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CHACOAL EVAPORATIVE COOLING TECHNOLOGY FOR STORAGE OF DWARF GER MARGLOBE TOMATO FRUITS

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ABSTRACT- Fruits and vegetables consumption contribute in human nutrition through the provision of essential nutrients for growth and good health. However, farmers, marketers, and consumers encounter major problems of keeping fresh commodities such as Dwarf ger. marglobe Tomato fruits to increase their shelf life due to quick degeneration and decomposition of the produce at storage. Demand in the consumption of fresh fruits and vegetables increased across the world which comes with major concern in storage of these perishables. The objective of the study was to develop Charcoal Evaporative Cooler (CEC), and compare with House Hold Fridge (HHF) and Control Sample of Dwarf ger. marglobe Tomato fruits grown in the Wa Municipality of the Upper West Region of Ghana. A total of thirty six fruits without any bruises and decay were used for the experiment. The tomato fruits were divided into three to represent the treated and untreated samples. The respective weights of the fruits were taken after natural air drying and monitored at Completely Randomized Design (CRD) was the experimental design used with three replications. Data on weight, decay severity and Colour changes of the produce were analyzed using MiniTab version 16 The results obtained on percentage weight reduction of fresh tomato fruits stored in Charcoal Evaporative Cooler House Hold Fridge and control temperature (CT) showed that, the latter recorded the highest average weight loss of 15.93% compared with HHF 4.68% and CEC 4.84% when the experiment was terminated. Storage for an experimental period of ten (10) days. Twelve (12) fruits were stored in the Charcoal Evaporative Cooler (CEC), twelve fruits were also stored in the House Hold Fridge (HHF) and twelve fruits were left at room temperature as control. The results also indicated that the least average colour of 4.5 was produced by fruits stored in Charcoal Evaporative cooler compared with average values of 5.4 and 6.0 for house hold fridge and control sample respectively. The trend on the decay severity demonstrated that the House Hold Fridge which produced 0.3 decay could reduce decay better than Charcoal Evaporative Cooler with 1.2 and Control sample with severity of 2.7 .The fact that the performance trend of the experiment on the use of Charcoal Evaporative Cooler on storage of fresh tomatoes could reduce decay, average weight, colour and maintain freshness of tomato fruits, it was safely concluded that, adoption of Charcoal Evaporative Cooler for cooling and extension of shelf life of tomato fruits at small scale and household levels for consumers would be appropriate in Wa Municipality

I. INTRODUCTION

Vegetables play an important role in human nutrition by providing essential nutrients for growth and good health. Tomato, Lycopersicum esculentum, of the nightshade family is consumed in diverse ways, including raw, as an ingredient in many dishes and sauces and in drinks. However, farmers, marketers, and consumers encounter major problems of storing vegetables to increase their shelf life due to quick degeneration and decomposition of the produce at storage. Demand in the consumption of vegetables increased across the world which comes with high concern in storage of these perishables to maintain their quality. In West Africa, the bulk of food commodities such as tomatoes, bananas, plantains, mangoes and leafy vegetables, are produced and marketed by peasant farmers and these people do not have adequate means of cooling, proper handling, transportation and storage [4]. The best method of increasing relative humidity is to reduce temperature. Another method is to add moisture to the air around the commodity as mists, sprays, or, at last resort, by wetting the store room floor [25-26]. Reduced temperature decreases physiological, biochemical, and microbiological activities, which are the causes of quality deterioration and weight loss of fresh produce such as tomatoes [16].

