Comparative Effect of Brick and Charcoal Made Evaporative Cooling Storage on Shelf Life of Tomato

Gutu Birhanu Oliy

Renewable Energy Engineering Team of Bako Agricultural Engineering Research Center, Oromia Agricultural Research Institute, P. O. Box 07, Bako, West Shoa, Oromia National Regional State, Ethiopia

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Abstract- Perishable agricultural product require great attention to sustain their supply on the market. For the lack of appropriate handling and storage, significant amount of product goes waste before it reaches market and consumption. During the peak production season, farmers are forced to sell the products at extremely low prices particularly for tomato because of lack of appropriate storage structure. Therefore losses can also be minimized by storing them at low temperature and high relative humidity environment. Low-cost or zero energy brick and charcoal made evaporative cooling chambers were constructed from local materials and research was conducted to evaluate performance of the storages. So, average based maximum and minimum ambient as well as room temperature variation at mid-day are 32.5 to 21.0 $°_C$ and 30.7 to 19.3 ^{0}c respectively whereas daily average based maximum and minimum bricks and charcoal evaporative cool chambers temperature become 26.2 to 17.0 ^{0}c and 24.4 to 17.0 ^{0}c respectively. Bricks cooling chamber reduced average daily temperature with ambient temperature that could be intercepted by minimum 4 ^{0}c to maximum 5.9 ^{0}c whereas charcoal cool chamber reduced temperature with minimum 4 ^{0}c to maximum 8.1 ^{0}c. Evaporative cooling chamber of bricks depicted maximum & minimum relative humidity of 94% & 66% whereas maximum & minimum relative humidity of charcoal storage and ambient relative humidity become 94 % & 70 %; 70% & 40% respectively. As the period of storage increased, rate of decomposition and losses increased slightly different in magnitude. For instance, at twenty days after storage cumulative decomposition and loss occurred in number with bricks and charcoal evaporative cooling chamber became 12.5%, 8.99%, 16 and 15 respectively.

Index Terms- *Storage, Tomato, Loss, Temperature & Humidity*

I. Introduction

Tomato (*Lycopersicon esculentum*) is one the most important and extensively grown nutritional vegetable in the world. It ranks next to potato and sweet potato in respect of vegetable production and widely cultivated in tropical, sub-tropical and temperate climates [1, 2]. In Ethiopia, tomato is mostly cultivated employing rain-fed and irrigation system in home garden and in the field for its adaptability to wide range of soil and climate condition of specific land. Local areas of Ethiopia have favorable agro-ecology that is suitable for growth of various crops and vegetables.

With aim of enhancing agricultural development, the government of Ethiopia is implementing a number of projects like small-scale irrigation scheme in supplement for rainfall harvesting. Small scale irrigation scheme is mostly implemented for off-season time in order to support on season production to ensure food security program thereby for market to improve living conditions of small holders.

As per the country in 2016/17, total area of land estimated to be covered by tomato farms was 6,299 ha with an estimated yield of 283,648 tones with rain-fed and irrigation system. Total an average production of country become 45ton/ha [3]. Oromia region contributes biggest share which account about 68% of total production with the remaining production coming from Amhara (9%), Tigray (5%) and Somali region (4%). According to Tefera and Tefera, 2013 [4] more than 254, 000 farmers are engaged in tomato farming practices.

Tomato production become lowers due to inadequate use of fertilizer, lack of adequate chemicals, knowledge gap in production and management techniques. At research station, average tomato yields can be as high as 40 tons/ha, 25 tons/ha at on-farm demonstration while national average yield is about 9 tons/ha [5].

In Western Shewa Zone, under rain-fed and irrigated production systems vegetables such as potato, onion, cabbage and garlic are dominant vegetables produced under rain-fed conditions, occupying 72% of the total area of vegetable production whereas 74% of irrigated vegetable land was allocated for potato, onion and tomato production [6]. Despite this the contribution of vegetable both for the diet and income generation in the region is insignificant.

