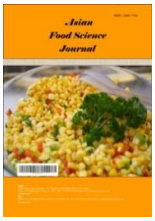

Asian Food Science Journal

15(2): 17-26, 2020; Article no.AFSJ.55674
ISSN: 2581-7752

Quality Evaluation of Oranges Stored in Evaporative Coolers

A. A. Balogun[1*], C. C. Ariahu[2] and M. O. Ojo[3]

[1]Institute of Food Security, University of Agriculture, Makurdi, Benue State, Nigeria.
[2]College of Food Technology and Human Ecology, University of Agriculture, Makurdi, Benue State, Nigeria.
[3]Department of Food Science and Technology, Federal University of Technology, Minna, Niger State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2020/v15i230148
Editor(s):
(1) Ahmed Mohamed El-Waziry, Alexandria University, Egypt and King Saud University, Saudi Arabia.
Reviewers:
(1) P. D. Sharma, Dr. Rajendra Prasad Central Agricultural University, India.
(2) Lum Mok Sam, Universiti Malaysia Sabah, Malaysia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/55674

Original Research Article

Received 10 February 2020
Accepted 17 April 2020
Published 25 April 2020

ABSTRACT

Large quantities of oranges are wasted during storage due to its highly perishable nature. Research was therefore conducted on quality evaluation of orange fruits stored in aluminum-cladded (ABBEC) and non-cladded burnt-clay-brick evaporative coolers (NBBEC) to prevent postharvest loss. Essentially, the evaporative coolers comprised of double burnt-brick walls (1.29 × 2.55 × 2.56 m) external and (1.13 × 1.27 × 2.08 m) internal, (L × W × H) with wet sand bed in between and a storage space of (1.13 × 0.36 × 1.32 m), (L × W × H). Metabolic rates of oranges were highest at ambient storage, intermediate in 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. ABBEC storage resulted in 4.0 to 5.3°C decrease in ambient temperature with corresponding higher relative humidity over the non-cladded burnt-clay-brick coolers.

Keywords: Postharvest loss; evaporative coolers; ambient; relative humidity.

**Corresponding author: Email: adenikebalogun27@yahoo.com;*

1. INTRODUCTION

Citrus is produced globally with Brazil leading as the largest producer followed by USA and China [1]. Nigeria ranked 9th among the major producing countries and it produced 3% of the total world citrus output between the year 2000 and 2004 [2]. Sweet orange constitutes the most important proportion among the citrus varieties grown throughout the world, accounting for more than two-thirds of total global production [1]. The overall world production stood at 51.8million metric tons in 2013-14 with Brazil and China leading [3]. In 2018, citrus fruit production for Nigeria was 4.07 million tonnes [4]. According to [5], Benue State is Nigeria's largest producer of orange. However, [6] reported annual losses of about 30 to 60% during peak harvesting seasons due to the highly perishable, non-climacteric nature of the fruits and process technology. Additionally, there are no package and cold storage facilities for fruits and vegetables in Nigeria; transportation from farms to the market is also crude [2]. Wills et al. [7] indicated that fresh fruits and vegetables deteriorate very easily under tropical ambient conditions mainly due to physiological and microbial activities. Jain [8] observed that the prevailing high temperature in the tropics not only hastens physiological activities such as respiration, transpiration and ripening of fresh produce but also affects the physico-chemical composition eventually leading to spoilage. There is need for further research to reduce the postharvest losses encountered by orange farmers in Nigeria [9]. According to [10], evaporative cooling is the process by which the temperature of a substance is reduced due to the cooling effect from the evaporation of water. The concept of evaporative cooling is that the surrounding air serves as a heat sink where sensible heat is exchanged for latent heat of water. Cooling by means of evaporation therefore provides a low cost and effective way of preserving the freshness and prolonging the shelf life of fruits and vegetables as it reduces the temperature and increases the relative humidity inside the storage structure [11]. Vigyan et al. [12] reported that the evaporative cooler is ecofriendly, less energy requiring which improves the quality and productivity of fruits and vegetables by reducing field heat, increasing shelf life and ultimately reducing postharvest losses. Considering acute energy shortage and inadequate cold storage facilities in rural areas, there is tremendous scope for the adoption of low cost evaporative coolers for short-term, on-farm storage of perishable farm produce. Evaporative coolers could lower temperature range of 10-15°C cooler than the outside temperature and maintain about 95% relative humidity [13].

