	20	34	96	68	99	69	97	77
18.	20	33	21	35	22	33	98	71	92	72	91	75
19.	20	35	20	35	21	35	91	74	89	76	88	77
20.	21	36	22	34	19	34	99	77	98	77	95	68
21.	19	35	20	35	20	35	98	76	96	80	96	86

Source: Author, 2023

KEY: ECCs = EVAPORATIVE COOLING CHAMBERS
AMB = AMBIENT (CONTROL) CONDITION

The data displayed in Figures 1.1 and 1.2 show the mean average temperature and relative humidity at ECCs and ambient conditions. At Bungi, Nyamanzi, and Dunga, the average temperature was 20.71 °C, 20.47 °C, and 20.52 °C, respectively, while the ambient temperature was 33.61 °C, 33.66 °C, and 33.95 °C Bungi, Nyamanzi and Dunga respectively. The average relative humidity at ambient conditions and ECCs for Dunga, Bungi, and Nyamanzi were 73.4%, 71.48%, 73.55%, and 94.71%, 95.33%, and 95.19 respectively, %. It clearly shows a highly significant difference between interior and ambient condition for both temperature and relative humidity, with a p-value < 0.05. It was observed that ECCs lower the interior temperature and increase the inside relative humidity, hence increasing the shelf life of tomato storage compared to ambient conditions.

This study is consistent with the findings reported by Sibanda and Workneh (2020). Chilling injury can occur in tomato fruits stored at temperatures below 10°C (Arah *et al.,* 2015). This is most likely becauses the relative humidity of above 85% required for storing tomatoes for weight loss prevention (Arah *et al.,* 2015).

3.2 Cooling efficiency

Table 1.2: The effectiveness of each ECC's

	AT DUNGA				AT BUNGI				AT NYAMANZI			
DAYS	Tdb in °C	Twb in °C	Ts in °C	Cooling efficiency in %	Tdb in °C	Twb in °C	Ts in °C	Cooling efficiency in %	Tdb in °C	Twb in °C	Ts in °C	Cooling efficiency %
1	35	17	20	83.33	35	19	20	93.75	34	16	20	77.77
2	34	17	20	82.35	34	17	20	82.35	33	15	20	72.22
3	33	18	20	86.66	33	17	20	81.25	35	20	20	93.75
4	35	18	20	93.75	35	18	20	88.24	35	17	20	83.33
5	36	19	20	94.12	34	16	20	77.77	34	18	20	87.5
6	35	16	20	78.94	35	20	20	93.75	35	16	20	78.95
7	29	15	20	64.28	30	17	20	76.92	31	15	20	68.75
8	31	19	20	91.66	33	18	20	86.66	33	17	20	81.25
9	32	18	20	85.71	34	18	20	87.5	34	17	20	82.35
10	34	18	20	93.33	32	18	20	85.71	34	18	20	87.5
11	35	19	20	93.75	33	19	20	92.86	33	18	20	86.66
12	33	18	20	86.66	34	19	20	93.33	35	19	20	93.75
13	34	18	20	87.51	35	16	20	78.95	31	16	20	73.33
14	34	17	20	82.35	31	17	20	78.57	30	18	20	83.33
15	35	19	20	93.75	33	18	20	86.66	33	17	20	81.25
16	35	17	20	83.33	35	19	20	93.75	34	16	20	77.77
17	34	15	20	82.35	34	19	20	93.33	33	15	20	72.22
18	33	17	20	81.25	33	18	20	86.66	35	19	20	93.75
19	35	16	20	93.75	35	17	20	83.33	35	18	20	88.24
20	36	19	20	94.12	34	19	20	93.33	34	19	20	93.33
21	35	19	20	93.75	35	18	20	88.24	35	16	20	78.95
AVG	**33.95**	**17.57**	**20**	**86.98**	**33.66**	**17.9**	**20**	**86.81**	**36.62**	**17.09**	**20**	**82.66**

Source: Author, 2023

AVG = AVERAGE

The temperatures of the dry and wet bulbs inside the evaporative cooling chambers are displayed in Table 1.1.

