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EVALUATION OF QUALITY AND SHELF-LIFE OF FRESH AND FLESHY CUCUMBER STORED IN CHARCOAL COOLER BIN IN THE TROPICS

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ABSTRACT

Adiabatic evaporative cooling is a concept and process adopted for extending shelf-life of fresh fruits and vegetables in tropics. This study evaluated the performance of Charcoal Cooler Bin (CCB) and its effects on the quality and shelf-life of cucumber. The storage microclimate and ambient conditions (air temperature and relative humidity) were measured using data logger developed for the purpose of this research consisting of a micro-control unit (MCU), a logging device and sensors. By monitoring the physiological and quality parameters, the effects of the storage media: CCB, open-air, refrigerator and laboratory conditions on the storability of cucumber, and effectiveness of the CCB for fresh cucumber preservation through percentage weight loss, visual quality, degree of shriveling, colour changes and life expectancy were evaluated. The CCB had an average cooling efficiency of 75.56%, an average relative humidity and temperature of 94.71% and 23.22^{o}C for the storage period. The CCB markedly maintained freshness, reduced weight loss (with weight loss of 3.4696% after the storage period relative to cucumber samples stored in the refrigerator, laboratory and open-air condition with 8.4176%, 9.8260%, and 11.2696% respectively) and extended the shelf-life of cucumbers fruits at CCB environmental conditions. Cucumber stored in the CCB were still acceptable for 14 days with weight loss of less than 5% while refrigerated, laboratory and open-air samples were acceptable for 9, 6 and 5 days having weight loss greater than 5% respectively. Therefore, CCB passive system is an inexpensive and reliable storage medium for reducing postharvest losses in a sustainable manner.

Keywords: *Charcoal cooler bin, cucumber, shelf-life, quality, evaporative cooling system*

INTRODUCTION

Cucumbers (Cucumis sativus L.) are fruit vegetables containing high amount of nutrient, vitamins and antioxidants. According to Dzivama *et al.* (2006), fruits and vegetables should be consumed in a fresh form for maximum usefulness and optimum nutritive value. Fruits and vegetables are generally regarded as essential herbaceous plants with high moisture content in their fleshy forms (Mogaji and Fapetu, 2011). Cucumber have a great importance all over the world today due to the social and economic value and are consumed in several ways. Based on the values and freshness for consumption, it is important to study various ways to maintain the cucumbers freshness after harvest to the point of consumption. The appropriate techniques and technology suitable for rural, small and medium scale farmers and fruits and vegetable dealers is the evaporative cooling storage (e.g. CCB). Charcoal cooler Bin technology is known and used to avert post-harvest losses and deterioration. The relationship between temperature and relative humidity of the air in the storage structure vis a vis evaporation in the storage bin is required in a passive system condition. The evaporative processes of CCB are used for all types of agricultural produce especially tropical fruits and vegetables. According to Ronoh *et al.* (2018), the evaporative cooling process is used to extend shelf-life of agricultural produce by slowing down of the rate respiration. The stored produce tends to take a considerably longer time for deterioration to be evident or undergo structural decay because of a reduced risk of microbial growth facilitated by lower temperatures and a higher relative humidity within the cold storage facility (Wills and Golding, 2016). The use of simple systems like evaporative cooling system (e.g. the CCB) would help in solving preservation problems in such marginalized areas (Liberty *et al*., 2013b). This study tends to proffer solution on postharvest handling of fleshy and fresh cucumbers to extend the shelf life as well as reduce the rate of deterioration of the fruit after harvesting. The objective of this study was to evaluate the quality and shelf-life of tropical cucumbers stored in charcoal cooler bin based on physical, chemical and physiological changes in cucumber during storage.

MATERIALS AND METHODS

Cucumber Preparation and Storage Conditions

Cucumber (Cucumis sativus L.) used for this research and analysis were obtained from a local farm in Nsukka, Enugu state, Nigeria on the 16th of December 2020. The cucumber were properly washed with clean water for eliminating microbial contamination and preventing fungal infections. Before storing the fruits in different medium (CCB, Open-Air, Laboratory and refrigerator), the cucumber were then randomly distributed into four groups of five (5) each for the four different storage medium considered and used in this research and labeled accordingly for recognition.