Many authors such as [14,9,15,16,17]; reported the effectiveness of evaporative coolers for storage of oranges. Adekalu [18] also reported its effectiveness on storage of pre-treated matured sweet oranges. Adekanye et al. [14] evaluated the performance of a prototype active evaporative cooling system for fruits and vegetable storage using oranges and tomato. Adekalu and Agboola [9] reported that sensory evaluation, marketability and acceptability of treated oranges were rated good at the end of 35 to 52 days' storage in evaporative coolers. Ubani and Okonkwo [15] reported that oranges stored for six weeks in evaporative cooler. The authors also observed that fruits in the evaporative cooler had weight loss of 4.2% and were in good and acceptable condition after storage.

Despite being the largest producer of oranges in the country, there is little or no research carried out in Benue State on the use of evaporative cooling in controlling postharvest losses of fruits and vegetables. The aim of this study therefore was to evaluate the storage of fresh oranges in evaporative coolers so as to prolong their shelf life and consequently reduce the postharvest loss of citrus in Nigeria.

2. 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 1200-1300 mm. About 90% of total annual rainfall occurs in the months of June to September [19]. Temperature rarely falls below 22°C with peaks of 40 and 30°C in February/March. In the wet season, the average temperature is within the range of 23.0-32.7°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:07.78915^{o} N, Longitude 008.61864^{o} E).

2.2 Design and Construction of Evaporative Coolers

Two almost identical burnt-clay-bricks evaporative coolers were designed and

constructed adjacent and about 1 m apart under two trees. One had two internal aluminum claddings and was designated as aluminum cladded burnt-clay-brick 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 (1.29 × 2.55 × 2.56 m) external and (1.13 × 1.27 × 2.08 m) internal, (L × W × H) with wet sand bed in between and a storage space of (1.13 × 0.36 × 1.32 m), (L × W × H). 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 2 cm 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 [20].

2.3 Commodity Storage Test

10 kg of ripe orange fruits (Ibadan sweet variety) 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.

2.3.1 Weight loss

Weight loss was measured before and after storage using an electronic weighing balance (Model: Mettler P1210). Ten orange fruits were drawn at random on the 1st, 7th and 21st days of storage. Weight loss for each sample of known initial weight was calculated as follows:

$$PWL\ (\%) = (W_o - W_t) / W_o \times 100 \quad (1)$$

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.

Plate 1. Evaporative Coolers 1 & 2
EC1= Non-Cladded Burnt-Clay-Brick Evaporative Cooler (NBBEC). EC2=Aluminum-Cladded Burnt-Clay Brick Evaporative Cooler (ABBEC)

2.3.2 Chemical analyses

Chemical analyses were performed according to the standard official methods described in [19]. Clear orange juice was extracted by pulping 100 g of edible portion in a household electric blender followed by straining using double-layered muslin cloth.

2.3.3 Moisture content

Moisture content was determined by weighing 5g of sample in crucibles whose weight have been determined. The crucibles and the samples were heated at 110°C in a Gallenkamp oven until constant weights were obtained. The dishes and their contents were cooled in a dessicator and then reweighed. The loss in weight was expressed in percentage:

$$\%\text{Moisture}=\frac{lossinweightondrying\times 100}{Initialsampleweight} \quad (2)$$

2.3.4 Ascorbic acid and total carotenoids

Ascorbic acid and carotenoids were determined by [21] 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/100 g.

2.3.5 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.

2.3.6 pH and titratable acidity determination

The digital pH meter (Model pH 211, HI Hanna Instruments, Italy) was used to measure the pHof the orange juice while total titratable acidity (expressed as citric acid %) was determined by titrating 5ml of orange juice with 0.1N sodium hydroxide- using phenolphthalein as an indicator [21].

2.4 Microbiological Analysis

Samples for total plate counts and fungal counts were prepared as described by [22]. Triplicate 2 g portions of orange fruit were squeezed and homogenized in a Warring blender which was previously washed and sterilized with 100 ppm 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 [23].

2.5 Sensory Evaluation

A consistent panel of 12 semi-trained judge was used to evaluate the appearance, texture and overall acceptability of orange fruit 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 [24].

