ORIGINAL RESEARCH ARTICLE

Performance evaluation of a scoria evaporative cooler for storage of mango fruits

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Abstract

The scoria evaporative cooler designed for this project applies the principle of evaporative cooling to reduce the temperature while at the same time increasing relative humidity inside the storage chamber. The modern preservation systems such as refrigerators are out of reach to most farmers; in-terms of cost and electricity which is costly and inappropriate for remote areas without electricity. The design consists of a cabinet box type whose dimensions of length, width, and height were 1000mm, 1000mm, and 1400mm, respectively. The performance of the scoria evaporative cooler was evaluated by monitoring the vitamin C, the weight, total soluble solutes, and firmness of the mango fruits and also the temperature and relative humidity throughout the study period. Mature and green apple mangoes were sourced directly from a farm in Tala Machakos County. Three labelled mangoes were randomly selected for evaluation of physiological weight and peel colour changes during storage and subsequent evaluation was repeated on the same fruits. The measurement of firmness, vitamin C and total soluble solids which involved destruction of fruits, the fruits were randomly selected, evaluated and discarded. The shelf-life and quality attributes (viz., physiological weight, firmness, TSS, and vitamin C) of the fruit stored in the cooler were evaluated against the fruits stored under ambient conditions. The temperature and relative humidity of storage environment for the cooler was of average value of 19.27 °C and 88.88% whilst the ambient storage were on average 30.41 °C and 35.28% respectively. Thus, the cooler lowered the storage temperature by 11.14 °C as compared to ambient conditions. This technology extended the shelf life of the apple mangoes by ten days as compared to storage under ambient conditions and this also preserved the quality of the fruit thereby reducing the losses and hence will make mango farming more profitable.

1.0 Introduction

Mango (*Mangifera indica L.*) is grown from 0 to about 1,600 m Above sea level on a variety of soil types; the optimum growing temperature is around 20–26°C, the appropriate rainfall 500–1,000 mm per year. Coast and the semi-arid parts of Eastern are the main mango producing areas of Kenya. The production of Mango fruits in Kenya was 705,195 metric tonnes in 2017 from an

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estimated area of 50,550 Ha (HCDA, 2017) and this translated to earnings were valued at KES 11,713,206,615.

According to HDCA (2012, 2014) the increase in productivity of mangoes was attributed to scientific research, adoption of high yielding varieties, irrigation and improved crop husbandry. The perishability of fruits is higher than that of other crops, making them more susceptible to higher losses. Globally, postharvest losses are estimated at 30% (FAO, 2011).

The scoria evaporative cooler is a new innovation which applies the principle of evaporative cooling to cool the mango fruits to be stored in it. Scoria stones, which are volcanic porous rocks, are used as the pad material for this cooler.

Postharvest losses occur due handling during harvesting, pests, diseases, immature harvesting and also due to inadequate storage facilities for mangoes particularly during the peak harvesting seasons. It is possible to develop effective storage systems and use them to reduce the losses thus improving the net returns for farmers (Jha, et al., 2010). An effective storage of the fruit can be achieved by controlling the storage environment. According to Ronoh et al (2018), the microclimate inside an evaporative cooler is affected by climatic parameters such as air temperature and relative humidity. The critical parameters in the modern storage systems include temperature, humidity, air velocity, lighting, air (gas) composition, and pressure (Uluko, 2006). Temperature and relative humidity greatly influence the shelf-life of fruit. Low temperature extends the shelf-life of the fruit by slowing down the rate of respiration and microbial activities. Kaminsa, (2014) reported that up to 68% of the total postharvest losses in Sub Sahara Africa occur due to lack of appropriate technology for handling, and storage of fruits and vegetables.