The findings revealed that the evaporative cooling chamber's average noontime cooling efficiency was 86.98%, 86.81%, and 82.66% for Dunga, Bungi, and Nyamanzi, respectively. This shows that all chambers perform their work effectively.

The cooling efficacy of the system, according to Arah *et al.,* (2015), is between 75% and 90%. When sun irradiation is at its greatest in the afternoon, higher temperatures and a lower relative humidity of ambient air provide superior cooling efficiency (Sibanda and Workneh, 2020).

3.3 Weight loss

Weight loss of tomato fruits increased with the duration of storage and was influenced by methods of storage conditions (Table 1.2)

Table 1.3: Physiological percentage weight losses of tomato at ambient and in ECCs for 21 days in grams.

AREA	TYPESOF TOMATO	INITIAL WL IN GRAM	% WL IN 3 DAYS	% WL IN 6 DAYS	% WL IN 9 DAYS	% WL IN 12 DAYS	% WL IN 15 DAYS	% WL IN 18 DAYS	% WL IN 21 DAYS	AVR% WL21 DAYS
NYMNZI	R.EGG	104	0.77	1.96	3.O8	4.76	5.87	6.54	7.5	4.35
	R.ROUND	93.13	3.22	3.4	5.85	6.58	7.52	7.8	8.5	6.12
BUNGI	R.EGG	97.7	0.96	1.74	2.61	3.77	5.19	7.51	9.46	4.46
	R.ROUND	82.25	1.67	2.55	3.12	4.92	6.08	7.57	8.51	4.92
DUNGA	R.EGG	97.7	2.05	2.88	4.45	5.07	6.67	8.51	9.93	5.65
	R.ROUND	86.25	0.69	1.5	2.55	3.25	4.06	5.37	7.66	4.58
AMBIENT (CONTROLL)	R.EGG	98.98	4.37	9.8	15.55	21.62	26.28	27.68	29.41	19.24
	R.ROUND	82.68	3.99	8.77	11.85	14.57	21.84	27.39	32.47	17.27

Source: Author, 2023

KEY: R.EGG = ROMA EGG

R.ROUNG = ROMA EGG

WL = WEIGHT LOSS

AVR = AVERAGE

NYMNZI = NYAMANZI

The average percentage weight loss of tomatoes (Roma round and Roma egg) in both ECCs as well as ambient condition (control) chambers are shown in Table 1.3

It was shown that tomatoes stored outside of a chamber (in ambient conditions) lost weight at a rate 21.52% greater than tomatoes placed within evaporative cooling chambers about 3.99% weight loss. The statistical analysis revealed a highly significant variance in percentage loss of weight between ambient and ECCs, with the average percentage mean being greater at the ambient condition than at the ECCs where p-value < 0.05. It is generally suggested that the physiological weight loss of tomatoes was high under ambient condition compared with ECCs storage conditions.

These findings are concurred with the study conducted by Tadesse *et al.,* (2015), which found that tomato preservation at high temperatures is unsustainable due to significant weight loss. The ECCs reported to considerable reduce postharvest weight loss in tomatoes (Ishaque *et al.,* 2019). Keeping harvested fruits cool at low temperatures of about 20°C will slow down many metabolic activities (Arah *et al.,* 2015). The addition of moisture (wetting fruits) in lower relative humidity storage can reduce weight loss and prevent fruit from shriveling (Arah *et al.,* 2015)

