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Comparative Study of the Performance of Kiln-Fired Brick and Mud block Zero Energy Cool Chambers in the Northern Region of Ghana

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Abstract: *Most horticultural crops including fruits and vegetables begin to deteriorate shortly after harvest. Refrigerated cool storage is considered the best method for storing fruits and vegetables even though it is highly energy intensive and requires huge initial capital investment. An evaporative cool chamber does not require mechanical or electrical energy input and can be constructed with locally available materials like fired kiln bricks using unskilled labour. It is economical and can store the fruits and vegetables for 3 - 5 days with no significant losses. The objective of this research was to evaluate the suitability of Zero Energy Cool Chambers constructed using fired kiln bricks and mud blocks as a short-term storage facility for fresh vegetables in the dry season in Northern Ghana. A comparative study was made for the storage of okro, jute mallow, tomato and amaranth using the cool chambers and a room at ambient conditions as treatments. Temperature and relative humidity measurements were taken three times daily in the chambers, in the surrounding environment and at room condition. Vegetable samples were measured for temperature and physical quality parameters such as freshness, colour and weight loss. Results show that the physical characteristics required for the determination of market quality of vegetables kept inside the chambers were fresh and marketable within 5-7 days of storage than those held in the room at ambient conditions. The study concludes that the chambers were more comparatively efficient in minimising post-harvest losses for short-term storage of vegetables due to the ability of the chambers to keep produce fresh with minimum changes in colour and weight.*

Keywords: *Kiln-fired brick, mud block, evaporative cooling, vegetables, temperature, humidity, storage, postharvest losses*

INTRODUCTION

Most horticultural crops including fruits and vegetables begin to deteriorate shortly after harvest. Refrigerated cool storage is considered to be the best method for storing fruits and vegetables. However, this method is not only highly energy intensive but also involves huge initial capital investment (HRD, 2013).

Horticultural produce are stored at lower temperatures because of their highly perishable nature. There are many other methods for preserving vegetables and fruits which include canning, freezing, drying and pickling but these approaches tend to change the overall texture of the product. Hence, preserving horticultural produce in their fresh form requires that the chemical, bio-chemical and physiological changes are restricted to a minimum by close control of space, temperature and humidity (Basediya *et al*., 2013).

One of the greatest challenges facing the agricultural sector in Ghana is that of post-harvest-losses, which accounts for about 30 per cent of the country's yearly food production and hence is a major threat to food security (FBSD, 2013). According to Appiah and Dari (2013), the factors that induce spoilage of vegetables like tomatoes and amaranth production in Northern Ghana include: lack of storage facilities, lack of ready markets for perishable produce, lack of awareness and technical know-how in simple post-harvest handling and technologies, lack of financial support, for investment in cold storage.

Different storage strategies have been promoted to help curb losses after harvest with a focus on less expensive strategies such as the brick and sand evaporative cooler (Acedo, 1997; Vanndy, 2008). The Zero energy cool chamber (ZECC) is a type of brick

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and sand cooler and is an eco-friendly storage system which does not require electrical energy. The low inner temperature and high relative humidity maintained by the ZECC are based on the standard principles of a passive evaporative cooling mechanism. Heat moves from the higher temperature of the air and brick walls to the lower temperature of the moistened sand and zeolite mixture due to convection and conduction, respectively. During this convection process the surrounding temperature decreases and reduces the temperature in the ZECC. This cooling effect of evaporation, lowers the inside temperature of the ZECC (Islam *et al*, 2012). The temperature is normally lowered by about 5 - 10°C depending on the relative humidity of the ambient air. The observed lower temperature stems from the combined effect of underground temperature, the moist inner walls which cools the chamber.

This research compared a ZECC constructed using kiln-fired bricks with that made from mud blocks with the following composition, gravel (40%), sand (40%) and silt (20%) and open sun dried for seven days in the quest for the selection of appropriate local construction material at an affordable cost for small scale farmers in the study region characterized by a Sodano-Sahel agro-climate. The mud blocks formulation was selected because mud blocks are used in the locality for domestic dwellings and so are cheaper and readily available. The kiln-fired bricks though recommended are not locally available in the Region and are thus expensive. To the best of our knowledge no such comparative study has been undertaken within the Ghanaian context and by extension in other sub-Saharan African countries for horticultural produce.

MATERIALS AND METHODS

Study Area

The study was carried out at the experimental farmstead of the University for Development Studies, Nyankpala, Tamale in the Northern Guinea Savannah agro-ecological zone (latitude 0° 59'W and 9° 24'N). The climate is warm, semi-arid with total annual monomial rainfall of about 1022 mm, which falls mainly between May and September each year. This short rainfall season is followed by a pronounced dry season between October and April. The temperature distribution is uniform with a mean monthly minimum value of 21°C and maximum value of 31 °C and relative humidity of 53% - 80% (SARI, 2004).