The reasons are very vulnerable for pests and diseases infestation, lack of attention to product quality and prevention of physical damage, lack of market structure, as well as the lack of storage and packing facilities [6-8]. Unlike others, vegetable are highly perishable commodities which begin deterioration sooner harvested and most are prone to handling damage. Products damage can particularly be occurred through all stage of the chain from harvest to consumption. Generally handling damage is greatly underestimated due to mishandling do not appears until damage occurred. Unfortunately poor handling and storage can easily result in a total loss of products [9].

Existing market infrastructure, poor transport and warehouse facilities do not suit perishable nature of vegetables as a result quality of vegetables such as tomato and onion deteriorates. During the peak production season, farmers are forced to sell the products at extremely low prices particularly for tomato and onion because of lack of appropriate storage thereby farmers get discouraged from producing in the immediate subsequent season [6]. Thus considerable amount of tomatoes goes waste before it reaches for consumption or sold at a thrown away prices. Due to their highly perishable in nature 30- 35% of total vegetable production go waste during various steps of the post-harvest chain [2, 10].

An average estimated loss of tomato due to postharvest loss and low moisture stress in west Shewa are 82% and 68% respectively [6]. The main losses of tomato occurs at different stages of handling and transportation from rural to urban market [11]. Although local demand for preserves is strong & stable, producers don't draw much profits from the market. They have trouble getting rid of their tomatoes, not least because of inadequate preservation and processing units [12].

Postharvest losses can also be minimized by storing them at low temperature and high relative humidity environment [13]. Low temperature handling and storage have been described as the most important physical method for post-harvest loss control [14, 15]. Low temperature storage system can effectively extend shelf life of vegetables by minimizing major postharvest losses through arresting metabolic breakdown and fungal deterioration [9].

Evaporative cooling is an efficient and economical means for reducing temperature and increasing the relative humidity of an enclosure, and has been extensively tried for enhancing the shelf life of horticultural produce [16, 17] which is essential for maintaining the freshness of the commodities [18]. It is low-cost, low-energy and environmental friendly air conditioning system that operates using induced processes of heat and mass transfer where water and air are working fluids [19, 20]. This evaporative cool chamber has been proved to be useful for short term, on-farm storage of vegetables in hot and dry regions and helpful to small farmers in rural areas [18, 20].

So far in Ethiopia evaporative cooler was studied and able to reduce the ambient temperature throughout the day from a range of 23-43 to 14.3-19.2 ^{0}C with an increase in relative humidity from 16-79% to 70-82.4% on average, the temperature and relative humidity differences were 10.7C & 36.7% respectively [21]. However Adet Agricultural Research center had constructed bricks type evaporative cooling and employed for some fruits and vegetables. According to the test results, sweet orange and green paper was stored in evaporative cooling chamber for two month and three weeks with damage of less than 25% & 20% respectively [22]. Thus brick type and charcoal made evaporative cooling were constructed and evaluated for tomato which is recently emerging crop.

II. MATERIAL AND METHOD

LOCATION

Bako district was previously known for its major cultivation of mango and sugarcane. However today many farmers residing in district are practicing irrigation mainly for tomatoes, onion and sugarcane cultivation. Snice district has great potential for tomato cultivation owning offseason harvesting, the study was conducted in Oromia Agricultural Research Institute Bako Agricultural Engineering Research Center. The center is located in Bako Tibe District of West Shoa Zone, Oromia National Regional State, Ethiopia which is located at 250 km in the western direction from Addis Ababa on the main road via Nekemte. The altitude of the center is 1650 meters above sea level whereas latitude and longitude of study area is 9^{0}07'N and 37^{0}03'E respectively. The mean minimum and maximum air temperatures of the location becomes 25 & 32 ^{0}C respectively.

MATERIAL

Local materials such as bricks, riverbed sand, stone, polyethylene sheet, mesh wire, bamboo, charcoal and thatch were used for construction of required size of chamber. Technical instruments like digital hygrometer, thermocouples & beam balance were employed during testing.

METHOD AND CONSTRUCTION OF THE STORAGE

Conceptual design as well as sketching and design specification were committed or commenced with inclusive of material selection. Based on design, materials for the constructions of evaporative cooling chamber was properly identified and selected. Construction of required storages were continued and completed. Simple practices are useful for cooling and enhancing storage system efficiency especially in developing countries where energy savings may be critical [10]. Therefore appropriate cooling storage are required for on farm storage for vegetables for very remote and inaccessible areas so as to reduce losses.