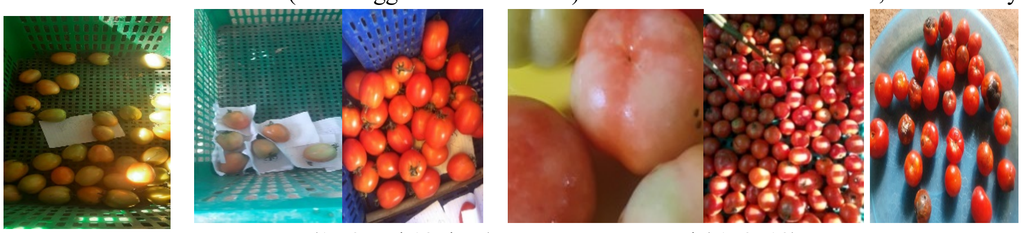
3.4 Color change

The color change of stored tomatoes was detected at both ambient conditions and at evaporative cooling chambers by visual appearance (observation) and camera shot in order to get good comparison between the storage packaging. The tomatoes color changed from pale yellow to red, and later on a spotted black was observed with yeast and mold at ambient conditions compared with evaporative cooling chamber conditions. The samples retained their color up to 21 days with little or no black and white color in ECCs storage.

The plate 1.5 shown the color-changed observations made over the 21-day storage period both inside and outside the chambers.

Roma egg (1, 9 and 12 days) Roma round (1, 9 and 12days)

Plate: 2.4 Tomatoes (Roma egg and Roma round) stored at ambient condition 1, 9 and 15 days



Roma egg (1 , 9 and 12 days) Roma round (1, 9 ,12)

Plate: 1.5 Tomatoes (Roma egg and Roma round stored at ECCs in 1 , 9 and 15 days

Source: Aurthor, 2023

3.5 Microbial Quality of stored tomato

The tables below present information regarding the analysis of microorganism detection 21 days of preserved tomatoes (Roma egg and Roma round). At each research site, the pH value of storage tomatoes in ambient and evaporative cooling chambers and TVC were analyzed as shown below.

Table 1.4: Isolated E.coli in CFU/g from storage tomato samples at ambient and ECCs within 21 days

DAYS	TYPES OF TOMATO	AMBIENT	BUNGI	DUNGA	NYAMANZI
1 day	R. round	2.38E6	2.61E6	2.66E6	2.86E6
	R. egg	3.34E6	2.81E6	3.42E6	2.78E6
1 week	R. round	4.18E6	3.22E6	3.88E6	3.37E6
	R. egg	6.56E6	3.42E6	4.49E6	3.52E6
2 weeks	R. round	7.21E6	3.88E6	4.33E6	4.23E6
	R. egg	8.12E6	4.48E6	4.77E6	4.52E6
3 weeks	R. round	8.57E6	4.32E6	4.68E6	4.68E6
	R. egg	9.35E6	4.53E6	4.88E6	4.75E6

Source: Author, 2023

Key: R. round = Roma round

R. egg = Roma egg

Table 1.5: Yeast (CFU/ g) isolated from storage tomato sample at ambient and ECCs within 21 day

DAYS	TYPES OF TOMATO	AMBIENT	BUNGI	DUNGA	NYAMANZI
1 day	R. round	3.18E6	3.35E6	2.95E6	2.42E6
	R. egg	3.28E6	3.56E6	3.15E6	3.64E6
1 week	R. round	5.26E6	3.58E6	3.11E6	3.66E6
	R. egg	5.66E6	4.34E6	4.16E6	4.29E6
2 weeks	R. round	7.88E6	3.88E6	4.45E6	4.88E6
	R. egg	8.25E6	4.52E6	4.48E6	4.65E6
3 weeks	R round	8.57E6	4.85E6	4.65E6	5.18E6
	R. egg	9.24E6	4.98E6	4.84E6	5.34E6

Source: Author, 2023

Key: R. round = Roma round

R. egg = Roma egg

Table 1.6: The results of Mold (CFU/g) isolated from stored tomatoes at ambient and ECCs within 21 days

