



STORABILITY POTENTIAL OF CARROT (*Daucuscarota L.*) UNDER STEM SPONGE PADDED EVAPORATIVE COOLING STRUCTURES

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ABSTRACT

Nearly all the produce from agriculture is prone to spoilage and deterioration they are biological material. Predominantly, the food waste resulting in lack of storage facilities for the entire food chain in Nigeria and the differential gap between abundance and scarcity constitute an impediment to economic growth of the nation. Hence, there is need to increase the shelf life of this carrots. A zero-energy stem sponge padded evaporative cooling storage was evaluated using fresh carrots (*Daucuscarota L.*) with control refrigerator and a similar structure without any cooling pad. The overall percentage loss in weight during the duration of the experiment for carrot in the refrigerator was 53.97%, control structure was 32.80% and evaporative cooling structure with was stem pad 25.19%. Similarly, trend of result was recorded in firmness, loss in firmness of the carrots stored in the control structure was greater than the ones in the evaporative cooling sytructure. However, the evaluation of the evaporative cooling system showed that the carrots could be stored for an average of twelve (12) days with insignificant changes in weight, colour and firmness unlike the refrigerator and the control structure that noticeable changes began to occur from the fifth day. In this study, zero-energy padded evaporative cooler was used. This helped to increase the relative humidity and reduce the temperatures; this in turn reduced the respiration and metabolic activities of microorganisms on the stored carrots leading to increase in the shelf-life.

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1.0 INTRODUCTION

Evaporative cooling is a thermodynamic process in which water evaporates from the surface thus provides cooling effect. In adiabatic evaporation process, both heat and mass transfer take place. The hot and dry air passes over a wet surface of the pad, the water evaporates and loses its sensible heat and gains equal amount of latent heat of water vapour, thereby reducing its temperature

(Kulkarni *et al.*, 2011).

It is an economical way of reducing the temperature by humidifying the air and environmentally friendly without the use of refrigerant. There are no moving parts therefore, no noise is produced and it's economical because it doesn't require the use of electricity to power it thus saves energy. It is a principle that is simple and little skill in operation with low investment and

operational cost. It can be swiftly and easily installed as it is simple in design with easy maintenance. It can be developed in remote areas with locally available fibre materials. It is environmentally friendly as it does not require chlorofluorocarbons (Jha, 2008, Gómez *et al.*, (2010); Nitipong and Sukum, 2011; Banyat and Bunjerd, 2013). In refrigeration, both humidity and temperature decrease while evaporative cooling reduces temperature and increases humidity which is more suitable for storing fresh perishable agriculture produce, that require low temperature (Nitipong and Sukum, 2011). ECSS had become a better alternative for storing agricultural produce due to their low investment, almost zero energy requirement and other merit over refrigeration system (Dash and Chandra, 1999; Rayaguru *et al.*, 2010; Nitipong and Sukum, 2011).

Carrot (*Daucus carota L.*) is a member of the *Apiaceae* family and is one of the most common root vegetables grown throughout the world. It is said to be the most popular crop of *Apiaceae* family (Megueni, *et al.*, 2017). Crops in the *Apiaceae* family have relatively small, almost completely white, 5-parted flowers structured in an umbrella-like inflorescence called umbel (Essing, 2013).

Carrot (*Daucus carota L.*) is the most significant crop of *Apiaceae* family. It is a root vegetable that is distributed worldwide. Carrots may be consumed raw, cooked, and mixed with other vegetables and meats in salads, fresh prepared foods and frozen prepared foods. Carrot (*Daucus carota L.*) is a dicotyledonous herbaceous crop grown for the enlarged tap roots. Carrots were initially consumed for medical purposes and then

gradually, purpose of consumption began to include consumption as food (Carlos and Dias, 2014). This vegetable is a source of biologically active chemical compounds with beneficial effects for consumer health. Carrot has a significant level of natural anti-oxidants and beta-carotene. Carrots are effective source of carbohydrates and minerals (Arscot and Tanumihardio, 2010). They are also an effective source of thiamine, riboflavin, vitamin A and vitamin C (Arscot and Tanumihardio, 2010; Sharma *et al.*, 2012). Nigeria, estimated production of carrot is about 23,500 tonnes from 27,500 hectares of land (FAO, 2006).