Experimental Treatments

The research project was established to compare the storage of vegetables in two types of evaporative cooler chambers; one constructed using kiln-fired bricks and the other constructed using locally sourced mud-blocks. These chambers were used as storage treatments in comparison with storage under standard room conditions and used as a control for the storage of tomato (*Solanum lycopersicum*), jute mallow (*Corchorus olitorius*) locally known as "*Ayoyo*", amaranth (*Amaranthus* spp) known locally as "Alefu" in Northern Ghana and okro (*Abelmoschus malvaceae*). Two local varieties of tomato were used for the experiment and single varieties for the other crops. All storage treatments were in duplicate and trials run two times with each variety being replicated four times.

Construction of ZECC, Data Collection and Analyses

An-upland having a nearby source of water supply was sited. The ground was levelled and an evaporative cooling chamber constructed. The constructed cooling chamber had a double wall with a height of 60 cm and wall cavity of 10 cm. The dimensions of the outer and inner brick walls were 170cm × 170 cm × 60 cm and 160 cm × 160 cm × 60 cm, respectively. The 10 cm gap between the outer and inner wall was filled with sea sand and a perforated water hose laid on the sand to facilitate the sprinkling of water onto the sand to moisten it. A standard water hose was connected to a water source which supplied 25 litres of water at each sprinkling session, thrice a day. A thermal insulating cover made from straw and thatch measuring (L×W) 170 cm × 170 cm was used to cover each chamber. A thatch and straw shed was erected over the chambers for protection from direct sun radiation, rain and predators.

Data was collected on wet-bulb and dry-bulb temperatures which were used on a psychrometric chart to determine the relative humidity in the chambers, under the shed and at room condition. Weight loss of stored vegetables were obtained by daily weight measurements and expressed as a percentage.

Loss in market quality was determined physically using 20% of surface damage, rotting for fruits such as tomato, necrosis and loss of green pigment in leafy vegetables and okro using the initial physical characteristic of vegetables as benchmark. Data was analysed using Minitab version 16 and significance determined using T-test.

RESULTS AND DISCUSSION

Zero Energy Cool Chambers

Two zero energy cool chambers were constructed using kiln-fired bricks and mud blocks for the storage of fruits and vegetables and are as illustrated in Figure 1 below. Tomato, okro, amaranth and jute mallow were stored in the chambers and room storage used as control

Daily Weight Loss

The daily percentage weight lost in stored vegetables is indicated in Table 1. All produce in the chambers had a shelf-life and market quality of between 4 - 7 days while vegetables in the control produce had a reduced shelf-life and market quality from the third day especially for the leafy vegetables which were shrivelled and had started browning. There were significant differences between treatments for okro and the control treatment on the fourth day had lost about half (50%) of its green pigment and had become fibrous as shown in Figure 2 below. At a p-value of 0.05, there were no statistically significant differences between treatments per weight for amaranths although visual observations indicate there were differences in the physical market quality evaluation.

Figure 1: Fired brick (left) and Mud block (right) Zero Energy Cool chambers

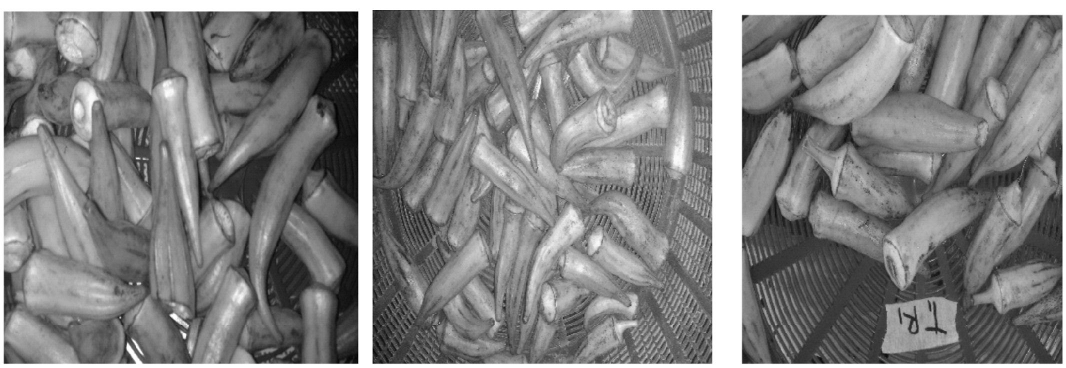

Figure 2: Evaluation of Okro market quality from the second to the fourth day in storage

Figure 3: Evaluation of Amaranth market quality from the second to the fourth day in storage

Figure 4: Evaluation of Jute mallow market quality during the period of storage

Figure 5: Evaluation of Tomato market quality during the period of storage

Even though there were variations in the weight, there were no statistically significant differences between tomato treatments for percent daily weight loss. The samples in the room storage however, had more fruits damaged beyond the estimated 20% surface damage and this could be attributed to the temperature and humidity at the time of storage. There were statistically significant differences for all jute mallow treatments where it can be seen that the room stored leaves had much higher weight loss.