DAYS	TYPES OF TOMATO	AMBIENT	BUNGI	DUNGA	NYAMANZI
1 day	R. round	3.27E6	2.95E6	3.14E6	3.32E6
	R. egg	3.31E6	3.14E6	3.43E6	3.52E6
1 week	R. round	3.62E6	3.25E6	3.58E6	3.63E6
	R. egg	4.46E6	3.82E6	3.87E6	3.82E6
2 weeks	R. round	5.78E6	4.21E6	4.25E6	4.45E6
	R. egg	5.53E6	4.38E6	4.42E6	4.55E6
3 weeks	R. round	6.82E6	4.69E6	4.58E6	4.62E6
	R .egg	7.94E6	4.48E6	4.65E6	4.68E6

Source: Author, 2023

Key: R. round = Roma round

R. egg = Roma egg

Table 1.7: The results of TVC (CFU/g) isolated from stored tomatoes sample at ambient and ECCs within 21 days

DAYS	TYPESOF TOMATO	AMBIENT	BUNGI	DUNGA	NYAMANZI
1 day	R. round	3.25E6	3.18E6	2.42E6	3.12E6
	R. egg	4.53E6	3.82E6	4.16E6	4.24E6
1 week	R. round	4.34E6	4.84E6	3.56E6	4.15E6
	R. egg	5.37E6	5.17E6	5.48E6	5.24E6
2 weeks	R. round	5.26E6	4.18E6	7.34E6	4.78E6
	R. egg	6.26E6	5.16E6	5.48E6	5.52E6
3 weeks	R. round	6.18E6	4.88E6	4.27E6	4.64E6
	R. egg	6.26E6	4.28E6	4.48E6	4.85E6

Source: Author, 2023

Key: R. round = Roma round
R. egg = Roma egg

Figure 1.7 shown the average Total Viable Count (TVC) of tomatoes rotting. The unit of measurement is CFU/g. In ECCs, the TVC was (4.44E6CFU/g, 4.65E6CFU/g and 4.58E6cfu/g in Bungi, Dunga and Nyamanzi, respectively) and in ambient, it was TVC (5.58E6 CFU/g). This indicates that a higher number of microbial forming unit in tomatoes that were storage under ambient conditions compared at ECCs. F-test shows a significant difference between TVC in ambient and ECCs, with p - value 0.039, at $p \leq 0.05$. This indicate that the number of microbes were higher at ambient storage which has high temperature and low relative humidity. Figure 1.5 shown the number of isolated yeast (4.13E6CFU/g, 3.98E6CFU/g and 4.26E6CFU/g in Bungi, Dunga and Nyamanzi, respectively) and mold was (3.87E6CFU/g, 3.99E6CFU/g and 4.07E6CFU/g in Bungi, Dung and Nyamanzi respectively) in figure 1.4. Fungi isolated from yeast and mold were *Aspergillus niger* and *Penicillium sp*. respectively.

At p - value 0.05, the statistical analyses demonstrated a more significant difference of *E.coli*, yeast, and between tomato that storage at ambient and ECCs with ($p = 0.034$) for *E.coli,* $p = 0.04$ for yeast, and $p = 0.039$ for mold. When compared to ambient settings, ECCs are the best for tomato preservation.

This study's findings largely corroborate previous findings by (Rida and Deeba, 2021). The bacteria recovered in this study are comparable to those obtained by (Mailafia *et al.,* 2017).The forms of fungus identified from the current research sample were harmful to tomatoes, based on the findings (Mailafia *et al.,* 2017).

3.6: pH

Table 1.8: pH change of stored tomatoes in ECCs and at ambient condition within 21 days

NUMBER OF WEEK	TYPES OF TOMATO	PH OF TOMATO AT DUNGA	PH OF TOMATO AT BUNGI	PH OF TOMATO AT NYAMANZI	PH OF TOMATO AT AMBIENT
1 day	R. round	3.86	3.76	3.69	3.88
	R. egg	3.95	3.82	3.86	3.93
Week 1	R. round	3.15	3.35	3.32	5.68
	R. egg	3.42	3.42	3.42	6.85
week 2	R. round	4.32	4.12	4.33	8.64
	R. egg	4.28	5.17	5.32	8.44
week3	R. round	5.33	5.52	5.46	9.24
	R. egg	5.43	5.87	5.68	9.64