The economic life of fresh vegetables can be sustained by prompt storage in an environment that conserves product quality. The craving environment condition can be achieved in a controlled atmosphere where temperature, air circulation, relative humidity, and sometimes atmosphere configuration can be controlled. Storage approach excluding refrigeration include: in situ, sand, cellars, barns, coir, pits, clamps, windbreaks, evaporative cooling, and night ventilation (El-Ramady *et al.*, 2015). Among the 39 common fruits and vegetables carrots have been ranked 10th in nutritive composition as reported by Acharya *et al.*, (2008).

Carrot is an efficient origin of dietary fiber and of the minor minerals; molybdenum, magnesium and manganese. Molybdenum assists in metabolism of fats, carbohydrates and is crucial for immersion of iron. Magnesium is essential for bone, protein, making new cells, activating B vitamins, relaxing nerves and muscles, clotting blood, and in energy production (Guerrera *et al.*,

2009). Insulin production and function is stipulated by magnesium (Bartlett and Eperjesi, 2008). Manganese is used by the body as co-agent for the antioxidant enzyme, superoxide dismutase. The intake of carrots has been connected with lower risk of heart attacks in females. Therefore, research is moved towards the usage of evaporative cooling system in preservation of carrot since this requires lower temperature and high humidity (Anyanwu 2004; Jain 2007; Ndukwu 2011).

2.0 MATERIALS AND METHODS

2.1.1 Materials

2.1.1.1 Raw material

Fresh carrot fruits used for this study were procured from main market in Akure, Ondo state southern part of Nigeria. The fruits were separated from ripe fruits by colour, damaged ones were also separated making using physical evaluation. Fruits were cleaned from

external impurities which may be attracted from the place of cultivation/harvest and conveyance process. The separated fruits were further transferred to the experimental site for the research.

2.1.2 Evaluation of evaporative cooling system with carrots

The evaporative cooling system consist of inner wall, external wall, water supply system and absorbent called pad materials. The cooler was majorly wooden structure similar to Manuwa and Odey (2012) with modification as shown in plate 1. The water distribution array of the system contains a water tank of 10 liters capacity and PVC pipe of 25 mm diameter for conveying water. Water is released from the overhead tank through a tap and drains through a pad material. As the water drips through the pad, naturally air blows through the wetted part into the cooling chamber.