Bricks and charcoal made evaporative cooling chambers were constructed for experimental test. Brick type chamber was made from bricks, cement and sand whereas charcoal chamber was entirely constructed from local materials. Construction of both brick and charcoal evaporative cooling chamber were proceeded as follow. At beginning floor of cool chamber that has 1.5m long and 0.8m width were made from brick as well as mixture of sand and cement for better basement for vegetable to be loaded in crate. And then double layer of walls that has 0.7m height were erectly built up. Four sided double walls have 7.5 cm cavity. These cavities were prepared to be filled with wet riverbed sand during experiment. Cooling chamber's top was covered with a lid made of grass and polyethylene sheet over a bamboo frame to protect tomato from sunlight and rain. For top cover case, fine mesh wire was tightly constructed or suited beneath top lid in order to protect the fruit from damage caused by rodents and others. Warm or wasted water was get rid of cavity through provided channel. Ultimately, all components get combined to build up complete feature of appropriate evaporative cooling chamber.

EVALUATION OF STORAGES

Each evaporative cool chamber has a capacity of storing one and half local standard box of tomatoes. Before storing the tomato, prerequisite data's particularly weight of tomato, volume of tomato, storage and ambient condition were collected & documented starting on loading day. Partially matured tomatoes were directly harvested from the farm and screening was made soon and separation of undamaged from damaged done earlier to storing them.

Since storage employs evaporative cooling where heat trapped from warmer pad, shelf life of stored product would be prolonged to better without significant decomposition &

deterioration. Maintaining respiration rate is so important phenomena, snice it directly influences storage performance more. Rate of respiration is mainly affected with temperature, relative humidity and surface area of containers. To proceed with test and to maintain cool chamber condition, initially all cavity had to be filled with river sand and then water was discharged over cavity every morning and evening to maintain the required temperature and humidity.

Then, healthy tomatoes was stored in all evaporative cool chamber in crates. Similar quantity of the products were kept in charcoal made storage chamber. The number and weight of products were recorded before storage and in the course of the experiment. Healthy products got replaced while shrunk or rot one get discarded. Loss of products was computed on number basis while Damage was estimated in weight. Therefore damage and survived tomatoes which determine storage performance were closely observed & data were being collected every day.
The relative humidity of the chamber would be maintained above 75% and monitored using a hygrometer. The cool chamber becomes more applicable where minimum and maximum room temperature is in between 22 to 27 ^{0}C, minimum and maximum atmospheric temperature is in between 10 to 30 ^{0}C.

III. RESULT AND DISCUSSION

Before storing begin, pre-requisite data's particularly on storage and surrounding condition were collected and recorded. Temperature and relative humidity of surrounding environment and storage were collected at day and night to characterize their daily status. As a whole, ambient temperature and humidity, temperature and humidity of storage, mass of damage and survived are among those important treatment collected to determine number of a day tomato get stored without inconsiderable losses occurred. Tomatoes were collected on 08 June 2018 and stored in both cooling storage by carefully recording important data.