The cucumber were stored in a CCB, a Scanfrost refrigerator (at 8^oC and 80-90% RH), open-air (ambient) and in the laboratory (at average room temperature and relative humidity). The external dimensions of the developed Charcoal cooler Bin are 580 mm long, 540 mm wide, 500 mm high (front side and rear side). The cooler room has charcoal-laden walls of 50 mm thickness held by weld and chicken wire meshes on the inner and by well perforated mild steel metal sheets on the outside. The cooler has a metal door measuring 2 m by 0.7 m. The cooler was developed at the department of Agricultural and Bioresources Engineering, Faculty of Engineering, University of Nigeria, Nsukka (UNN). Figure 1. show the charcoal cooler bin used in this study.

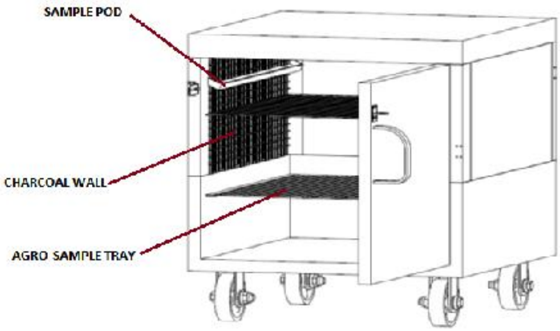


Figure 1. The charcoal cooler bin

Fruits Measurement and Analysis

The Physiological Loss in Weight were calculated as the difference between the initial weight of the fruit and the weight of the fruit at time of measurement and expressed as percentage. Weight losses were determined by weighing the cucumber samples using an electronic weighing balance and recording every day for all storage media calculated as a percent of the initial weight using the following equation (1) (Moalemiyan and Ramaswamy, 2012):

$$WL\ (\%) = 100 \times (W_A - W_B)/W_A \quad (1)$$

Where: W_A = the weight on the first day of storage [kg] and W_B = the weight on the tested day [kg].

Visual qualities, degree of shriveling and colour changes are important parameters in the evaluation of fruits and vegetables quality and deterioration rates. These quality parameters for different storage conditions were evaluated through the use of the rating charts adopted by Munoz *et al.* (2017) as basis of evaluation. To obtain reliable data on this part of the study, evaluation were conducted with the aid of five (5) students from the University of Nigeria, Nsukka. The data obtained from the result of evaluation were analyzed using a measure of central tendency which is mode, to represent each storage condition and respective quality parameter with respect to storage time on the graph. The temperature and relative humidity were measured for the CCB and ambient conditions and stored in a digital data logger developed for the purpose of this research. The temperature and humidity data were used to analyze the behavior of open-air and CCB setups. All measurements were determined in quintuplicate in all storage media for analyses purpose and the data generated were statistically analyzed using means for weight losses and modes for other quality parameters in Microsoft Excel 2013. The linear regression model in Microsoft Excel 2013 was used for the life expectancy of the cucumber samples stored in CCB.

RESULTS AND DISCUSSION

The Charcoal Cooler and Environmental Conditions

The CCB attained a relatively high cooling efficiency varying between 50.05% and 100.05% with 75.56% average throughout the period under consideration, in agreement with Babaremu *et al.* (2018) which found a varying cooling efficiency and an average of 86.01%. The temperature of the Open-air (ambient) varied between 18°C to 33°C with an average of 27.84°C while the CCB temperature varied between 18°C and 26°C with an average of 23.22°C throughout the storage period, The relative humidity of the CCB ranged from 93% to 95% (on the average 94.71%) while that of the ambient ranged between 12% and 95% (average of 54.32%). Babaremu *et al.* (2018) also found a significantly varying temperature and relative humidity between an evaporative cooling system and the ambient. Figures 2. and 3. shows the trends in average temperatures and relative humidity for the CCB and open-air conditions respectively. The cooling efficiency (η) of the CCB, indicating the extent to which the dry bulb temperature of the cooled air approaches the wet bulb temperature of the ambient air were calculated as defined in the following equation (2) (Echiegu and Ugwuishiwu, 2015):

$$\eta = {(\boldsymbol{To} - \boldsymbol{Ts})}/{(\boldsymbol{To} - \boldsymbol{To,wb})} \qquad (2)$$

Where: η = Cooling efficiency [%]; TO = Outside temperature [◦C]; TS = the inside air temperature [◦C]; and To,wb = the outside air wet bulb temperature [◦C].