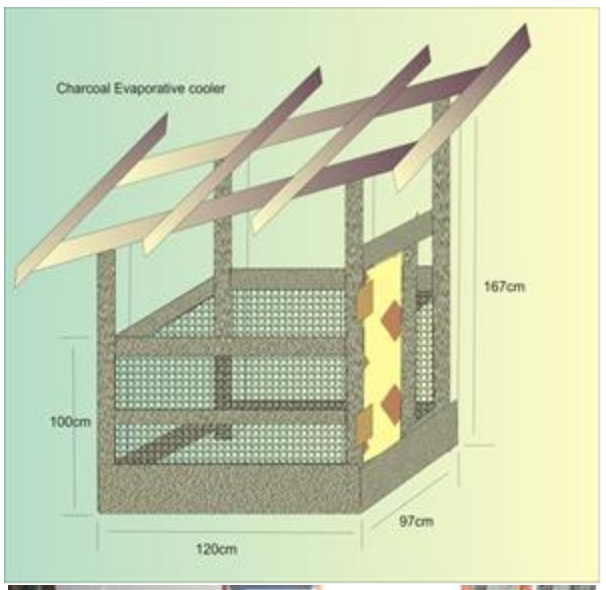
Fruit weight loss increased with storage, and was found lower in fruit stored at 15^{O}C than at ambient [3]. Low temperature storage is well known to be the most effective method of prolonging shelf life of fresh produce including tomatoes [19]. Decay can be a problem, but can be controlled by washing produce in chlorinated water prior to cooling [12, 13]. Reduced temperature decreases physiological, biochemical and microbiological activities, which are the causes of quality deterioration such as flavour and colour [8, 9, 23, 25]. Throughout the period between harvest and consumption, temperature control has been found to be the most important factor in maintaining product quality. Fruits and vegetables are living, respiring tissues separated from their parent plant. Reducing the rate of water loss could cuase the rate of shriveling and wilting, which could result in serious post-harvest losses. Similarly, temperature of the surrounding air of produce can be reduced by forced air cooling, hydro cooling, vacuum cooling, ice cooling and adiabatic cooling [21]. Evaporative cooling has been reported for achieving a favourable environment in greenhouses [7] animations and the storage structure for fruit and vegetables [6, 22].

II. MATERIALS AND METHOD

A. Construction stages

The charcoal Evaporative cooler was constructed from an open timber frame of approximately 50mm x 25mm in section. The door was made by simply hinging one side of the frame. The wooden frame was covered in mesh, inside and out, leaving a 25mm cavity which was filled with pieces of charcoal. The charcoal was sprayed with 20 liters of water, and wet provides evaporative cooling. Mesh, Nails, Charcoal, Pieces of wood example (Wawa board) were the main local materials used

Mature Dwarf Ger. Marglobe fruit were purchased from a commercial farmer at Busa in the Wa Municipality. A total of thirty six fruits without any bruises and decay were used for the experiment. The entire sample was divided into three to represent the different treatments. Tomato fruits were washed to remove dirt and allow to natural air dry before storage in the different structures.



B. Design of Experiment

The experimental set up was done using the appropriate materials and equipment. A total of thirty six fruits were used for the experiment. The tomato fruits were divided into three to represent the treated and untreated samples. The respective weights of the fruits were taken after natural air drying and monitored at storage for an experimental period of ten (10) days. Twelve (12) fruits were stored in the Charcoal Evaporative Cooler (CEC), Twelve fruits were also stored in the House Hold Fridge (HHF) and Twelve fruits were left at room temperature as control. Completely Randomized Design (CRD) was the experimental design used and each treatment was replicated twelve times.

C. Data Analysis

Data on weight, decay severity and Colour changes of the produce were taken every two days for an experimental period of ten (10) days. Data that were generated from the recordings of weight, computed for and analyzed based on every two days recordings from the experiment. However data on consumer acceptance and Colour changes were transformed into their log forms to allow for the use of ANOVA. The analysis of the data was done using MiniTab version 16. The one factor analysis of variance with replications was used at 5% alpha level to test for any significant differences among the treatment. Means separation was done by Tukeys studentized

D. Decay Severity

The results produced on decay severity of fresh Tomato fruits stored in a Charcoal Evaporative Cooler (CEC), House Hold Fridge (HHF) and Control Temperature (CT) showed that, on day 2 of the experimental periods, there were no changes with decay on fresh Tomato fruits. The results obtained on decay severity of Tomato fruits stored in CEC, HHF and CT showed that, Tomato fruits that were stored in the Charcoal Evaporative Cooler and House Hold Fridge indicated no signs of decay on day 4 but Tomato fruits sample stored as Control produced an average decay severity of 0.8. However, the results obtained on decay severity of Tomato fruits stored in a HHF, CEC and CT showed that, on day 8 of the experimental period, Tomato fruits stored in House Hold Fridge recorded an average decay severity of 0.1 compared with Charcoal Evaporative Cooler 0.3 and Control Temperature 2.6. Based on the results produced on decay severity, it was clear that Tomato fruits stored as Control produced the highest decay severity of 2.7 on day 10 compared with decay on the Charcoal Evaporative Cooler 1.2 and House Hold Fridge 0.3. . Means were statistically different among the treatments(Table 1)

Table 1. ANOVA on Decay severity of Tomato fruits

Source	DF	SS	MS	F	P
Storage treatment	2	41.22	20.613	26.73	0.000
Residual	12	9.252	0.771		
Total	14	50.472			

N	MEAN	GROUPING
CONTROL	5	4.85 A
HHF	5	1.35 B
CEC	5	1.32 B

Means that do not share a letter are significantly different.