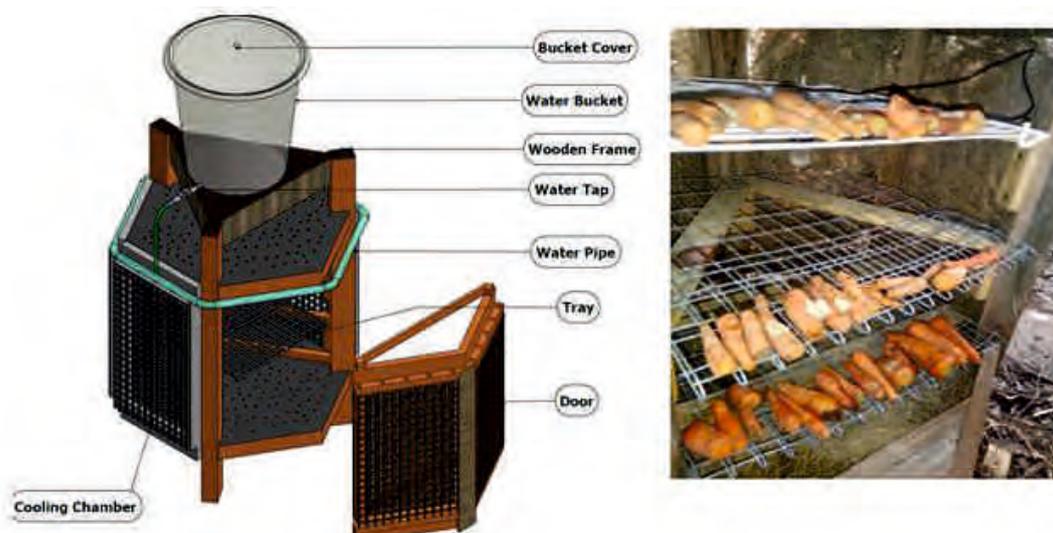


Plate 1: Stem sponge padded evaporative cooling system

2.1.3 Research location

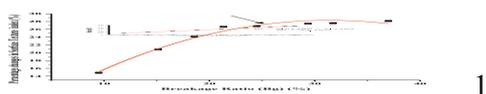
The research was carried out at the Meteorological station of The Federal University of Technology, Akure (FUTA) is located on spatial coordinates 07°17'41"N, 05°08'50" E at an altitudinal range of 290 m to 370 m above mean sea level. Weather station instrument coupled with data logger designed in the Department of Meteorology FUTA was used in obtaining the relative humidity and temperature of the project site.

2.2 Experimental Method

Fresh carrots were obtained from market, the fruits were sorted, washed, weighed, labelled and then arranged inside the cooler.

2.2.1 Physiological Weight Loss

The differences in weight of the carrots stored in both the control and in the evaporative cooling structure were taken on daily basis. The percentage weight loss was estimated using the equation as given by Moalemiyan and Ramaswamy, (2012).



Where, W_0 is the weight on the first day of storage and

W_1 is the weight in the tested day.

2.3 Chemical Analysis on stored carrots

2.3.1. Microbiological Analysis

Samples of each carrot in the storage structures were randomly chosen and evaluated. Methods to determine microbiological contamination followed the recommended Standard method of pour plate 9215 (2012) for the detection of total coliforms, moulds and yeast. Colony forming units per gram (CFU/g) of carrots were

determined.

2.3.2. Ascorbic acid (Vitamin C)

The Vitamin C content was determined using the method described by Vinta *et al.*, (2012). Quantification was obtained from a standard curve based on the reduction of 2, 6-dichlorophenolindophenol (DIP) and results were expressed as mg of ascorbic acid/100g.

2.3.3. Total sugar

The total reducing sugar of the samples was analysed using standard method of AOAC 2000.

3.0 RESULTS AND DISCUSSIONS

3.1 Evaporative Cooling Storage System

The passive direct evaporative cooling structure used for the research was fabricated in the Department of Agricultural and Environmental Engineering, FUTA. The cooler is a wooden framed of hexagonal structure with stainless wire mesh partitions fitted with a water supply system and with absorbent materials (stem sponge) as the evaporative cooling pad. The structure was designed to be dependent on zero external energy, therefore the cooler is powerless. This insinuates that the cooler is fully dependent on the environmental or atmospheric condition. In view of this, the structures (padded and unpadded) were sited at a location with natural shade and cooling by trees and the atmospheric data of the site location was obtained through the use of meteorological instruments and a data logger while the physical properties of the samples were taken manually with a digital weighing balance. The water supply system is made of a

9litres water tank on top of the cooler. The water in the tank drains through 2.5 cm flexible pipes, splashes on the top edges of the cooling pad (stem sponge) and is further distributed naturally through capillarity and gravity.

3.2 Weather parameter

The weather parameter that had significant effect on the storability potential of the stored carrots were temperature and relative humidity.