2.6 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 [25]. For this storage studies with orange fruits, the variables evaluated were influences of 3 storage times (1^{st}, 7^{th} and 21^{st} days) and 3 storage conditions (Atmosphere, NBBEC and ABBEC).

3. RESULTS AND DISCUSSION

3.1 Physiological Loss in Weight

Fig. 1 shows the effect of storage condition on physiological weight changes of orange fruit. Physiological loss in weight is one of the main factors in determining the quality of stored fruits and vegetables. Minimal weight loss was recorded for oranges stored in aluminum burnt-clay-brick evaporative cooler (5.2%), 7.5% for those stored in NBBEC and maximal weight loss of 48.0% for oranges in ambient storage. These findings showed that oranges under ambient storage conditions shriveled fast and lost weight more quickly than those stored in evaporative coolers. The increase in weight loss with storage period may be due to the effect on reduction in moisture content on respiration. Oranges stored at ambient had wilted and shriveled after only 3 days of storage while those in evaporative

coolers remained fresh and appealing even after 21 days of storage. Ubani and Okonkwo [15] reported that oranges stored at ambient lost weight rapidly resulting in fresh weight loss of 31.1% after one month of storage while oranges stored in evaporative cooler had weight loss of 4.2%; were good and acceptable even after six weeks of storage. Similarly, [9] reported that treated oranges stored for between 35 and 52 days. They reported that weight losses of evaporatively stored pretreated oranges was below 5% unlike the control that was over 7%. According to [1], the reduction in weight could make orange fruits wrinkle and less firm and therefore may be less attractive to consumers if storage conditions are not modified. The authors observed that the decrease in fruit firmness at ambient condition could be attributed to fruit senescence due to poor storage condition. Nunes [26] also reported that reduced humidity during storage results in loss of moisture and orange dehydration, but may also lead to peel damage.

3.2 Chemical Analysis

3.2.1 Moisture content

Moisture content is an important quality feature that directly influences storability of fruits and vegetables. It is an index of water activity of many foods. The high moisture content of oranges (84.69%) in this study as shown in Table 1 implies that these fresh produce might be highly perishable because spoilage microorganisms thrive in high moisture foods and is also indicative of low total solids. Similarly, the high moisture content provides for greater activity of water soluble enzymes and co-enzymes needed for metabolic activities of fresh produce [27].

Table 1. Moisture content of orange

Fruit	Moisture content (%)
Orange	84.69

3.2.2 Ascorbic acid and total carotenoids

The effect of storage condition on ascorbic acid content of orange fruit is shown in Fig. 2. The ascorbic acid values for orange juice decreased significantly during storage. The initial ascorbic acid content of fresh orange fruit was 37.72mg/100g which decreased to the lowest value of 22.20 mg/100 g in ambient storage, 23.35 mg/100 g in NBBEC storage and 26.83 mg/100 g in ABBEC storage. The differences in ascorbic acid content of orange fruits observed for all the storage duration and different storage conditions were quite significant ($p<0.05$). These values were slightly lower than those obtained by [28] which ranged from 23.01 to 42.50 mg/100 g and [29] who reported a similar value of 43.78 mg/100 g. According to Holcombe [30], ascorbic acid content of citrus fruit is never constant but varies with factors which include climatic/environmental conditions, maturity stage, handling and storage, ripening stage,species, and variety of the citrus fruit as well as temperature.

Beta carotene content of oranges decreased significantly from 2385.20 to 1158.50µg/100 g. After 21 days of storage, higher carotenoid content was recorded for oranges stored in ABBEC (2147.40 µg/100 g), intermediate in NBBEC (1167.20 µg/100 g) while the minimum was recorded for oranges stored at room temperature (1158.50 µg/100 g). [31] reported a much lower value of 355 µg/100g for oranges. Rodriguez- Amaya [32] observed that concentrations of beta carotene vary with the species and variety of orange and with growing, harvesting and storage conditions.