E. Peel Colour appearance

The results produced on colour changes of Tomato fruits stored in a Charcoal Evaporative Cooler (CEC), House Hold Fridge (HHF) and Control Temperature (CT) indicated that, on day 2 of the experimental period, there were changes with the colour of fresh Tomato fruits stored in CEC 2.3 as compared with HHF 2.0 and CT 2.0. However, on day 6 of the experimental period the results obtained on colour changes of tomato fruits stored in a CEC, HHF and CT demonstrated that, there was gradual increase in colour on Tomato fruits stored at Control Temperature 2.6 compared with Charcoal Evaporative Cooler 2.3 on day 6 of the experimental periods. Also, the results obtained on colour changes of fresh tomato fruits stored in a Charcoal Evaporative Cooler, HHF and CTS indicated that, on day 8 of the experimental period Tomato fruits stored in the Charcoal Evaporative cooler indicated an average colour of 5.4 compared with House Hold Fridge 4.5 and Control Temperature 6.0. Based on the results produced on colour, it was clear that Tomato fruits stored as control Temperature produced a high average colour of 6.0 on day 10 compared with Charcoal Evaporative Cooler 5.4 and House Hold Fridge, 4.5. The results could not statistically produce any significant difference.(Table 2)

Table 2. ANOVA on Peel colour of Tomato fruits

Source	DF	SS	MS	F	P
Storage treatment	2	3.43	1.72	1.01	0.387
Residual	15	25.46	1.70		
Total	17	28.89			

	N	MEAN	GROUPING
CONTROL	6	3.717	A
HHF	6	3.250	A
CEC	6	2.650	A

Means that do not share a letter are significantly different.

F. Percentage Weight reduction

The results obtained on percentage weight loss of fresh Tomato fruits stored in a Charcoal Evaporative Cooler, House Hold Fridge and Control Temperature showed that, Tomato fruits stored in a CEC recorded an average weight of 0.58% compared with HHF 0.76% and Control sample with an average weight loss of 2.11%.

However, on day 6 of the experimental period, the results produced on percentage weight loss indicated that, there was gradual loss of weight in Tomato fruits stored in the CEC with 1.47% compared with the weight of Tomato fruits stored in HHF 3.24% and CT 9.52%.

Based on the results produced on percentage weight loss of Tomato fruits stored in CEC, HHF and CT on 10 days of the experimental period, it was clearly indicated that Tomato fruits stored as control temperature (CT) recorded the highest average weight loss of 15.93% compared with HHF 4.68% and CEC 4.84%. . Means were statistically different among the treatments (Table 3)

Table 3. ANOVA on Percentage weight reduction of Tomato fruits

Source	DF	SS	MS	F	P
Storage treatment	2	152	75.7	6.98	0.010
Residual	12	130	10.9		
Total	14	282			

	N	MEAN	GROUPING
CONTROL	5	9.33	A
HHF	5	3.03	B
CEC	5	2.214	B

Means that do not share a letter are significantly different.

G. Sensory Evaluation

The results obtained from the data on sensory evaluation test scored by 15 untrained panelists on overall acceptance and texture of tomato fruits stored in a CEC, HHF and CT showed that, a high level of overall acceptability and texture was found with fruits stored in the CEC which recorded an average acceptable and texture value of 8.07 and 2.33 respectively. However the results obtained from the data on sensory evaluation test scored by 15 untrained panelists on overall acceptance and texture of fresh tomato fruits stored in a CEC, HHF and CT indicated that, an average acceptable and texture value of 6.0 and 1.73 was scored by the panelist for fresh tomato fruits stored in CT and results produced on fresh tomato fruits stored in the House Hold Fridge (HHF) recorded an average acceptable value of 7.27 whereas 2.13 was also scored for texture by 15 untrained panelists.