3.2.1 Temperature drop

The temperature difference is the variation in the temperature of the different structures. The temperature in all the structures excluding the refrigerator is determined by digital thermometer with sensor connected to the data logger placed inside the structure and the weather station for ambient weather

parameters. The temperature of the inlet had the highest temperature of 26.66 °C on day seven and lowest temperature of 24.99 °C on the first day. The temperature drops of the padded evaporative cooling system is between 2.41°C and 8.66°C which showed the effectiveness of the padded cooling structure. The temperature of the evaporative cooling system is between 24.41°C and 26.66°C similar to generally human thermal comfort temperature that is between 20 and 27°C (Lazzarin, 2012). The ambient temperature is transmitted by the air that enters into the various compartments and is then cooled inside each structure. The refrigerator shows greater variations as a result of inconsistent electrical power supply for the duration of the experiment. The evaporative cooling structure with stem sponge was the most efficient in maintaining stable temperature throughout

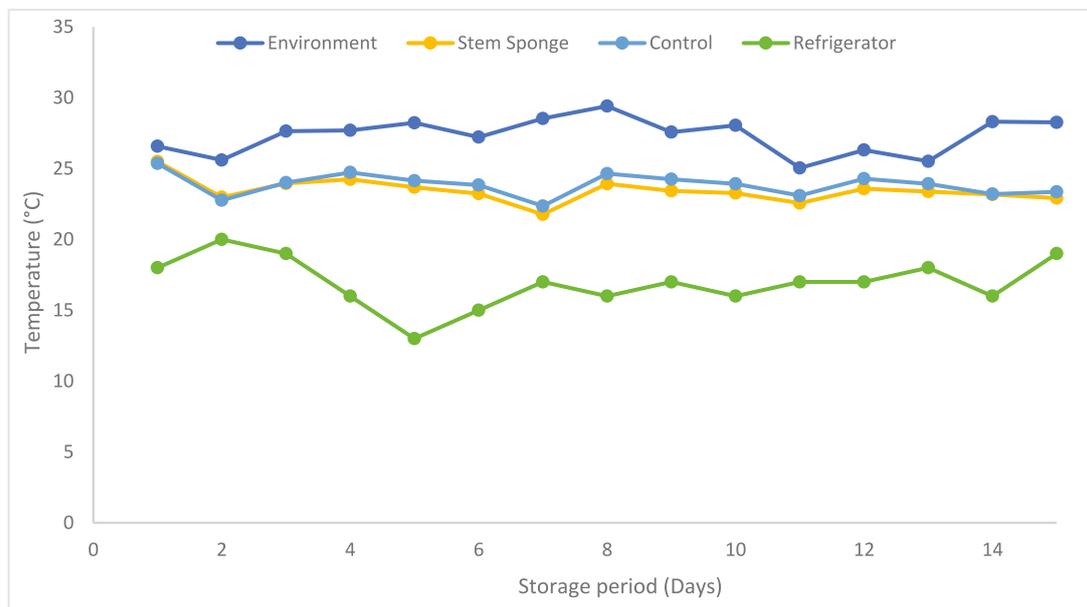


Figure 1; Temperatures of the evaporative cooling systems and Ambient temperature in day(s)

the experiment as shown in Figure 1.

3.2.2 Relative humidity

The relative humidity of the evaporative cooling storage structure remained well above 90% and moderately stable throughout the experiment despite the variations in ambient relative humidity. The variations in the ambient relative humidity is as a result of

changes in ambient temperature and rainfall. The ambient relative humidity spikes on days with extended periods of rainfall and falls on days when temperature rises. Refrigerator had a constant value for the duration of study with variations in the cooling structures ECSS control and the stem sponge structure as shown in Figure 2.