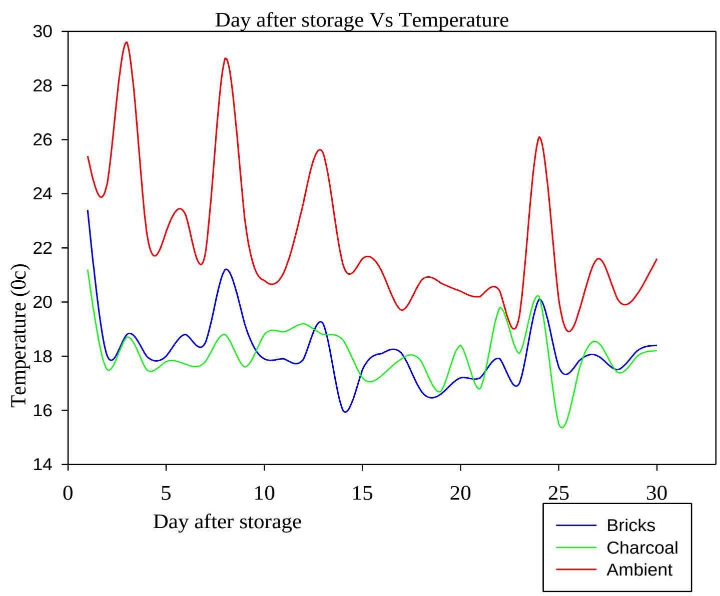

Figure 1:- Temperature variation during mid-day

Evaporation activity in cooling can lower the temperature of a container depends on wet bulb and dry bulb temperatures difference. In reality, though, while is not possible to achieve 100% of the theoretical maximum temperature drop, a substantial reduction in temperature is possible [16]. Therefore temperature variation have to be investigated in order to see performance of all cooling chambers.

Thus, average based maximum and minimum ambient and room temperature variation at mid-day are 32.5 to 21.0 $°_C$ and 30.7 to 19.3 ^{0}c respectively whereas daily average based maximum and minimum brick and charcoal made evaporative cooling chambers temperature become 26.2 to 17.0 ^{0}c and 24.4 to 17.0 ^{0}c respectively. Cooling chamber characterized with brick type reduced average daily temperature with ambient temperature that could be intercepted by minimum 4 ^{0}c to maximum 5.9 ^{0}c whereas charcoal cooling chamber reduced temperature with minimum 4 ^{0}c to maximum 8.1 ^{0}c.

According to Saltveint, 2005 & Irtwange, 2006 [23, 24] respiration is mostly affected temperature, atmospheric composition, physical stress and stages of development. Ambient temperature can directly affect or influence respiration and metabolic rates. Respiration rate of agricultural product become higher and shelf life of stored commodities get shorter under ambient temperature ranging from 25 to 35 $°_C$ [10]. If the temperature of surrounding area goes beyond the range, deterioration of tomatoes began unless relative humidity get maintained. Thus temperature control is one of the most important factors in maintaining product quality, throughout the period between harvest and consumption [25].

Burzo 1980 [26] determined average values of respiratory activity of several vegetables at 0 ^{0}c and recorded that the respiratory activity increased much as temperature get increased. He concluded that 0 to 30 ^{0}c an increased in temperature causes an exponential rise in respiration rate. According to Mangaraj & Kumar 2009 [27] an averaged values of respiration rate of tomato was estimated to be 10 times at 5 ^{0}c, 15 times at 10 ^{0}c, 22 time at 15 ^{0}c, 35 times at 20 ^{0}c and 43 time at 25 ^{o}c. As can be seen from this literature increasing temperature of chambers increases metabolic rate which inversely decrease shelf life of tomato. Intensive respiration activity of tomatoes was found to be varying greatly depending on variety, maturity and onset of climacteric respiration [27].

Tano 2007 [28] studied effects of temperature fluctuation on quality of mushroom and matured green tomatoes. They found temperature fluctuation had a major impact on composition of the package atmosphere and on product quality. Quality of the products stored under temperature fluctuation regime was severely affected as weight loss, loss of ethanol on plant tissue, and infection due to physiological damage as compared to products stored at constant temperature.

Therefore to prolong or extend shelf life of any vegetable proper storage practices which include temperature control, relative humidity and maintenance of space between products must be asserted. One way of increasing shelf life of a product can achieved by storing them at low temperature and high relative humidity conditions. These conditions are usually achieved in cold storages. For storage losses are mainly caused by the processes like respiration, evaporation of water from the tomato, spread of diseases, changes in the chemical composition, physical properties and extreme temperature. Moreover storage life of a product varies with variety and pre-harvest conditions like quality and maturity.