Source: Author, 2023

Key: R. round = Roma round
R. egg = Roma egg

During observation, at Dunga the average mean pH of preserved tomatoes for both types in the first, second, and third weeks was 3.25, 4.32 and 5.43, respectively. The first, second, and third weeks at Bungi was 3.44, 4.33 and 5.15, respectively. At Nyamanzi, the first, second, and third weeks was 3.57, 4.12 and 5.32, respectively. The ambient conditions were 5.68, 7.23 and 8.64 in the first, second, and third week respectively. The study revealed that the pH value increased with storage time; therefore, tomatoes were detreated first at ambient storage compared at ECCs. During decomposition, tomatoes go from acidity to alkalinity. According to the study's findings, most microorganisms grow and reproduce successfully at pH levels ranging from 8.0 to 10.5 (Alam *et al.,* 2012)

At $p \leq 0.05$, the F - value was 3.7 and the p - value was 0.029, showing a significant difference in pH value between tomatoes stored in ambient and evaporative cooling chambers. The rise in pH shows that the fruit's acid content has decreased, indicating that tomatoes are ripe for degradation (Alam *et al.,* 2012).

CONCLUSION

The effectiveness of evaporative cooling chambers as a climate change mitigation approach for tomato storage was investigated in this study.

The results of the study showed that all three evaporative cooling chambers maintain quality and extend the shelf life of tomatoes as compared to storage at room temperature. ECCs extended for 19 days up to 21 days without decaying, while it look only 4 days for storage at room temperature. The evaporative cooling chambers extend the shelf life and quality of tomatoes by lowering storage temperatures and increasing relative humidity without destroying the ozone layer, hence tending to mitigate climate change. A decrease in surrounding temperature and an increase in relative humidity regulate cooling efficiency by increasing the moisture content of the air. This study found that more microorganisms flourish under ambient conditions than ECCs, providing a potential alternate technique for tomato preservation. ECCs are a feasible alternative approach to both ambient and mechanical refrigerators for extending and maintaining tomato postharvest shelf life through reducing greenhouse emissions that harm the environment. Consequently, ECCs were best for tomato storage solution in order to maximize productivity while also improving food security.

ACKNOWLEDGMENT

I wish to thank the Almighty God for providing me with the energy and health to do this strenuous work. My gratitude goes to the SUA scientists and technicians who tested my samples. Special gratitude goes to COSTECH number CST/NFASTRG/CRG/2018.012 for financing the study, which enabled me to complete my research.

CONFLICTS OF INTEREST

The authors declare that they have no competing concerns in the publication of this study's results.

Referrences

Abdalla, N. A. (2021). *Factors Affecting Market Access Among Spice Farmers in Zanzibar: A Case of Zanzibar State Trading Corporation (ZSTC)* (Doctoral dissertation, The Open University of Tanzania).

Arah, I.K., Amaglo, H., Kumah, E.K. and Ofori, H., 2015. Preharvest and postharvest factors affecting the quality and shelf life of harvested tomatoes: a mini review. *International Journal of Agronomy*, *2015*.

Barth, M., Hankinson, T.R., Zhuang, H. and Breidt, F., 2009. Microbiological spoilage of fruits and vegetables. *Compendium of the microbiological spoilage of foods and beverages*, pp.135-183.

Bilaro, J. S., Materu, S. F., & Temba, B. A. (2022). Dietary risk assessment of selected organophosphorus and pyrethoid pesticide residues in fresh harvested tomatoes at Makambako Town, Njombe region, Tanzania. *Food Additives & Contaminants: Part B*, *15*(3), 235-243

Birhanu, G. A., & Belay, A. N. (2023). Enhancing the shelf life of injera: design of an evaporative cooler clay chamber derived from local clay in Bahir Dar, Ethiopia. *Design Science*, *9*, e8.