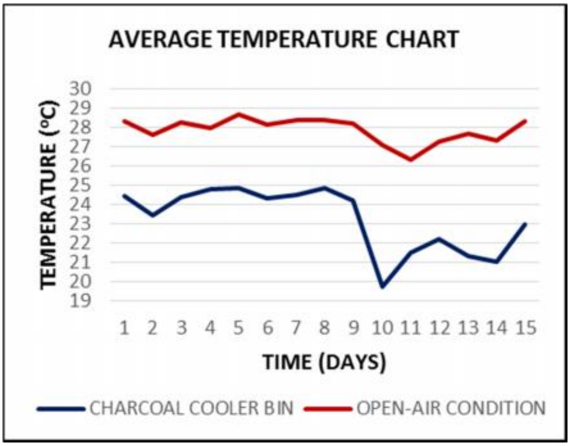


Figure 2. Daily average temperature chart

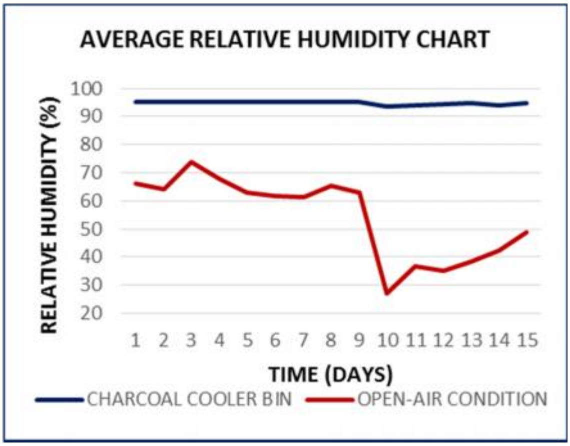


Figure 3. Daily average relative humidity chart

Percentage Weight Loss

The stored cucumber samples in the CCB, refrigerator, laboratory, and open-air (ambient) had an average daily percentage weight loss of 0.2569%, 0.6099%, 0.7458% and 0.8527%. Cucumber samples in the CCB had the least increase in percentage weight loss after the storage period with 3.4696%, compared to 8.4176%, 9.8260% and 11.2696% for refrigerated, laboratory and open-air samples respectively. Figures 4. and 5. below shows the cucumbers weight loss as a function of storage time and temperature, indicating increasing percentage weight loss of the samples during