According to Korir et al (2016) the post-harvest losses experienced by Mango farmers in Kenya can be solved by embracing new technology of development and improved store facilities. In a given country, there exists a strong correlation between the extent of losses after harvest and both the technology that is available and how advanced the markets are (Parfit et al, 2010). Postharvest loss reduction technologies will offer farmers unique income and whereas citizens will gain through food security opportunities for the over 200 million people that face food insecurity in the sub-Saharan Africa (FAO, 2019; Kikulwe et al., 2018). Application of postharvest technologies has proven quantifiable postharvest losses reduction in different part of the world and could be a strategic pathway to reduce poverty, hidden hunger and malnutrition in Sub Sahara Africa (Affognon et al, 2014).

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2.0 Materials and methods

2.1 The design of the evaporative cooler

The experimental evaporative cooler was of cabinet box type, the dimensions of the cooler namely length, width, and height were 1000mm, 1000mm, and 1200mm, respectively. To prevent splash water from entering the cooler, it was raised above the ground by 0.15 m. The main frame was made of angle line steel bars (3/4'') and steel-flat bars. The pad of the cooler was of scoria stones (porous volcanic stones). A water reservoir linked to the cooler at the top through a flexible pipe (PPR half inch) supplied water to the cooler. Water seeped through the scoria walls and evaporate at the wall outer surfaces so as to have a cooling effect. The storage chamber was subdivided by three shelves made from coffee tray mesh (Ø 0.5 mm, spacing 5 mm).

The apple mango variety was selected for this study since it is among the most common mango varieties grown by the farmers in the Lower Eastern region of Kenya. Three trials were run during the 2022 mango season. Mature and green fruits were sourced directly from identified farmer in Tala. For every experiment, 60 mangoes were selected at the start from the farmer's harvest and transported in crates to the experimental site. Harvesting was done Early in the morning and then fruits transported on the same day. Upon arrival at the experiment site, the mangoes were washed separately using tap water, wiped, labelled and stored in the Cooler and another set in the ambient conditions. Three labelled mangoes were randomly selected in each storage method for evaluation of physiological weight and peel colour changes during storage. Subsequent evaluation was repeated on the same fruits since the measurement of weight and peel colour was non-destructive. The measurement of firmness, vitamin C and total soluble solids (TSS) which involves destruction of fruits, the fruits were randomly selected, evaluated and discarded. The shelf-life and quality attributes (viz., physiological weight, colour, firmness, TSS, and vitamin C) of the fruit stored in the cooler were evaluated against the fruits stored under ambient conditions.

2.2 Physiological weight loss

To evaluate the weight loss of mangoes during storage, the selected samples were marked, weighed before start of experiment and thereafter weighed on a daily basis using a digital scale (model mettle Toledo, Switzerland). The percentage physiological loss in weight was calculated based on equation (1).

$$W_l=\left(\frac{w_o-w_f}{w_o}\right)100 \quad (1)$$

Where; W_l, is the physiological loss in weight (%), w_o, the weight of a mango fruit before storage (g) and, w_f weight of the mango fruit at inspection date (g).

2.3 Vitamin C

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Vitamin C was evaluated using indophenol titration method. This method determines the vitamin C concentration in a solution by a redox titration using DCIP (2, 6 Dichlorophenol indolephenol). This test was done on daily basis during the experiment period. A standard ascorbic acid was prepared (1mg/ml TCA), the 2ml of it was titrated with DCPIP until the colour changed to permanent pink. The vitamin C was then calculated using equation (2);

$$Vitamin\ C(\frac{mg}{100g}) = \frac{sample\ titre*c*100}{sample\ weight} \tag{2}$$

2.4 Total soluble solids (TSS)

To determine effect of storage conditions on TSS, the TSS was determined as percentage Brix using a digital hand-held pocket refractometer (PAL-1, ATAGO Company, Tokyo, Japan)

3.0 Results and discussions

3.1 Performance evaluation of the developed evaporative cooler store with load

Figure 2 presents variation in temperature of storage environment for the cooler and ambient conditions with time of day. The temperature of storage environment for the cooler ranged from 17.56 to 19.97°C (average value of 19.27°C). Further ambient temperature was in the range of 25.09 to 33.41°C (average value of 30.41). This implied the temperature in cooler was lower by 11.14°C compared to ambient conditions.

