Original Research Article

QUALITY EVALUATION OF FRESH TOMATO STORED IN EVAPORATIVE COOLERS

Abstract

A study was conducted to assess the performance of evaporative coolers for the storage of fruits and vegetables. Two evaporative coolers [Aluminum-cladded burnt-clay-brick evaporative cooler (ABBEC) and non-cladded burnt-clay-brick evaporative cooler (NBBEC)] for the storage of fruits and vegetables were designed, constructed and tested. The evaporative coolers comprised of double burnt-brick walls (1.29×2.55×2.56m) external and (1.13×1.27×2.08m) internal, (L×W×H). The physicochemical, microbiological and sensory attributes of fresh tomatoes stored in the coolers and at ambient were evaluated. Metabolic rates of tomatoes were highest at ambient storage followed by NBBEC with the least value in ABBEC. Beta carotene, ascorbic acid and acidity decreased while total soluble solids, pH and microbial loads increased during storage of tomatoes. Fresh tomatoes stored in ABBEC exhibited lower biochemical and physiological reaction rates hence tissue breakdown, colour changes, pH and titratable acidity were lower in ABBEC than NBBEC and ambient. ABBEC storage further improved the microbial quality and shelf life of fresh tomatoes. The aluminum cladded evaporative cooler was the best storage facility for stop gap extension of shelf life of tomatoes.

Keywords: Evaporative cooler, Titratable acidity, Tomatoes, Total Soluble Solids.

1.0 Introduction

Tomato (Lycopersicum esculentum) is considered an important cash and industrial crop in many parts of the world. The demand for tomato and its by-products outweighs its supply. According to Kitinoja and Kader (2015), tomato experiences great postharvest losses due to its natural perishability, precarious transportation, storage conditions and improper packaging. They reported that postharvest losses of fruits and vegetables in developing countries accounted for almost 50% of the produce. Similarly, in Nigeria, out of about 1.8 million tonnes of tomatoes produced, over 50% were lost due to poor storage systems, poor packaging/transportation and lack of processing enterprises among others (Ugonna *et al.*, 2015). According to Nkama *et al.* (1994) and Ministry of Agriculture, Benue (2010), the postharvest losses of fresh tomatoes in Nigeria were put at about 113.1 to 282.75×10^3 metric tonnes. This is because unsold produce was allowed to rot away due to high perishability and high transportation costs. Also tomato fruit quality could be affected by many other factors including genetic, environmental, preharvest and postharvest factors. Their storage at room temperature favours decay, weight loss, softening, wilting and off-flavour development. These undesirable effects of excessive temperature are directly linked to higher respiration rates, transpiration and ethylene production. Odesola and Onyebuchi (2009) noted that lower storage temperatures and higher relative humidity will generally maintain the nutritional quality, appearance and flavour with minimal effect on softening and wilting of fresh produce. Mechanical refrigeration is one of the techniques used to achieve high relative humidity and low storage temperatures in developed countries (Woldermariam and Abera, 2014). However, such technologies require uninterrupted electricity and high initial capital for procurement and installation which prohibits the use of cold rooms for storage by small holder farmers resulting in increased losses. Since most farmers in developing countries cannot afford the high cost of storage facilities; the FAO (1983) advocated for low cost and energy saving storage systems based on the principle of evaporative cooling. Evaporative cooling is an innovative and environmentally friendly air conditioning system that operates using induced processes of heat and mass transfer where water and air are the working fluids (Camargo, 2007). Reduced temperature of evaporative cooling would decrease physiological, biochemical and microbiological activities which are the causes of quality deterioration and weight loss of fresh produce such as tomatoes.