3.2.3 Total soluble solids of oranges

Fig. 3 presents the effect of storage condition on the total soluble solids of orange fruit in this study. The total soluble solids of fresh oranges before storage was 3.47^{o}Brix which increased significantly to the highest value of 14.18^{o}Brix in ambient, 12.70^{o}Brix in NBBEC and the lowest value of 10.40^{o}Brix in ABBEC storage condition. The increasing TSS could be due to increase in sugar content as acidity level in the fruit decreased in holding. Fruit palatability might increase as a result of high TSS to acidity ratio. The values reported by [28] were slightly lower and within the range of 5.50 to 11.80% while that of [29] was a high value of 33.88% as a result of the addition of sugar to the orange juice. According to AOAC [33], about 15% of the soluble constituents of orange juice are other than sugars and organic acids. This fraction consists of inorganic compounds, amino acids, ascorbic acids and small amounts of pectins, essential oils, esters, glucosides and other organic compounds. These compounds are commercially important in that the occurrence of off-flavours is either natural or processed orange juice is due to the oxidation and decomposition of these substances.

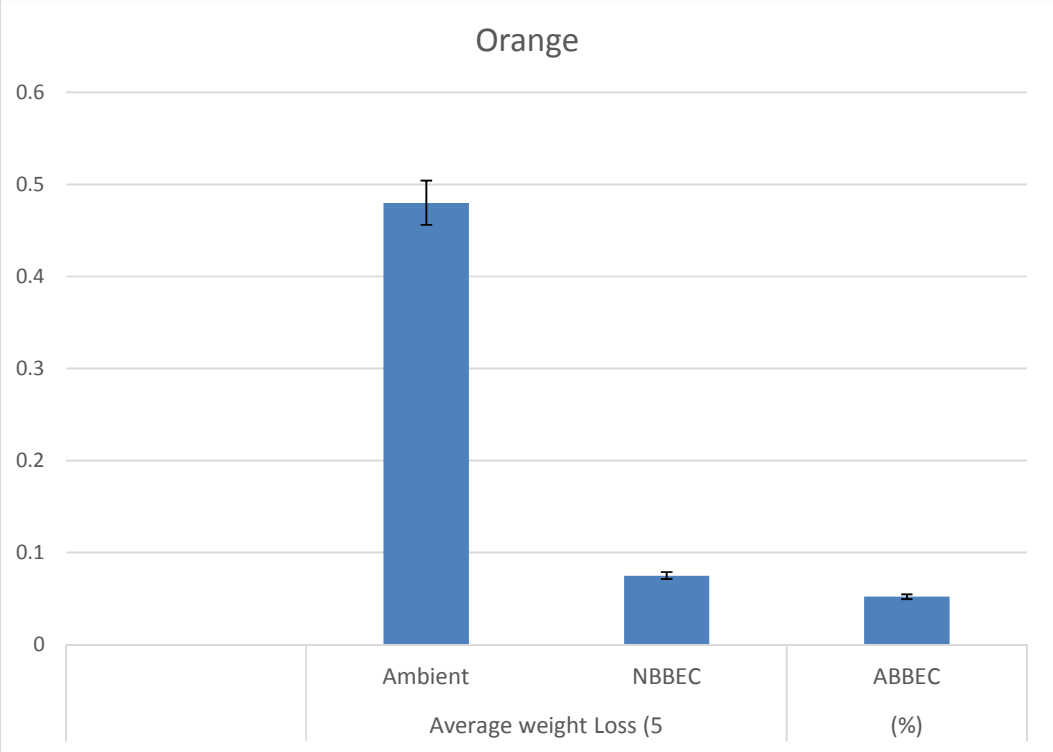

Fig. 1. Effect of storage condition on physiological weight changes of orange fruit