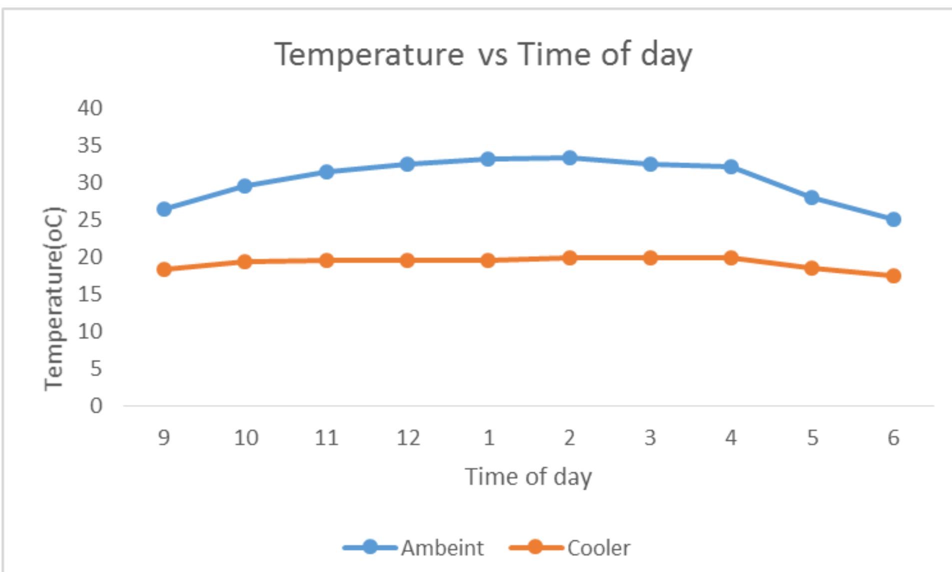

Figure 2: Comparison of temperature in the cooler and ambient conditions.

The variation in relative humidity of storage environment for the cooler and Ambient conditions with time of day was also investigated (Figure 2). The relative humidity of cooler ranged from 86.15 to 96.97% (average value of 88.88%) whilst for the ambient conditions was in the range of

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29.43 to 50.45% (average value of 35.28%). This indicated that the relative humidity in cooler was higher by 53.52 compared to Ambient Conditions.

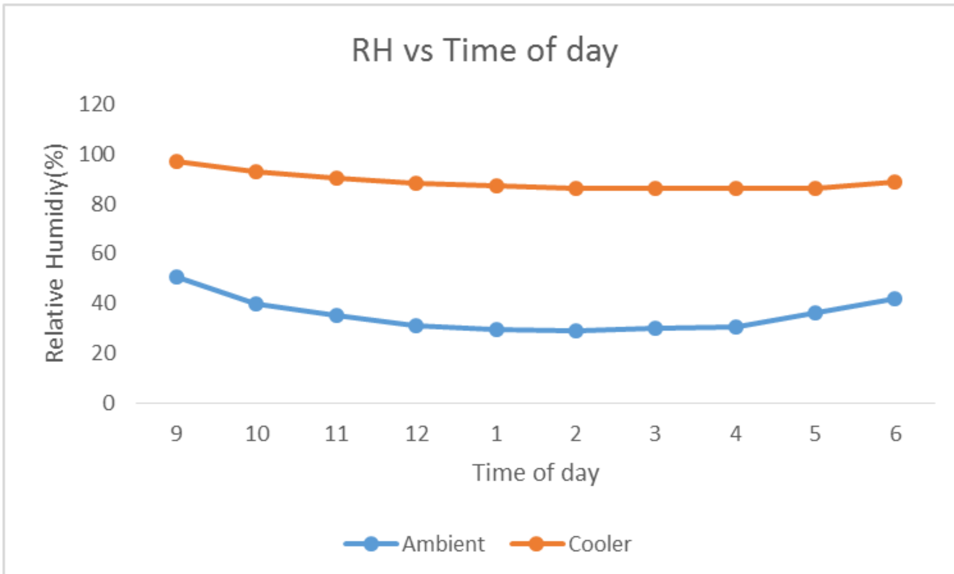

Figure 3: Comparison of relative humidity in the cooler and ambient conditions

Figure 3 shows the developed cooler loaded with mangoes at the beginning of an experiment to determine the effect of storage environment on quality of the fruit.