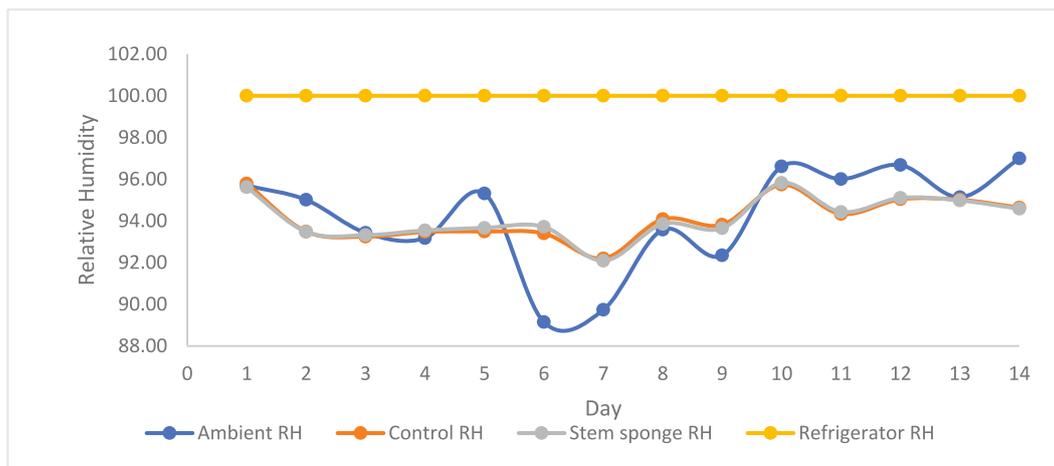


Figure 2; Relative humidity in the Ambient, Refrigerator and evaporative cooling systems.

The high relative humidity and low temperatures in the padded evaporative cooling system demoralized microorganism action on the stored carrots leading to an increased shelf-life (Wills and Golding, 2016). For the control environment evaporative cooling without pad, the relative humidity is relative lower than the cooler's microclimate and the outdoor temperature is also high. The control ECSS conditions provide an optimum environment for microorganisms' respiration and metabolism of the carrots similar to reports of Ndukvu and Manuwa, (2015). Hence, the carrot is subject to a hastened structural decay as compared to the carrot stored in the evaporative cooling system. Hence, the carrot is subject to an induced structural decay as compared to the

carrot stored in the padded evaporative cooling system. Generally, preservation is based on lowering the system's temperature and maintaining a relatively high humidity (Liberty et al., 2013a). It is purposed to extend the shelf-life and also enhance the sustainability quality of the vegetable, thereby leads to reduction in postharvest wastage associated with storage (Wills and Golding, 2016; Rayaguru *et al.*, 2010).

3.3 Quantitative Properties

Food spoilage includes physical damage or quantitative losses in the physical properties of the food material. The quantitative properties used in evaluating the evaporative cooling structures are; physiological weight

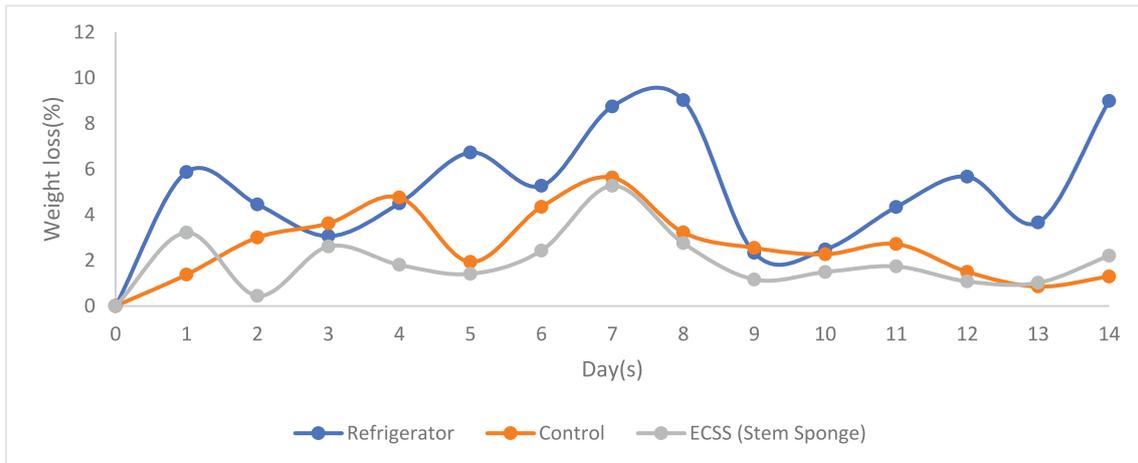


Figure 3. Percentage weight loss of stored carrots under Refrigerator, ECSS control and ECSS stem sponge.

loss and firmness.