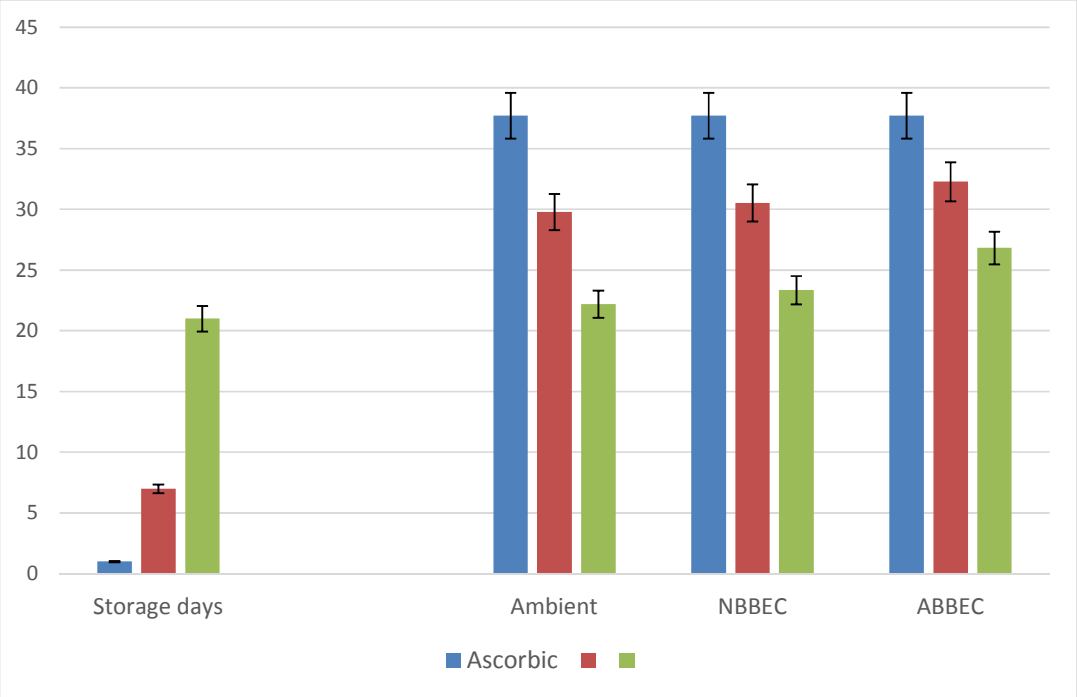

Fig. 2. Effect of storage condition on the ascorbic acid content of orange

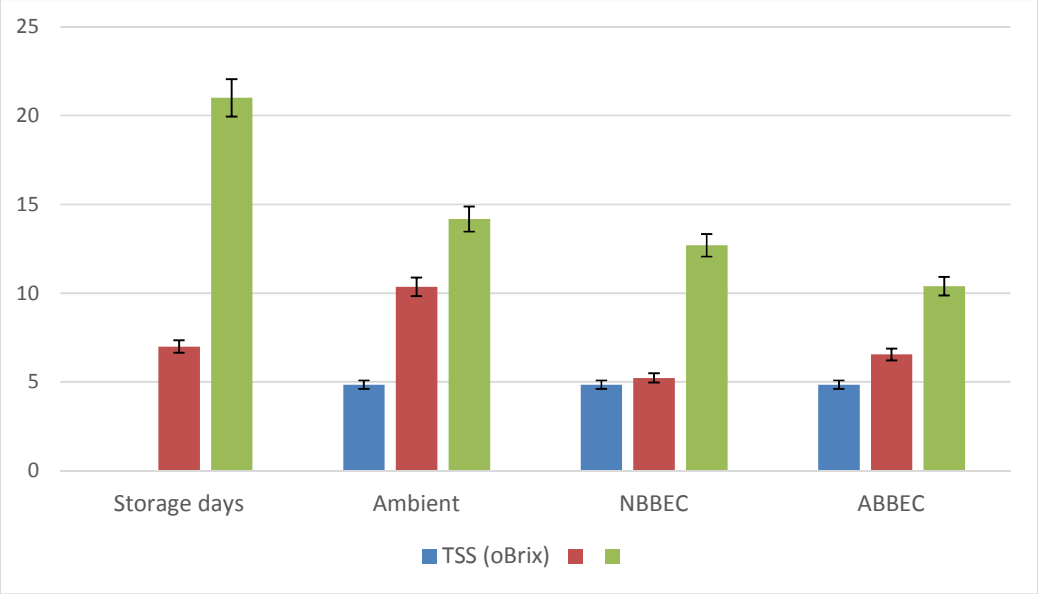

Fig. 3. Effect of storage conditions on the TSS of orange

3.2.4 pH and total titratable acidity

The pH of orange juice in this study showed a gradual increase from 3.36 to 3.80 (Table 2). Significant differences ($p<0.05$) existed in the level of pH during storage duration from day 1 to day 21. However, the differences in pH was not significant on day 1 and day 7 in NBBEC and ABBEC storage. This could be due to the relatively lower temperature and higher relative humidity exhibited by the evaporative coolers. This result was similar to that of [28] who reported pH values of 3.23 to 4.08. Other researchers such as [34,29] and [35] reported similar values of 3.4 to 4.6; 3.50 and 3.30 respectively. In fruits, the palate acidity depends on the hydrogen ion concentration which is affected by the degree of the acid. pH levels increased as sweet orange fruits were stored over a period of time which enhanced sweetness as the acidity level of fruits decreased due to increase in sugar content.