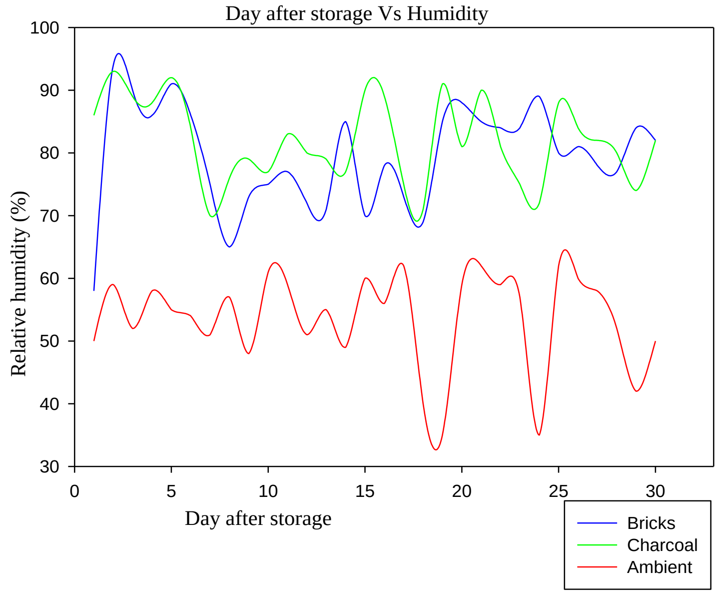

Figure 2: Humidity variation during mid-Day

In order to extend product shelf life, relative humidity and temperature maintained. When high relative humidity accompanied with low temperature storage achieved better shelf life. However high relative humidity and high temperate in combination favors the growth of fungi and bacteria to cause infection on stored products [9]. Cooling efficiency, temperature drop and increase in relative humidity inside the cool chamber largely depends on operating parameters. According to heat transfer application heat goes from higher to lower temperature. When water is added in cavity, the water trap heat from product stored and the storage get cooled. As soon as warm water get evaporated from tomato surface, the storage get cooled.

Both brick and charcoal made evaporative cooling chambers were evaluated parallel in order to investigate their cooling effectiveness of the storage. Accordingly brick and charcoal evaporative cooling chamber depicted maximum & minimum relative humidity of 94% & 66% and 94 % & 70 % respectively. Whereas maximum & minimum relative humidity of ambient air become 70% & 40%. Relative humidity of both evaporative cooling chambers were properly maintained as compared with many literature.

At high relative humidity and low temperature, according to Odesola & Onyebuchi, 2009 [16] agricultural products maintain their weight, wilting and softening are reduced and rate of water evaporation is low and therefore cooling is low. However maintaining high humidity only around harvested produce reduces water loss, which would result in decreased returns through poor quality which mean wilting and loss of saleable weight [10].

As water evaporates from a surface it tends to raise the humidity of the air that is closest to the water surface. If humid air remains in place, the rate of evaporation will start to slow down as humidity rises. On the other hand, if the humid air and the water surface constantly been moved away the rate of evaporation will either remain constant or increase. The greater the surface area from which water can evaporate, the greater the rate of evaporation [16].

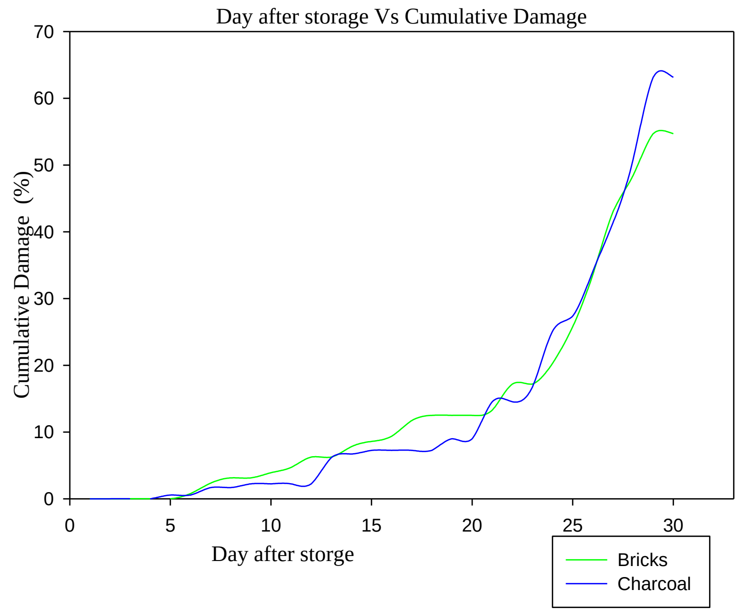

Figure 3: Cumulative Damage of Tomato

As the period of storage increased, rate of decomposition and losses increased slightly different in magnitude. For instance, at twenty days after storage cumulative decomposition and loss occurred in both brick and charcoal made evaporative cooling chamber become 12.5% and 8.99% respectively. Loss due to damage and decomposition of the tomato were mainly caused as a result of mechanical injury, rough handling and packing, transportation from field in to storage and respiration processes.