Based on the results produced on texture and overall acceptance of Tomato fruits stored in CEC, HHF and CT for 10 days of the experimental period, it was clearly indicated that out of 15 untrained panelists Tomato fruits stored in the CEC recorded the highest overall acceptance of 8.07 compared with HHF 7.27 and control sample 6.60. Means were statistically different among the treatments (Table 4)

Table 4. ANOVA on sensory evaluation of Tomato fruits

Source	DF	SS	MS	F	P
Storage treatment	2	16.18	8.09	3.05	0.058
Residual	42	111.47	2.65		
Total	44	127.67			

	N	MEAN	GROUPING
CONTROL	15	8.07	A
HHF	15	7.27	AB
CEC	15	6.60	B

Means that do not share a letter are significantly different

III. DISCUSSIONS

A. Decay Severity

The results produced by the data on decay severity of tomato fruits stored at 8ºC 18ºC and 28ºC demonstrated that, there was significant difference in decay on the first six days. However the results obtained from the statistical analysis on decay severity of tomato fruits stored at 8ºC 18ºC and 28ºC demonstrated that, there were no significant differences in decay severity of produce on day 8 and day 10 of the experimental period (Table 4.1 to 4.3). The difference in decay of produce for the first six days may be attributed to microbial activities. In this research, the findings agreed with similar research which indicated that, tomato is often affected by Alternaria rot or Alternaria alternate and microbial activities that cause decay at higher temperatures [11, 5]. The differences produced by the results on decay severity could also be due physiological breakdown and natural ripening process. This statement agreed with earlier findings which indicated that, deterioration of fresh commodities can result from physiological breakdown due to natural ripening process, water loss, temperature injury, physical damage or invasion by microorganisms [18, 19]. The differences produced by the results on decay severity as storage period proceeds could also be due improper handling of produce at storage. This statement agreed with earlier statement which demonstrated that injuries that are visible on fruits and vegetables are caused by mishandling or other cause which leads to cracks, bruises, cuts or abrasion which makes the produce not attractive and also less remarkable [10]. The difference in decay of produce may also be attributed to the nature of the storage devices.

B. Peel Colour appearance

The result produced by statistical analysis on colour changes of tomato fruits stored at 8ºC 18ºC and 28ºC demonstrated that, there was no significant difference in colour on day 2. However the results obtained from the statistical analysis on colour changes of tomato fruits stored 8ºC 18ºC, 28ºC demonstrated that, there were significant differences in colour of produced on day 6, and day 8 of the experimental period (Table 4.1 to 4.4). The difference in colour of produce may be attributed to, the storage period and low relative humidity. In this research, the findings agreed with similar research which indicated that, no significant influence on colour, and texture was observed on tomato fruits stored at 18ºC and 28ºC after 2 days at storage [20]. The differences that were observed on the results could also be due to storage temperature which confirmed the findings reported by [2]. which demonstrated that fruits stored at temperatures higher than 8ºC are most likely to record a low average in terms of colour. The differences produced by the results on colour changes as storage period proceeds could also be due to the characteristics of control sample without any protective skin. This statement agreed with earlier statement which demonstrated that tomato fruits stored as control are vulnerable to discoloration because of damaged cells and tissues, and lack of protective skin [17].

C. Percentage Weight Reduction.

The results obtained from the statistical analysis on percentage weight loss of tomato fruits stored at 8^{O}C, 18^{O}C and 28^{O}C indicated that, there were significant differences in weight loss of tomato fruits stored at 8^{O}C, 18^{O}C and 28^{O}C from day 2 to day 10 of the experimental period. (Figure 4.1 to 4.4). The factor that may have accounted for the results obtained could be respiration rate. In this research, the findings confirmed earlier research which demonstrated that, rise in temperature increases respiration rate substantially which leads to dehydration resulting in weight loss of tomato fruits stored in a cooler [26,24]. Also [15] demonstrated that in most vegetable products, when the external oxygen presence is low, there is decrease of respiration activity, which is attributed to reduction of oxidize activities, such as polyphenol-oxidase, ascorbate-oxidase and glycolic-oxidase. The difference in fruit weight loss increased as the storage periods proceeds. Which agreed with similar findings which demonstrated that, tomato fruits increased weight loss with storage [3]. The difference in fruit weight loss could be due to physical and chemical processes. The statement agreed with earlier findings which demonstrated that, a number of chemical and physical processes take place in vegetables during shelf storage also, quality of most fruits and vegetables is affected by water loss during storage, which depends on the temperature and relative humidity conditions [14].