Previous studies conducted on evaporative cooling storage of fresh produce have shown that temperature can be maintained 10-15^{o}C below the normal ambient while relative humidity can be increased up to 90% (Kitinoja, 2013). Ogbuagu et al. (2017) worked on the performance evaluation of a composite-padded evaporative cooling storage bin. The facility was able to sustain tomatoes, garden eggs and carrots for 10 days. Zakari et al. (2016) designed and constructed an evaporative cooler for tomato storage. The tomatoes had a shelf life of 5 days with negligible changes in weight, colour, firmness and rottenness. Deoraj et al. (2015) stored tomatoes in evaporative cooler and this was found to be the best storage method in terms of preserving the acidity of tomatoes as well as their total soluble solids. Despite being a food basket of the nation (Nigeria), there is little or no research carried out on evaporative cooling in Benue State. Hence, this research was conducted to evaluate the performance of two evaporative coolers- ABBEC and NBBEC, in preserving the postharvest quality and extending the shelf life of tomatoes.

2.0 Materials and Methods

2.1 Study Area/Scope of research

Makurdi is the capital of Benue State, Nigeria. The town is dominated by guinea savannah type of vegetation. The mean annual rainfall is favourable for food production. Makurdi has a sub-humid, semi-arid tropical climate with mean annual precipitation at 1200-1300mm. About 90% of total annual rainfall occurs in the months of June to September (Odiaka et al., 2008). Temperature rarely falls below 22^{o}C with peaks of 40 and 30^{o}C in February/March. In the wet season, the average temperature is within the range of 23.0-32.7^{o}C. Data generated were the average for 2014 to 2017 for the evaporative coolers located beside the College of Food

Technology Complex at the University of Agriculture, Makurdi (Latitude:07°45’23” N, Longitude 08°34’23” E).

2.1 Design and Construction of Evaporative Coolers

Two almost identical burnt clay bricks evaporative coolers were designed and constructed adjacent and about 1m apart under two trees. One had two internal aluminum claddings and was designated as aluminum cladded burnt clay evaporative cooler (ABBEC); the outer aluminum wall was perforated. The other cooler had no internal aluminum cladding and was referred to as native burnt brick evaporative cooler (NBBEC). The pictorial views of the cooling structures are shown in Plate 1. Essentially, the evaporative coolers consist of double jacketed rectangular burnt clay brick wall. The cavity between the inner and outer walls of each cooler was filled with river-bed sand. The floors were cemented with mortar (cement, sand and water mixture) to an even 2cm thickness. The doors to the storage spaces were made of white wood with zinc roofing sheet cladding for protection against rodents and termites. A make-shift thatched roof cover was built above each of the coolers to provide extra protection against direct sunlight in addition to the shade provided by the trees so that the fullest advantage of evaporative cooling could be harnessed. In order to maintain the sand completely wet during the study, 500litres of water was used to wet the sand twice a day.

Plate 1: Evaporative Coolers 1 & 2

EC1= Non-Cladded Burnt-Clay-Brick Evaporative Cooler (NBBEC)
EC2=Aluminum-Cladded Burnt-Clay-Brick Evaporative Cooler (ABBEC)

2.1 Commodity Storage Test

10kg of ripe tomato fruits (Roma vf) were purchased from Makurdi Wurukum market and transported to the laboratory in jute bags. They were then washed with tap water to remove adhering sand and other foreign matter.

2.1.1 Weight Loss

Weight loss was measured before and after storage using an electronic weighing balance (Model: Mettler P1210). Ten tomato fruits were drawn at random on the 1st and 21st days of storage. Weight loss for each sample of known initial weight was calculated as follows:

$$PWL\ (\%) = (W_o - W_t) / W_o \times 100$$

Where, PWL= physiological weight loss; W_o= initial weight of sample and W_t= weight of sample at time, t. The mean for the ten samples were then reported.

2.1.2 Chemical Analyses

Chemical analyses were performed according to the standard official methods described in AOAC (2005). Clear juice of tomato fruit was extracted by pulping 100g of edible portion in a household electric blender followed by straining using double-layered muslin cloth.

Ascorbic acid and Total Carotenoids

Ascorbic acid and carotenoids were determined by AOAC (2005) methods. Ascorbic acid content was determined by titrimetric method with the titration of filtrate against 2,6-dichlorophenol indophenols and the result expressed as mg/100g.