3.3.1 Physiological weight loss/ Percentage weight loss

After 14 days, the weight loss for carrots kept under ECSS control was 32.8%, refrigerator 53.97% and 25.19% for ECSS with stem pads cooler conditions, respectively. This clearly indicates that the weight loss of carrots stored inside the cooler was lower than those stored inside the refrigerator and unpadded cooling structures. The evaporative cooler microclimate increased the shelf-life of carrots to 14 days. The microclimate evaporative cooler was in agreement with Basediya *et al.*, (2013) reported that fresh perishable crops could be stored at lower temperatures. The increasing of the shelf-life is thus adequate for ensuring that carrots take a

relatively longer time before they go bad.

The changes in weight of the carrot were monitored for the samples based on the appearance (shrinkage) caused by change in weight which were kept in the refrigerator, control and evaporative cooling system (stem sponge). Figure 4 shows the physical appearance of carrots stored in the evaporative cooling system (A) in the control samples (B) in the refrigerator samples (C) as shown in Figure 4.

3.4 Chemical Analysis

Food spoilage chemical changes which are due to contamination of food by yeast or bacteria (Cueva *et al.*, 2011). Some of the chemical changes used in the research are as



Figure 4. Pictorial view of the firmness of the stored Carrots in Evaporative cooling storage structure; stem sponge(A), ECSS Control (B) and Refrigerator (C).

follows;

3.3.1 Microbial contamination

Microbiological characterization of carrot is highly important as this fruit is consumed fresh. Microbial contamination of carrots can be a major cause of deterioration and present a health hazard to their consumer. The coliforms for the carrots stored control had the highest value of 7.94 CfU/g with ECSS, REF with 5.78 CfU/g and SS with lowest value of 3.81 CfU/g, respectively. The major microorganisms found in post harvested are coliforms, moulds and yeast. It is influenced mainly by temperature of the environment that affects microbial growth and activity, due to its enzymatic activity on their tissues and outer membrane. The main causes of contamination are related to hygiene, mixed cropping method of farming, the latter may become sources of contamination, especially by moulds and yeasts, also bolstering cross-contamination, with dust (Ayala-Zavala *et al.*, 2008).

The fungi/mould for the carrots stored under padded cooling structure (ECSS control)

had the highest value of 1.785 CfU/g with Refrigerator (Ref.) and 1.38 CfU/g and stem padded evaporative cooling structure (SS), with lowest value of 1.375 CfU/g, respectively. The presence of these microorganisms does not necessarily indicate fecal contamination, as the majority of coliforms are found in the environment. The consumer must be aware that good product appearance is not a synonym of absence of microbial contamination.

3.3.2 Ascorbic Acid

Overall ascorbic acid content for the stored carrots increased in all storage environments (Figure 6) on the third day and reduced on the 9th and 14th day of storage. Ascorbic acid content slightly increased for carrots stored under (SS), (Ref.) and (ECSS control) environments for the first three days, the concentration in the last three days reduced. However, there was no significant ($P > 0.05$) difference in the ascorbic acid content for carrots stored under the three storage environments. Ascorbic acid concentration