Daily Temperature and Humidity Readings

Daily temperature (dry and wet) and humidity in the storage facilities, under the shed and in the storage room were taken for the assessment of variation within chambers to determine if the chambers have desired conditions for the storage of produce. Ten days temperature and relative humidity readings from the storage facilities are as indicated in Figure 6 and Figure 7 below.

From the dry temperature and relative humidity results, both chambers provided lower temperature ranges for the storage of vegetables compared to the control. Relative humidity figures for both chambers

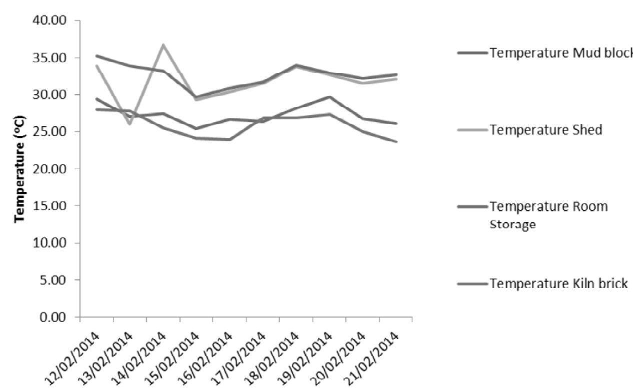

Figure 6: Ten days mean Temperature of storage areas

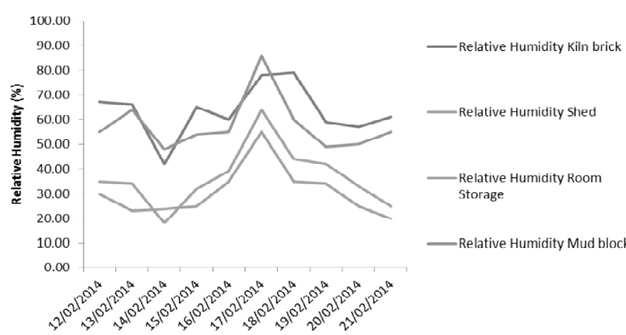

Figure 7: Ten days mean relative humidity of storage areas

were close to optimum for the selected vegetables compared to the control. This result indicates that both chambers created a cooler environment for the produce which could contribute to a longer shelf-life and also promote improved market quality.

CONCLUSION

Environmental conditions such as temperature, relative humidity, storage type and duration of storage influenced the physical changes of vegetables. The ZECC was able to maintain relatively low inside temperature and high relative humidity as compared with outside temperature and relative humidity. Temperature inside the chambers was reduced through the ability of the bricks to absorb of moisture and the prevailing wind which facilitated the process of evaporative cooling within the chamber. Very dry, low humidity air can absorb a lot of moisture so considerable cooling occurs. This evaporative process was aided with the sprinkling of water (25 l) into the sand in the cavity of the chamber thrice a day. The use of local shading material for the shed also protected the ZECC against direct exposure to solar radiation.

The research concluded that both chambers were more efficient in minimising post-harvest losses for short term storage of vegetables compared with room storage at ambient conditions which is the common practice. The factors that enhanced the operation and the efficiency of this type of evaporative cooling chamber was the ability of the brick/block (s) to absorb more moisture from the moistened sand, resistance to rodent attack and mechanical impact; conditions which the mud block chamber also offered but with limitations. The kiln-fired bricks have a shelf-life of three years while the mud block lasted three months because of surface and particle disintegration due to the regular moistening and gnawing of the blocks by rodents.

Table 1
Percentage daily weight loss of stored vegetables

Crop	*Day*	*Room Storage*	*Kiln brick*	*Mud Block*
Amaranth	2	15.60[a]	11.10[a]	19.20[a]
	3	24.40[a]	13.00[a]	23.40[a]
	4	nill	15.20[a]	31.90[a]
Tomato	2	5.00[a]	0.80[a]	1.69[a]
	3	14.17[a]	5.78[a]	6.78[a]
	4	15.00[a]	9.01[a]	8.47[a]
	5	18.30[a]	18.18[a]	16.95[a]
	6	19.20[a]	19.00[a]	17.79[a]
	7	21.70[a]	19.83[a]	19.49[a]
Jute Mallow	2	27.80[a]	9.10[b]	10.50[c]
	3	44.40[a]	6.10[b]	5.30[c]
	4	nill	9.10[a]	10.50[b]
	5	nill	12.10[a]	15.80[b]
Okro	2	25.50[a]	6.40[b]	6.10[c]
	3	37.30[a]	4.30[b]	8.20[c]
	4	49.00[a]	8.50[b]	14.30[c]

* Means in the same row with different superscripts are significantly different

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