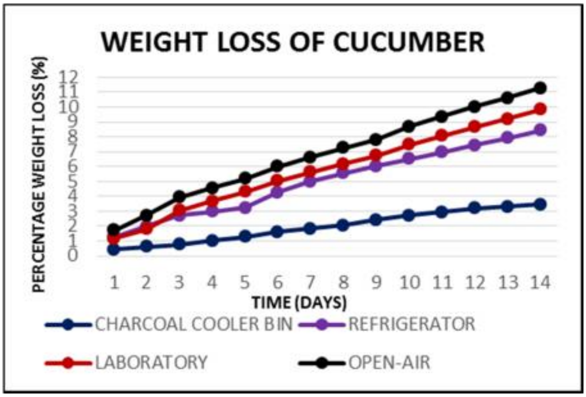


Figure 4: Percentage weight Loss of Cucumber

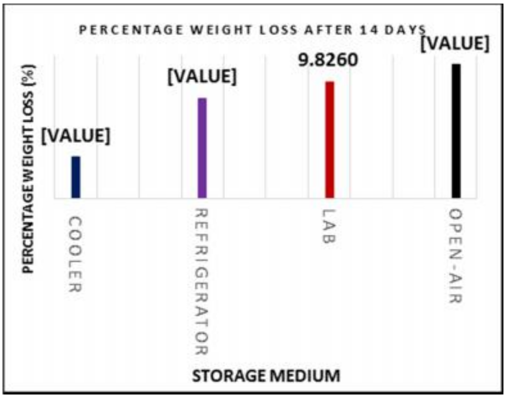


Figure 5: Percentage Weight Loss After 14 Days

the 14 day storage in the media with the storage time. The CCB microclimate (lower temperature and higher relative humidity) reduced the rate of weight loss of samples agreeing with the findings by Basediya *et al*. (2013) that fresh horticultural produce (such as fruits and vegetables) should generally be stored at lower temperatures because of their perishable nature and indicates a lower cucumber weight loss samples stored inside the cooler than those stored outside the chamber. Phal *et al.* (2013) found that the use of evaporative cooling system (ECS) and high density polyethylene (HDPE) with higher relative humidity (93%) than the ambient reduced the weight loss of cucumber from 21% in the ambient to 3.09% during 8 days storage period with fewer changes in other quality parameters.

Quality Parameters

The cucumber samples in the CCB had better visual quality and remained in good condition (with minor defects) compared to samples stored in other storage media which had poor condition (serious defects and limit of usability) as shown in Figure 6, also samples stored in the CCB had minor signs of shriveling, wilting or dryness compared to samples stored in other media which either had evidence of shriveling, wilting or dryness or were severly wilted (Figure 7.). As water is lost from the tissue, turgor pressure decreases, and the cell begins to shrink and collapse, thus leading to loss of freshness (Jadhav, 2018), this can be attributed to the significant loss of freshness for laboratory, open-air and refrigerated fruits due to their increased weight loss. Considering all samples in the different storage medium, cucumbers stored in the CCB maintained the colour of cucumber and had only minor changes in colour comapared to other samples which had either serious evidence of yellowing or major changes in colour at the end of 14 day. The reduced loss of quality and color changes of fruits in CCB may be due to high CO_2 and/or low O_2 levels in the internal atmosphere of the fruits (Moalemiyan and Ramaswamy, 2012).

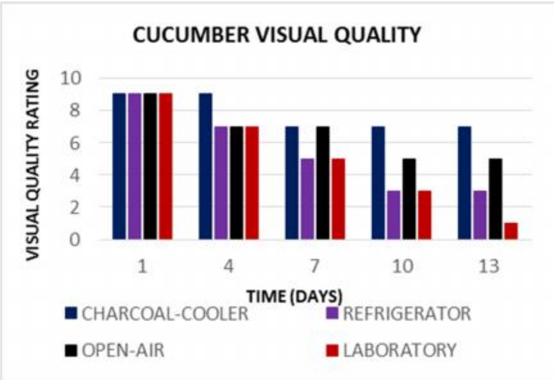


Figure 6: Cucumber visual quality chart

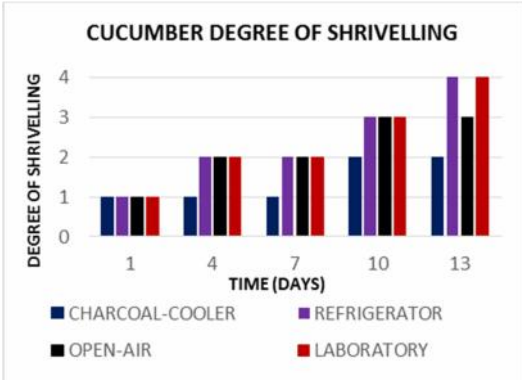


Figure 7: Cucumber degree of shriveling rating chart

8a

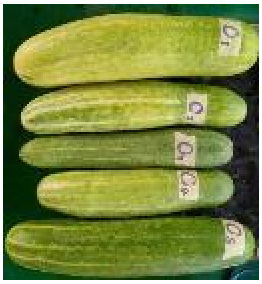
8b

8c

8d

Reduced temperature of cucumber lowers their rate of ripening and deterioration (Kays, 1991), this explains why samples in the CCB maintained their dark green colour more than fruits in other storage media. The established fact that the CCB reduced the degree of shriveling (wilting or dryness) and maintained good visual quality of cucumber is in agreement with the results of Munoz *et al.* (2017) that evaporative cooling systems preserve the quality of fruits and vegetables. The images in figure 8 show the conditions of cucumber samples at the initial and final stages of the experiment clearly showing the colour differences, degree of shriveling and visual quality.