D. Sensory Evaluations

The results obtained from the statistical analysis on sensory evaluation on consumer acceptance of tomato fruits stored at 8^{O}C, 18^{O}C and 28^{O}C was evaluated by 15 untrained panelists who indicated that, there were significance differences of tomato fruits stored at 8^{O}C, 18^{O}C and 28^{O}C of the experimental period. (Table 4.1 and 4.2). The difference in texture of the produce could be attributed to mishandling at storage. However, in this research, the findings agreed with earlier statement which demonstrated that tomatoes are highly perishable and very susceptible to mechanical damage [1]. The difference in overall acceptance of the produce could be attributed to the maturity stage. The findings agreed with earlier statement reported by [5] which demonstrated that, there was influence of tomato cultivar and maturity stage on the postharvest quality of tomatoes stored under different conditions.
Based on the results obtained on decay severity of tomato fruits store in Charcoal Evaporative Cooler and House Hold Fridge for an experimental period of ten (10) days, significant difference waere found with the use of Charcoal Evaporative Cooler and House Hold Fridge on Decay severity of fresh tomato fruits stored on day 2, 4 and 6 of the experimental period. However, no significant difference was found with decay severity of produce stored on day 8 and day 10 of the experimental period (Table 4.1 to 4.3) and therefore the first null hypothesis cannot be validated.

Also, the results produced no significant difference in colour on day 2 of tomato fruits stored with Charcoal Evaporative Cooler and House Hold Fridge, However the results obtained from the analysis on colour changes of tomato fruits stored at 8ºC and 18ºC, demonstrated that, there were significant differences in colour of produced on day 6, and day 8 of the experimental period (Table 4.1 to 4.4) and therefore the second null hypothesis cannot be claimed.

The results obtained on percentage weight loss of fresh tomato fruits store in Charcoal Evaporative Cooler and House Hold Fridge showed that, there were significant differences in weight loss of tomato fruits stored at 8ºC, 18ºC and 28ºC from day 2 to day 10 of the experimental period. (Figure 4.1 to 4.4) which demonstrated that the differences in weight loss was affected by storage temperature, relative humidity and respiration rate of fresh tomato fruits stored in Charcoal Evaporative Cooler and House Hold Fridge.

The fact that the performance trend of the experiment on the use of Charcoal Evaporative Cooler on storage of fresh tomatoes could reduce decay, average weight, colour and maintain freshness of tomato fruits, it can safely be concluded that, the storage of tomato fruits with Charcoal Evaporative Cooler to extend their shelf life for consumers would be appropriate in Wa municipality. However, this study has shown the effectiveness of a low cost, simplified and energy–free cold storage system constructed for perishable fruit and vegetables (tomatoes) thus making it appropriate for rural and small–scale storage of fruit and vegetables. Furthermore, the storage of fruit and vegetables inside the Charcoal Evaporative Cooler (CEC) extended the shelf life of the stored produce better than tomato fruits stored as control temperature.

IV. RECOMMENDATIONS

Based on the findings on the use of Charcoal Evaporative Cooler and House Hold Fridge in cooling and storage of fresh tomato fruits, the researchers will like to make the following recommendations.

i. Further research should be done to come out with appropriate technologies for cooling and storage of perishable produce such as fresh tomatoes to ensure its availability for consumers all year round.

ii. The storage temperatures of the produce could be varied from 8ºC and, 18ºC for produce stored with Charcoal Evaporative Cooler and House Hold Fridge respectively to different temperatures (7ºC and 13ºC) to ascertain the effects of various temperatures on quality of fresh tomato fruits.

iii. The sample size should be increased from 36 to 48 to allow for broader assessment of the treatment means

iv. The duration of storage of fresh tomato fruits should be extended from ten (10) days to fourteen (14) days to determine appropriate consumer acceptability.

v. Trials of this experiment should be undertaken at the peak of harvest to allow for the repetition of the entire experiment.

vi. Materials such as plastic sealing's should be avoided to prevent it from generating heat to stored fruits.

vii. Sacks spread on Evaporative Cooler floor should not be too wet to avoid microbial activities and early decay.

viii. Experiment should be conducted by placing CEC in the field to discover the field conditions.

ix. Different sizes of Charcoal should be placed in the cavity to discover how size could influence cooling.

x. Length of the post (stand) on which the CEC is mounted should be raised higher to avoid attack by pest.

xi. CEC should be used to test the efficiency on cooling on different perishable commodities.

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