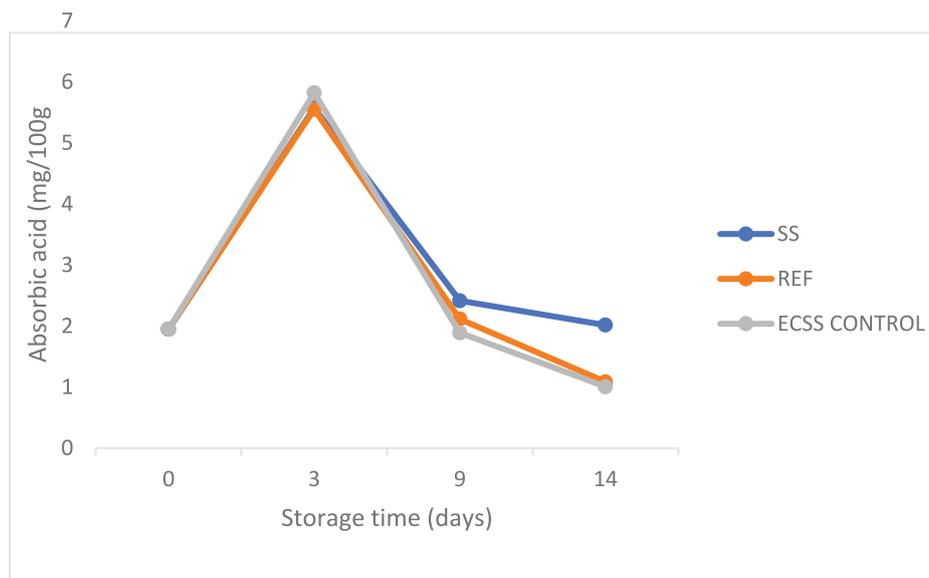


Figure 6. Ascorbic acid of carrot under (SS), (REF) and (ECSS control)

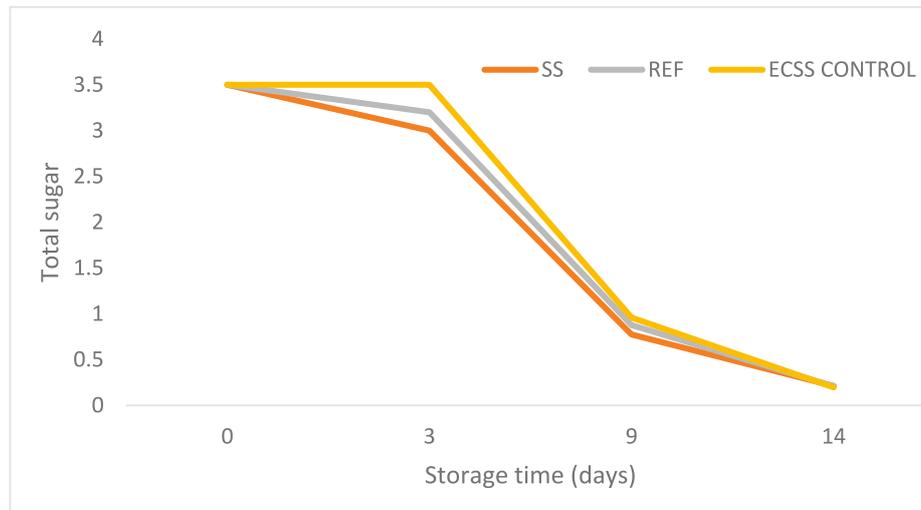


Figure 7. Total sugar of carrot under (SS), (REF) and (ECSS control)

for the carrots stored under (SS), (REF) and (ECSS control) ranged between 5.571 - 2.015 mg/100g, 5.820 – 1.005 mg/100g and 5.550 – 1.889 mg/100g, respectively.

4.1 Conclusions

The modification of the microclimate by use of the evaporative and evapotranspirative cooling principles helps attain the microclimate conditions favourable for longer storage periods. With reference to the developed stem sponge padded cooler in this study, the modified environment helped in reducing respiration and metabolic rates in the stored carrots. The overall percentage loss in weight (during the period of experiment) of the carrot was much in the refrigerator (53.97%) and control structure (32.80%) compared to those stored in the evaporative cooling structure (25.19%). The change in firmness was obvious in the carrots stored in the refrigerator compared to ones in the control structure. Similarly, loss in firmness of the carrots stored in the control structure was greater than the ones in the evaporative

cooling structure.

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