Total Soluble Solids (TSS)

TSS in degree brix was directly measured using Abbe refractometer (Model: Bellingham & Stanley Limited, England) by placing a drop of supernatant on the prism of refractometer.

pH and Titratable Acidity Determination

The digital pH meter (Model pH 211, HI Hanna Instruments, Italy) was used to measure the pH of the tomato juice while total titratable acidity (expressed as citric acid %) was determined by titrating 5ml of tomato juice with 0.1N sodium hydroxide- using phenolphthalein as an indicator (AOAC, 2005).

2.2 Microbiological Analysis

Samples for total plate counts and fungal counts were prepared as described by Kramer & Twig (1970). Duplicate 2g portions of tomato fruit were sliced and homogenized in a Warring blender which was previously washed and sterilized with 100ppm sodium hypochlorite solution and rinsed with sterile deionized water. Serial dilutions of homogenate ranging from 10^{-1} to 10^{-5} were obtained using sterile saline solution. Total aerobic plate counts and fungal counts were performed on nutrient agar and Saboraud dextrose agar respectively using the pour-plate method described by Harrigan and McCance (1990).

2.3 Sensory Evaluation

A consistent panel of 12 semi-trained judge was used to evaluate the appearance, texture and overall acceptability of tomato sample using the descriptive sensory profile developed based on perceptions of the judges for quality of fruits and vegetables. Sensory evaluation was conducted under fluorescent light in a special sensory testing room with partitioned booths. The degrees of preference based on the descriptive terms were then converted to scores with 7=very firm and 1=Putrid/mushy for texture, 7=very fresh and 1=extremely mouldy for appearance and 7=highly acceptable and 1=disgusting for overall acceptability.

2.4 Statistical Analysis

The results obtained were evaluated using the analysis of variance with the aid of Statisca 6.0 software package (Stafso, Inc. USA). The means of factors showing significant (p=0.5) differences were separated using Tukey's LSD test (Ihekoronye and Ngoddy, 1985). For this storage studies with tomato, the variables evaluated were influences of 3 storage times (0, 7th and 21st days) and 3 storage conditions (Atmosphere, NBBEC and ABBEC).

3.0 Results and Discussion

3.1 Physiological Weight Loss

The result of the physiological weight loss of tomatoes is presented in Table 1. It was observed that weight loss was minimum when the tomatoes were stored in the evaporative coolers (31.5% for NBBEC and 15.0% for ABBEC), while it was maximum at ambient storage (82.5%). Islam *et al*. (2012) reported that a postharvest change in firmness could occur due to loss of moisture through transpiration, respiration and enzymatic changes. In this study, the change in firmness was much noticed in tomatoes stored at ambient after the third day of storage. After the sixth day of storage, most of the tomatoes at ambient storage had rottened but those stored under NBBEC remained fresh till the 19th day of storage while those stored under ABBEC remained fresh till after 21days of storage. Similar findings were reported by Islam *et al*. (2012) that physiological loss of weight (5.4%) was faster for tomato fruits held at ambient temperature. Mogaji and Fapetu (2011) reported weight loss of about 18kg for tomatoes at ambient storage while tomatoes kept in the evaporative coolers had only an approximate 5kg loss. Tefera *et al.* (2007) and Hirut *et al.* (2008) reported that weight loss of fruits increased as storage period advanced; they also observed that increased rate of weight loss could be related to stage of ripeness in tomatoes as there could be increased fruit permeability as ripening progresses. Abiso et al. (2015) reported that the cool and humid condition inside the evaporative coolers were able to reduce the rate of transpiration and respiration resulting in low water loss and consequently reduced weight loss. Table 1 presents the physiological weight loss of tomato:

Table 1: Physiological Loss in Weight

Parameters	**Ambient**	**NBBEC**	**ABBEC**
Storage Period (Days)	10	19	21
PLW (%)	82.5	31.5	15.0

3.2 Chemical Analyses

3.2.1 Ascorbic acid and Carotenoids

Ascorbic acid is usually used as the quality index of nutrients in processing and storage owing to its instability. Ascorbic acid in this study ranged from 11.37 to 11.93mg/100g (Table 2). Adejumo (2012) reported a higher value of 13mg/100g. Losses of ascorbic acid were rapid in ambient stored fruits compared to the evaporatively cooled tomato. Weichmann (1987) established that ascorbic acid degrades steadily during prolonged storage due to oxidation. The slightly higher levels of ascorbic acid inside the evaporative coolers may be attributed to lower temperature and higher relative humidity which tends to slow down the metabolism (including respiration) and eventually reduced the extent of microbial activities as well as the chemical reactions taking place inside the evaporative coolers.