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Figure 4: shows the developed cooler loaded with mangoes at the beginning of an experiment to determine the effect of storage environment on quality of the fruit

3.2. Effect of storage environment on the shelf-lives of the apple mangoes

3.2.1 Physiological weight loss

Figure 5 shows increasing trend in physiological weight loss for Apple mangoes stored in the cooler and ambient conditions. At the end of the experiment, the corresponding weight losses were 7.14% for cooler and 15.63% for ambient conditions. In this study, the trend in loss of weight results are in agreement with that reported by Korir et al (2016) who investigated weight loss of apple and his results were that the physiological weight loss for Apple mangoes stored in the cooler and Room conditions were 17.28±0.57, and 19.03±1.04%, respectively.

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Figure 5: Variation in physiological weight loss with storage period for Apple mangoes stored in scoria cooler and ambient conditions.

The physiological weight loss in apple mangoes stored in the cooler was reduced by 8.49% compared ambient conditions. The weight loss values are within the maximum acceptable limit of mango fruit. According to literature, the maximum acceptable weight loss of mango fruit stored at is 4%, and 9% (Nunes et al, 2007). The shelf-life of the Apple mangoes stored in the cooler and ambient condition were 20 and 10 days, respectively based on the acceptable weight loss for mangoes. According to Rathore et al,(2007), physiological loss in weight is due to respiration, transpiration of water through the peel tissue, and other biological changes taking place within the fruit.

3.2.2 Firmness

The experiment was run from day zero to 20th day when the mangoes deteriorated. The firmness of the peel for Apple mangoes decreased significantly during storage. Figure 5 shows changes in the peel firmness during storage for Apple mangoes under the two treatments. The average firmness of the peel for Apple mangoes at the beginning of the experiment was 17.4 Kg/cm^2 of which decreased to 0.13 Kg/cm^2 for the fruit stored in the cooler and to 0.6 Kg/cm^2 for the fruit stored under ambient conditions at the end of experiment.

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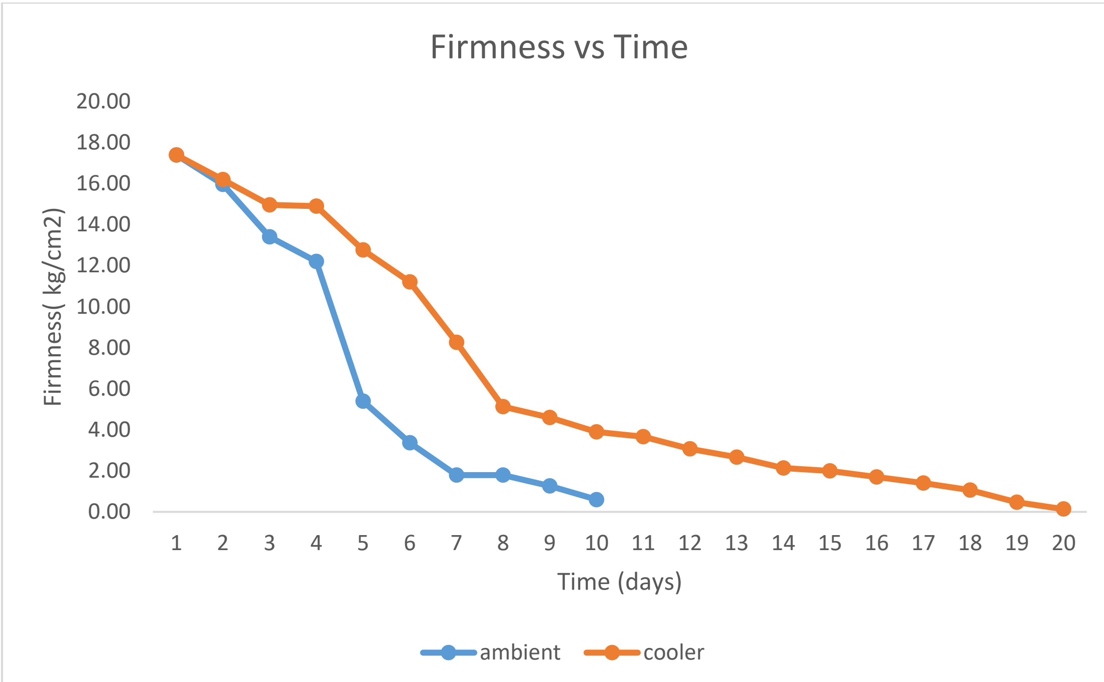