Changes in total titratable acidity were significantly affected by the rate of metabolism especially respiration which consumed organic acid (Table 2). However, the total titratable acidity of oranges were not significantly ($p>0.05$) different (0.97-1.25%). Ndife et al. [28] reported values of 0.4 to 1.06% while [29] and [35] reported 0.1% and 0.13% respectively. The gradual decline in TTA levels during storage could be attributed to increased sugar substrates in the fruit which could be due to increased respiratory activity in orange fruit. Lower acid content is also known to improve fruit flavour.

3.3 Microbiological Analysis of Oranges

The results of microbial analysis of orange fruit samples are presented in Table 3. There were significant differences within the three storage conditions. There was no fungal load in evaporative coolers but ambient storage recorded $0.25Log_{10}cfu/g$ after 21st day of storage. However, significant differences existed in the fungal counts on days 7 and 21. [34] Recorded higher total plate count of 5 $Log_{10}cfu/g$ and total fungal count of 2 to $2.85Log_{10}cfu/g$ while [36] reported highest volumes of contaminants ranging from 7.88 to $7.95Log_{10}cfu/g$ in their orange juice samples. Low temperatures in the evaporative coolers slowed down the plant's metabolic processes such as respiration, ethylene production and enzyme activity. This explains the lower microbial counts recorded in ABBEC storage due to the lower heat sinks of aluminum.

3.4 Sensory Evaluation of Oranges

The effect of storage condition on sensory scores of orange fruit is presented in Table 4. Panelists scored fresh orange sample 6.71 out of total

Table 2. Effect of Storage Conditions on pH and TTA of Orange

Parameter	Storage Time(Days)	Ambient	NBBEC	ABBEC	LSD
pH	0	3.36^{a}	3.36^{a}	3.36^{a}	
	7	3.53^{cd}	3.39^{a}	3.36^{a}	
	21	3.80^{d}	3.43^{c}	3.37^{c}	0.43
TTA (%)	0	1.25^{a}	1.25^{a}	1.25^{a}	
	7	1.08^{c}	1.15^{ab}	1.21^{a}	
	21	0.97^{c}	1.05^{c}	1.18^{ab}	0.74

Table 3. Effect of storage conditions on microbial load of orange

Microbial Parameter	Storage Time (Days)	Storage Conditions Ambient	Storage Conditions NBBEC	Storage Conditions ABBEC
Total Plate Count(Log_{10}cfu/g)	0	0.31^{b}	0.31^{b}	0.31^{b}
	7	0.33^{a}	0.33^{a}	0.32^{ab}
	21	1.35^{a}	2.18^{d}	0.32^{ab}
Yeast & MouldCount(Log_{10}cfu/g)	0	0.00^{c}	0.00^{c}	0.00^{c}
	7	0.23^{b}	0.22^{b}	0.21^{b}
	21	0.25^{a}	0.24^{a}	0.23^{a}

NBBEC= Non-cladded burnt-clay-brick evaporative cooler. ABBEC= Aluminum-cladded burnt-clay-brick evaporative cooler. Values for each parameter with common superscripts are not significantly (p>0.05) different

Table 4. Effect of storage conditions on sensory scores of orange

Sensory Attribute	Storage Time(Days)	Storage Conditions Ambient	Storage Conditions NBBEC	Storage Conditions ABBEC
Appearance	1	6.62^{a}	6.62^{a}	6.62^{a}
	7	5.15^{b}	6.20^{ab}	6.11^{a}
	21	3.67^{c}	5.69^{b}	5.82^{c}
Texture	1	6.71^{a}	6.71^{a}	6.71^{a}
	7	5.19^{b}	6.30^{b}	6.33^{b}
	21	3.68^{d}	5.69^{c}	5.82^{bc}
Overall Acceptability	1	6.69^{a}	6.69^{a}	6.69^{a}
	7	4.76^{bc}	5.79^{b}	6.16^{a}
	21	3.74^{e}	5.66^{b}	5.71^{b}

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

value of 7.0 for texture which decreased significantly ($p<0.05$) to 3.68 in ambient storage, 5.69 and 5.82 in NBBEC and ABBEC storage respectively (Table 3).