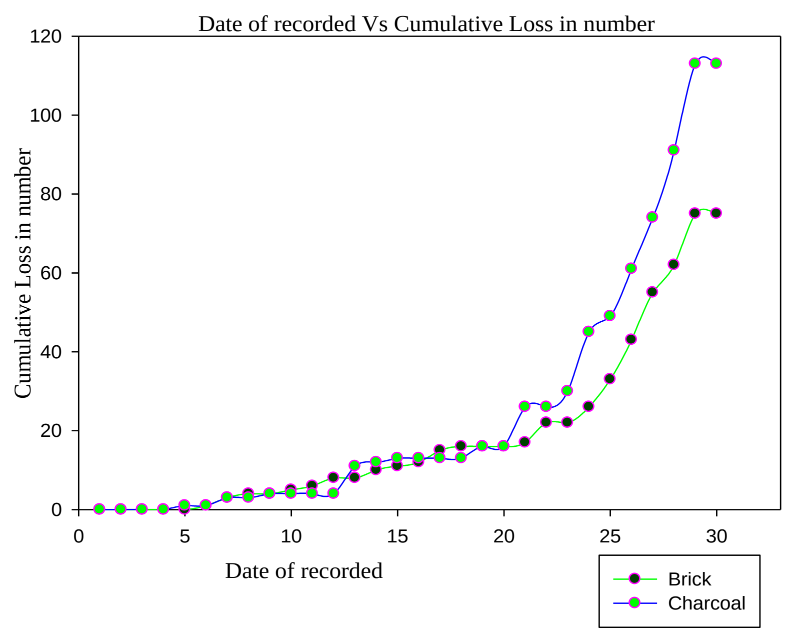

Figure 4: Comparison of the storability of tomato in cool chambers

Charcoal made storage is still better in extending shelf life and minimizing losses occur in storage when compared with the remaining cooling storage. This cooler has more water holding capacity and retain better air recirculation in the system. Until twenty three days cumulative losses of tomato was not above 20% and can tolerably loss occur. Surviving rate is reverse of cumulative losing of tomato. Charcoal made evaporative cooling chamber reveals more surviving rate and minimize losses as compared to other storage. Surviving rate of charcoal cooling chamber became above 90% until twenty days where as brick made enable to survive above 88.35% until twenty day.

IV. CONCLUSION AND RECOMMENDATION

It is observed that while experimental test, some parameters are involved to determine tolerably storage day & quantity of tomato. In addition to temperature and relative humidity, damage and loss of tomato have great contribution in order to decide shelf life of tomato. Therefore, physical damages can be minimized or reduced by taking care during transportation from field to the storage and harvesting time whereas losses caused due to microbial infection can be minimized by dropping evaporation rate & avoiding contact of water from product. However, maintaining temperature and relative humidity of cooling chambers must be done to make appropriate media to store agricultural produces more storage day. Maintaining the cooling chamber is more impressive. Moreover amount of water applied and frequency of irrigating the chamber are other important factor. These all parameter significantly influenced shelf life of stored agricultural produces in cooling media. As can be seen literatures and observed from our experiment, increasing temperature of chambers increases metabolic rate which inversely decrease shelf life of tomato. Both brick and charcoal evaporative cooling media have prolonged shelf life of tomato for tween three days with losses less than 20 %. As day of storage increased further, cumulative losses of tomato stored in charcoal storage became smaller and grown slowly when compared to brick type. Beyond these days both evaporative cooling store becoming not as such important, since losses occurred is not easily manageable. Therefore with above stated gab, charcoal evaporative cooling chamber can be recommended for storing of tomato to extend shelf life thereby to sustain availability of product over market at peak period.

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Corresponding Author:- Gutu Birhanu Oliy, Department of Renewable Energy Engineering, Bako Agricultural Engineering Research Center Oromia Agricultural Research Institute, gtbr2006@gmail.com or baerc2007@gmail.com contact number; Mobile number +251913357962, Office Fixed Telephone number +251576650045.