Figure 6: Variation in firmness of the peel with storage period for Apple mangoes stored in the cooler and ambient conditions.

During the experiment the fruits were handled in a similar way, hence the softening was due to postharvest physiological changes in mango involving ethylene release, sugar metabolism acid degradation, terpene volatile synthesis and degradation of cell wall pectin (Liu, et al., 2022)(~~Liu et al, 2022)~~. Further, Hosakote et al,(2006) reported that ripening of mangoes is accompanied by a series of biochemical changes resulting in gradual textural softening. Moreover, (Jha, et al., 2010) indicated that the firmness of the mango fruits remained almost constant over the period of growth and it decreased after attaining the maturity.

3.3 Effect of storage environment on the chemical properties of apple mangoes

3.3.1 Total soluble solids (TSS)

The average TSS for Apple mangoes at the beginning of experiment was 7.4 %Brix of which it increased to 19.4and 19.6 %Brix at the end of the experiment for the fruit stored in the cooler and ambient conditions respectively. These results are comparable to those reported by Doreyappa et al, (2001) who investigated different varieties of mango fruits during storage. Further, Mamiro et al., (2007) reported TSS of 18.9% for the *Dodo* mango during room temperature ripening.

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Figure 7 shows changes in TSS for Apple mangoes stored under the two storage conditions, respectively. An increasing trend in the TSS was observed with the fruits stored in the cooler having lowest increasing TSS compared to those stored in ambient conditions.