Beta-carotene helps fight free radicals thereby boosting immune function, enhancing vision and preventing cancer. Beta-carotene of tomatoes ranged from 1278 to 1670µg/100g in this study. These values were higher than those reported by Nwaichi *et al.* (2015) with values ranging from 330 to 430µg/100g. According to Bolanle *et* al. (2004), these differences could be due to variation between cultivars.

3.2.2 Total Soluble Solids

Soluble solids content is an indicator of sweetness, although sugars are not the sole soluble component it measures. The TSS of tomato fruits ranged from 4.85 to 6.78^{o}Brix in this study as presented in Table 2. This is in agreement with the findings of Abdul Hameed *et al.* (2009) and Kumar *et al.* (1993) whose report was in the range of 4.80 to 8.80%. According to Naik (1993), increase in TSS during ripening is due to the degradation of polysaccharide to simple sugars. Nath *et al.* (2011) reported that the increase in TSS of tomato fruits could be due to excessive moisture loss which increases concentration as well as the hydrolysis of carbohydrates to soluble sugars.

3.2.3 pH and Titratable Acidity

There were no significant ($p>0.05$) differences in the pH values of tomato at the various storage conditions. The pH of tomato fruits ranged from 4.90 to 5.20 as presented in Table 2. Agbabiaka *et al.* (2015) reported similar pH values within the range of 4.90 to 5.40. Higher increase in pH was observed at ambient storage. Changes in pH may be due to metabolic activities of tomato fruit.

The changes in total titratable acidity were significantly affected by the rate of metabolism especially respiration which consumed organic acid. The titratable acidity result for tomato obtained in this study ranged from 0.63 to 0.75% (Table 2). The decrease recorded might be due to the inhibited activities of enzymes to change the titratable acidity contents due to the reduced temperature and high relative humidity of the evaporative coolers. Abdul Hameed *et al.* (2009) recorded slightly lower result which ranged from 0.48 to 0.51%.

Table 2: Effect of Storage Conditions on Chemical Characteristics of Tomato

Parameters	Storage Time (Days)	Ambient	NBBEC	ABBEC	LSD
B-Carotene(µg/100g)	0	1670^{a}	1670^{a}	1670^{a}	
	7	1475^{b}	1570^{d}	1635^{f}	
	21	1278^{c}	1468^{c}	1586^{g}	3.66
TSS (^{o} Brix)	0	4.85^{c}	4.85^{c}	4.85^{c}	
	7	5.37^{d}	5.23^{d}	4.90^{d}	
	21	6.78^{a}	6.40^{a}	5.25^{b}	1.10
TTA (%)	0	0.75^{a}	0.75^{a}	0.75^{a}	
	7	0.68^{ab}	0.70^{a}	0.73^{a}	
	21	0.63^{b}	0.65^{a}	0.71^{a}	0.63
Ascorbic Acid (mg/100g)	0	11.93a	11.93^{a}	11.93^{a}	
	7	10.75^{b}	11.67^{b}	11.83^{a}	
	21	9.53^{c}	11.43^{d}	11.37^{d}	0.65
pH	0	4.90^{a}	4.90^{a}	4.90^{a}	
	7	5.00^{a}	4.98^{a}	4.92^{a}	
	21	5.20^{a}	5.10^{a}	5.00^{a}	0.44