Oranges stored in ABBEC were preferred because samples were judged superior organoleptically in quality than those stored in ambient, retaining more of its colour, flavour and viscosity. Idah et al. [37] in agreement with this result inferred that for consumers to obtain optimum nutrients from their products, oranges should not be stored beyond two weeks as the pot-in pot evaporative cooler storage system is concerned. Shrinkage rate for sweet orange in ABBEC was very slow compared to those stored at ambient conditions.

4. CONCLUSION AND RECOMMENDATIONS

The evaporative coolers maintained a better quality in the physicochemical characteristics of orange fruit. In general, percentage weight loss, total soluble solids and pH increased with storage while beta carotene, total titratable acidity, and ascorbic acid decreased. The evaporative coolers gave an alternative approach to mechanical refrigeration for increasing the shelf life and maintaining the quality of oranges.

The ABBEC stored oranges exhibited lower biochemical and physiological reaction rates hence tissue breakdown, colour changes were lower in ABBEC than in NBBEC and ambient. The authors therefore recommend aluminum-cladded burnt-clay-brick evaporative coolers for on- farm storage of oranges.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Alhassan A, Adjei PY, Mohammed S. Effect of maturity stage and storage duration on physicochemical properties of citrus (*Citrus sinensis var Late Valencia*). European Scientific Journal. 2014; 10(36):148-162.
2. Olife IC, Ibeagha OA, Onwualu AP. Citrus Fruits Value Chain Development in Nigeria. Journal of Biology, Agriculture and Healthcare. 2015;5(4):36-47.
3. USDA. Citrus: World Markets and Trade, Foreign Agricultural Service, Office of Global Analysis. United States Department for Agriculture; 2014.
4. Knoema Team: Citrus Fruit Production in Nigeria. 1750 Tysons Blvd McLean, VA, 22102
5. FAO. The State of Food and Agriculture. Investing in Agriculture for a Better Future; 2012.
   Available:www.fao.org/publications/sofa/en/
6. Onwualu AP, Obassi E, Olife IC. Policy brief on fruit juice and concentrates. Raw Materials Research and Development Council (RMRDC); 2013.
   [ISBN: 13-978-978-52367-4-3]
7. Wills RBH, Lee TH, Graham D, McGlasson WB, Hall EG. Postharvest: An introduction to the physiology of fruits and vegetables. New South Wales University Press; Kensington, Australia. 1981;163.
8. Jain. Development and testing of two-stage evaporative cooler. Building and Environment. 2007;42(7):2549-2554.
9. Adekalu AO, Agboola DA. Effect of herb treatments on the storability of sweet oranges (Citrus sinensis Osberk) stored in Evaporative Cooler. Journal of Postharvest Technology. 2015; 03(02):043-049.
10. La Roche PM. Passive Cooling Systems in Carbon Neutral Architectural Design, Boca Raton, FL: CRC Press. 2012;7(7.4):242-258.
11. Munoz RC, Diuco 11 LT, Martinez SS, Oliveria IA, Quiroz NA, Sta Maria DR. Automated Electronic Evaporative Cooler for Fruits and Vegetables Preservation. International Journal of Engineering Sciences and Research Technology. 2017;6(6):352-364.
12. Vigyan JK, Deri R, Singh LK. Zero energy cool chamber, low cost storage structure for vegetables and fruits in Churachandpur District of Manipur. ICAR Research complex for NEH region, Manipur Centre, Imphal-795 004 (Manipur). 2018;7(1):216-219.
13. Kitinoja L. Use of cold chains for reducing food losses in developing countries (13):1-16. PEF White Paper No. 10-03; 2013.
14. Adekanye T, Babaremu K, Okunola A. Evaluation of an active evaporative cooling device for storage of fruits and vegetables. Agricultural Engineering International: International Commission of Agricultural and Biosystems Engineering (CIGR) Journal. 2019;21(1):203-208.
15. Ubani ON, Okonkwo EU. A review of shelf-life extension studies of Nigerian indigenous fresh fruits and vegetables in the Nigerian Stored Products Research Institute. African Journal of Plant Science. 2011;5(10):537-546.
16. Babarinsa FA. Reduction of Weight Loss in Valencia Oranges using a Brick Walled Cooler. Tropical Science. 2000;40(2):92-94.
17. Babarinsa FA, Williams JO, Omomukoyo A. Effects of three skin-coating materials on the storage of Valencia oranges. Postharvest Science. 2002;1(1):7-11.
18. Adekalu OA. Studies on the physico-chemical properties, handling and storage of sweet oranges (Citrus sinensis Osberk) PhD Thesis submitted o College of Natural Sciences. Federal University of Agriculture, Abeokuta; 2014.
19. Odiaka NI, Akoroda MO, Odiaka EC. Diversity and production methods of fluted pumpkin (*Telfairia occidentalis* Hook F.); experience with vegetable farmers in Makurdi, Nigeria. African Journal of Biotechnology. 2008;7(8):944-954.
20. Balogun AA, Ariahu CC, Ikya JK. Quality evaluation of fresh tomato stored in evaporative coolers. Asian Food Science Journal. 2019;11(3):1-8.