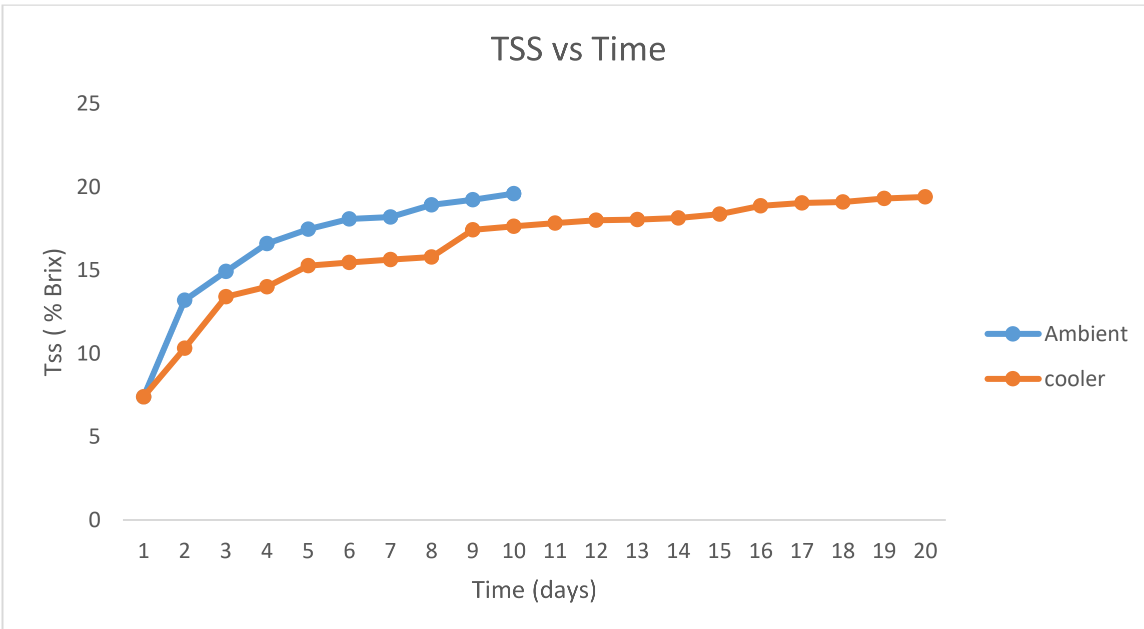

Figure 7: Variation in TSS with storage period for Apple mangoes stored in the cooler and ambient conditions

3.3.2 Vitamin C

The findings of this study indicate that vitamin C content decreased with increasing days of storage during the ripening (Figure 8). In the study by Anowar et al (2014), there is a decrease in vitamin C for mangoes during storage with a lower rate for evaporative cooler as compared to ambient conditions. The reduction in vitamin C content of the fruit during ripening may be due to the susceptibility of ascorbic acid to oxidative destruction particularly at high ambient storage temperature.

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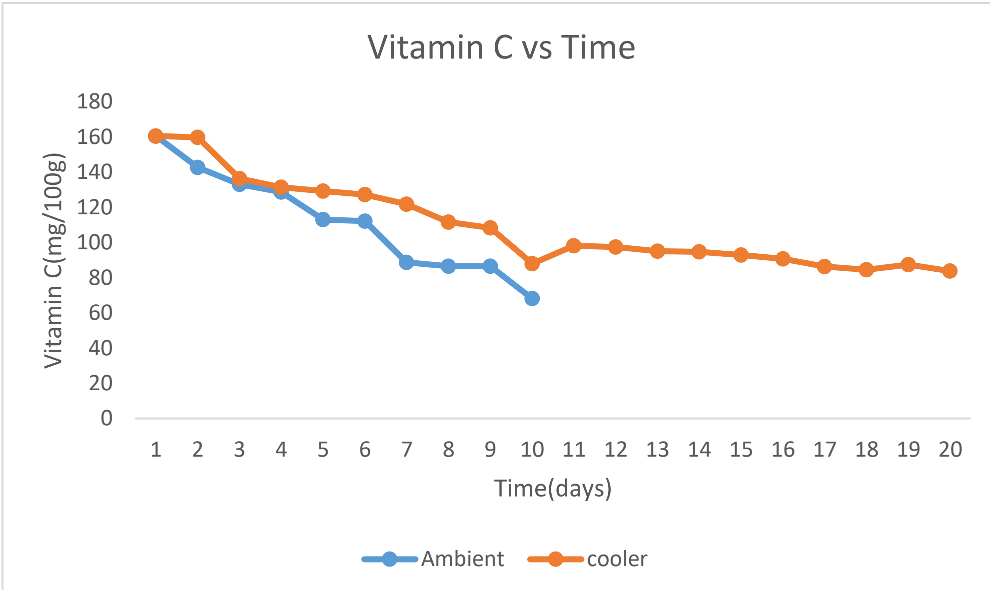

Figure 8: Variation in vitamin C with storage period for Apple mangoes stored in the cooler and ambient conditions

4.0 Conclusion

The scoria evaporative cooler had an effective reduction in temperature by 11.14 ^{o}C as compared to ambient conditions and was able to increase the relative humidity in the storage chamber by 53.32% as compared to ambient conditions. This combined enabled the cooler to extend the shelf-life of the mangoes by 10 days as compared to ambient conditions. Thus this cooler is effective in preservation of fresh fruits, it is an affordable alternative to farmers as it requires only the initial installation capital.

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