3.3 Microbiology of Tomatoes

Tomato fruits had total plate count which ranged from 1.54 to 3.22 Log_{10}cfu/g; yeast and mould count ranged from 1.18 to 3.17Log_{10}cfu/g. Higher values were recorded by Agbabiaka *et al.* (2015). These authors reported total plate count which ranged from 6.54 to 6.60Log_{10}cfu/g and total fungal count of 6.20 to 6.54Log_{10}cfu/g. Susceptibility of tomato to microbial colonization was due to its differential chemical composition such as high level of sugar, low pH (4.9 to 6.5) and its high water activity (p>0 99) which favours the growth of microorganisms and recognized as a source of potential health hazard to man and animals (Oyemaechi *et al.*,2014). Higher microbial counts for ambient may be due to relatively higher temperature and exposure to contamination from the environment. Table 3 presents the effect of storage conditions on the microbial load of tomato:

Table 3: Effect of Storage Conditions on Microbial Load of Tomato

Microbial Parameter	Storage Time (Days)	Storage Conditions		
		Ambient	**NBBEC**	**ABBEC**
Total Plate Count (Log_{10}cfu/g)	0	1.54^{a}	1.54^{a}	1.54^{a}
	7	2.15^{b}	1.78^{c}	1.70^{c}
	21	3.22^{d}	2.04^{c}	1.81^{c}
Yeast & Mould Count (Log_{10}cfu/g)	0	1.18^{e}	1.18^{e}	1.18^{e}
	7	1.70^{f}	1.36^{g}	1.30^{g}
	21	3.17^{h}	1.74^{k}	1.48^{l}

3.4 Sensory Evaluation

According to Iwe (2010), sensory evaluation is the only commercial test used in the fresh produce sector. Appearance is the key factor for consumers in making purchases of fresh produce. Tomatoes stored at ambient condition were found to have decayed with dark colour and spots which could be due to the growth of moulds. In contrast, tomatoes stored under NBBEC and ABBEC conditions were bright in colour. This was because cool temperature slowed down colour development and the ripening process. Similarly, evaporatively stored tomatoes maintained their firmness and did not record appreciable weight loss (Table 4). The cooler storage temperatures decreased enzyme activity. The sensory results in this study revealed that the shelf life of tomato was 10days, 19days and 21days for ambient, NBBEC and ABBEC storage conditions respectively. Seyoum and Woldetsadik (2000) reported similar findings in which evaporative cooler storage was able to maintain tomato 100% marketable for at least 15days.

Table 4: Effect of Storage Conditions on Sensory Scores of Tomatoes

Sensory Attribute	Storage Time	Ambient	NBBEC	ABBEC
Appearance	0	6.68^{a}	6.68^{a}	6.68^{a}
	7	4.29^{b}	5.90^{b}	6.40^{ab}
	21	2.18^{d}	5.64^{b}	5.77^{b}
Texture	0	6.28^{a}	6.28^{a}	6.28^{a}
	7	5.40^{b}	5.62^{ab}	5.93^{ab}
	21	3.40^{c}	5.21^{b}	5.75^{ab}
Overall Acceptability	0	6.15^{a}	6.15^{a}	6.15^{a}
	7	3.96^{b}	5.79^{ad}	6.01^{a}
	21	2.93^{c}	5.20^{d}	5.97^{a_d}

Values for each attribute with common superscripts are not significantly (p>0.05) different.

Each result is the mean of 12 panelists responses on a scale with 7=excellent and 1=very poor.

ABBEC=Aluminum-cladded burnt-clay-brick evaporative cooler

NBBEC= Non-cladded burnt-clay-brick evaporative cooler

4.0 Conclusion and Recommendation

Fresh tomatoes stored in aluminum-cladded burnt-clay-brick evaporative cooler and non-cladded burnt-clay-brick evaporative cooler exhibited lower biochemical and physiological reaction rates hence tissue breakdown, colour changes, pH and TTA were lower in ABBEC than in NBBEC and ambient. Evaporatively cooler stored tomatoes had lower microbial load compared to ambient storage with aluminum cladding of the cooler (ABBEC) further improving microbial quality and shelf life. ABBEC are recommended for stop-gap extension of shelf life of fresh tomato especially at the rural level. Government should therefore encourage the construction of evaporative coolers for on-farm storage and at strategic markets for reduction of postharvest losses.

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