Deoraj, S., Ekwue, E. I., & Birch, R. (2015). An Evaporative Cooler for the Storage of Fresh Fruits and Vegetables. *The West Indian Jouranal of Engineering*, *38*(January), 86. http://sta.uwi.edu/eng/ wije/

Deribe, H., Beyene, B., & Beyene, B. (2016). Review on pre and post-harvest management on quality tomato (Lycopersicon esculentum Mill.) production. *Food Science and Quality Management*, *54*, 72-79.

Ishaque, F., Hossain, M. A., Sarker, M. A. R., Mia, M. Y., Dhrubo, A. S., Uddin, G. T., & Rahman, M. H. (2019). A study on low cost post harvest storage techniques to extend the shelf life of citrus fruits and vegetables. *Journal of Engineering Research and Reports*, *9*(1), 1-17.

Islam, M. R., Chowdhury, M. A. H., Saha, B. K., & Hasan, M. M. (2013). Integrated nutrient management on soil fertility, growth and yield of tomato. *Journal of the Bangladesh Agricultural University*, *11*(452-2016-35528), 33-40.

Lal Basediya, A., Samuel, D. V. K., & Beera, V. (2013). Evaporative cooling system for storage of fruits and vegetables-a review. *Journal of food science and technology*, *50*, 429-442.

Liberty, J. T., Okonkwo, W. I., & Echiegu, E. a. (2013). Evaporative Cooling: A Postharvest Technology for Fruits and Vegetables Preservation. *International Journal of Scientific & Engineering Research*, *4*(8), 2257–2266.

Luzi-Kihupi, A., Kashenge-Killenga, S. and Bonsi, C., 2015. A review of maize, rice, tomato and banana research in Tanzania. *Tanzania Journal of Agricultural Sciences*, *14*(1).

Mutayoba, Venance, and Deus Ngaruko. "Assessing tomato farming and marketing among smallholders in high potential agricultural areas of Tanzania." *International Journal of Economics, Commerce and Management* 6, no. 8 (2018): 577-590.

Rida, B., & Deeba, F. (2021). *Microbiological Safety Assessment of Fresh Fruits and Vegetables Collected Journal of Bioresource Management Microbiological Safety Assessment of Fresh Fruits and Vegetables Collected from Main Markets of Multan , Pakistan*. *October 2018*. https:/doi.org/10.35691/JBM.8102.85.

Sairi, M., Ghazali, N.S., Ying, J.C.L., Basri, M.S.H., Ramli, S.H.M., Mail, M.F., Noh, A.M., Sahari, Y., Azizan, M.S., Amin, M.Z.M. and Hamzah, A., 2023. Performance Assessment of Evaporative-Cooled Storage System in Short-Term Storage of Fruit Vegetables during Transportation. *Advances in Agricultural and Food Research Journal*, *4*(1).

Sibanda, S., & Workneh, T. S. (2019). Effects of indirect air cooling combined with direct evaporative cooling on the quality of stored tomato fruit. *CyTA-Journal of Food*, *17*(1), 603-612.

Sibomana, M.S., Workneh, T.S. and Audain, K.J.F.S., 2016. A review of postharvest handling and losses in the fresh tomato supply chain: a focus on Sub-Saharan Africa. *Food Security*, *8*, pp.389-404.

Tadesse, T. N., Ibrahim, A. M., & Abtew, W. G. (2015). Degradation and formation of fruit color in tomato (Solanum lycopersicum L.) in response to storage temperature. *American Journal of Food Technology*,*10*(4),147–157.

Wang, H., Feng, H., Liang, W., Luo, Y. and Malyarchuk, V.I.K.T.O.R., 2009. Effect of surface roughness on retention and removal of Escherichia coli O157: H7 on surfaces of selected fruits. *Journal of food science*, *74*(1), pp.E8-E15.

Workneh, T. S., & Woldetsadik, K. (2004). Forced ventilation evaporative cooling: A case study on banana, papaya, orange, mandarin, and lemon. (179). *Tropical agriculture*.