21. AOAC. Official methods of analysis of the association of official analytical chemists, 22nd Ed, Association of Official Analytical Chemists, Washington D.C; 2005.
22. Kramer A, Twig BA. Quality Control for the Food Industry, Vol. 1. The AVI Publishing Co., Inc., West Port, Connecticut. 1970;556.
23. Harrigan WF, McCance M. Laboratory methods in food and dairy microbiology. Academic Press Inc., London. 1990;25-28.
24. Iwe MO. Handbook of Sensory Methods and Analysis. Rojoint Communication Science Ltd. Enugu Nigeria. 2010;75-78.
25. Ihekoronye AI, Ngoddy PO. Integrated food science and technology for the tropics. Macmillan Education Ltd London and Oxford. 1985;199-200.
26. Nunes MCN. Impact of environmental conditions on fruit and vegetable quality. Article in Stewart Postharvest Review; 2008.
Available:https://www.researchgate/publication/233564257
DOI:10.2212/spr.2008.4.4
27. Ekpunobi UE, Ukatu SC, Ngene BO, Onyema CT, Ofora PU. Investigation of the Thermal Properties of Selected Fruits and Vegetables. American Journal of Science and Technology. 2014;1(5):293-297.
28. Ndife J, Awogbenja D, Zakari U. Comparative evaluation of the nutritional and sensory quality of different brands of orange juice in Nigerian Market. African Journal of Food Science. 2013;7(12):479-484.
29. Obasi BC. Studies on Microbiological and Physico Chemical Analyses of Commercially and Laboratory Prepared Orange Juices. Being a MSc. Thesis in Microbiology from Ahmadu Bello University, Zaria and Kaduna State; 2005.
30. Holcombe GD. Fruit Growth and Development, Applied Botany, 1st ed. Livingstones Publisher, Churchill. 1992;46.
31. Self-nutrition data. Foods Highest in Beta carotene in Fruits and Fruit juices 2014 Conde Nast. US Patent No 7,620,531; 2014.
32. Rodriguez- Amaya DB. Food carotenoids Analysis, composition and alterations during storage and processing foods. Forum Nutrition. 2003;56:35-37.
33. AOAC Official Methods of Analysis of the Association of Official Analytical Chemists 15th Ed, Association of Official Analytical Chemists, Arlington V. A. 1990;1058-1059.
34. Agwa OK, Ossai-Chidi LN, Ezeani CA. Microbial Evaluation of Orange Fruit Juice Sold in Port Harcourt, Nigeria. American Journal of Food Science and Nutrition Research. 2014;1(5):28-33.
35. Bello OO, Bello TK, Fashola MO, Oluwadun A. Microbiological Quality of some Locally-Produced Fruit Juices in Ogun State, Southwestern Nigeria. *E3* Journal of Microbiology Research. 2014;2(1):001-008.
36. Aguoru CU, Maaji S, Olasan JO. Bacteria Contaminants on Surfaces of Some Edible Fruits Sold in Makurdi Metropolis, Benue State, Nigeria. International Journal of Current Microbiology and Applied Sciences. 2015;4(6):334-340.
37. Idah PA, Musa JJ, Abdullahi M. Effect of Storage Period on Some Nutritional Properties of Orange and Tomato. AU Journal of Technology. 2010;13(3):181-185.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/55674