8e 8f 8g 8h

Figure 8: Stored cucumbers at initial and final stages of experiment: (a)Charcoal cooler bin (day one), (b) Laboratory (day one), (c) Open-Air (day one), (d) Refrigerator (Day one), (e) Charcoal cooler (day 14), (f) Laboratory storage (day 14) (g) Refrigerator (day 14), (h) Open-Air (day 14).

Shelf-life and Life Expectancy

After storage period, the data from the weight loss of cucumber stored in the CCB were used to produce a trend line to show the relationship of percentage weight loss with respect to time. These also indicate the possible percentage weight loss of the cucumber samples for the next six days. According to FAO (1989), when the harvested produce losses 5 or 10 percent of its fresh weight, it begins to wilt and soon becomes unusable. As indicated in the graph (Figure 8.), the percentage cucumber weight loss in the CCB will reach 5% after 20 days of storage, agreeing with the results of Munoz *et al.* (2017) that commodities stored in an evaporative cooling system has lesser inclination in the trend line from a linear regression model over time accessed in terms of weight loss. This technique was used to determine the time when the Figure 8 shows the trend line and the equation derived from the regression method. The CCB delayed deterioration and increased the shelf life of cucumber which was detected by observing external appearance, shriveling, the loss of color, and weight loss data. The loss of color, wilting, and weight were greater in cucumbers kept in other storage media than in cucumbers kept in the CCB. Cucumber stored in the CCB were still acceptable for 14 days with weight loss of less than 5% while refrigerated, laboratory and open-air samples were acceptable for 9, 6 and 5 days having weight loss greater than 5% respectively.

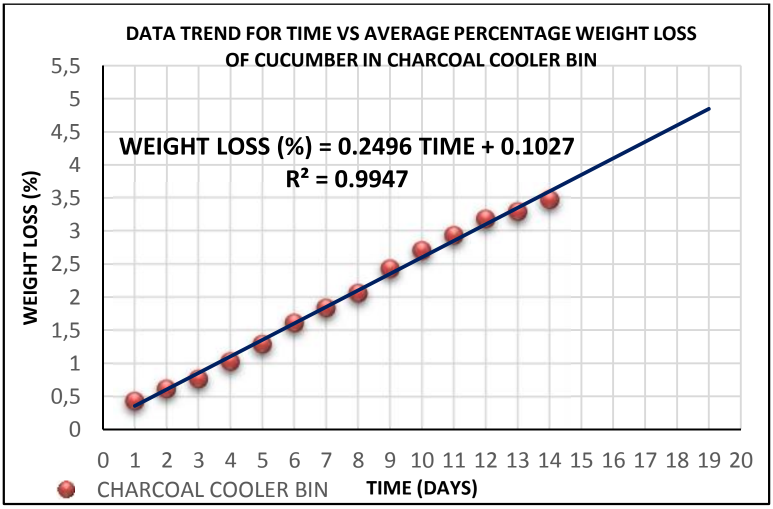


Figure 8: Data trend for time against percentage weight loss of cucumber in the CCB

CONCLUSIONS

This research focused on the evaluation of quality and shelf-life of fresh and fleshy cucumber stored in charcoal cooler bin in the tropics. It can be concluded that the CCB was effective for reducing moisture loss and prolonging the storage life of cucumber. The microclimate of the CCB helped to better retain the different quality parameters by reducing changes in color, degree of shriveling and loss in weight. Commodities stored inside the evaporative cooler show better conditions in terms of weight, visual quality and degree of shriveling compared to those stored in other media. The study proved that the usage of evaporative CCB can prolong the cucumber shelf-life of and perhaps other fruits and vegetables and therefore, proffer a good solution to the issues of postharvest losses.

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