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Impact of evaporative cooling preservation on the shelf life of fruits and vegetable in South Western Nigeria

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Abstract

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Maintaining the freshness of vegetables and fruits even for a short period in a tropical environment is difficult. Fresh fruits and vegetables usually deteriorate faster than other products because they increase in respiration while in storage, due to high moisture content and high tropical heat which lead to a number of physical and physiological changes affecting the viability, quality and marketability of the produce. The use of evaporative cooling system showed improvement in the shelf life of fruits and vegetables stored. The stored vegetables in the cooler showed higher moisture and vitamin C content while the withered control has higher ash, protein, fibre and carbohydrate content. However, the fruits stored in the cooler had lower vitamin C and higher moisture than the control which showed good quality and crispiness while the control deteriorated at the same period. The results suggest that the integration of evaporative cooling system with good sanitation along the marketing channel from the harvest point until the consumption point will help to attain high quality level of freshness for some period.

Keywords: environmental friendly; refrigeration; freshness; cold storage; food quality

The use of evaporative cooling in lowering the temperature of ambient air and improving the relative humidity of the draft air is very old (Watt 1997). Its application has generated a lot of research especially in the temperate region of the world mostly for house cooling (Otterbein 1996). This is due to environmental friendliness and high energy efficiency ratio over compressed air-conditions (Xuan et al. 2012). However in the tropical environment with its high solar load it has not been fully exploited, despite the fact that any marginal decrease in the ambient temperature in a tropical environment will have a very great cooling effect. This is because it has been suggested that the use of evaporative cooling for house cooling in the tropical environment would introduce a lot of moist air into the building which would lead to some discomfort since the greater part of the year is wet and very humid. Therefore, research is moved towards the application of evaporative cooling system in fruit and vegetable preservation since this requires lower temperature and high humidity (Anyanwu 2004; Jain 2007; Ndukwu 2011). The working fluid in evaporative cooling is wa-

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ter. When water evaporates it draws energy from its surroundings, which produces a considerable cooling effect. Evaporative cooling occurs when air which is not too humid passes over a wet surface. The driving force for heat and mass transfer between air and water is the temperature and partial vapour pressure differences (Xuan et al. 2012). Due to the humidity difference of the incoming air in contact with water, water absorbs the heat from the incoming air, thereby lowering its temperature and increases its humidity. The sensible heat from the air is then converted to the latent heat and the water uses it to evaporate (Watt 1963). This non-saturated air cooled by heat and mass transfer process is forced through wet surface (cooling pads) by natural convention (passive cooling) or utilizing blowers or fans (active cooling). The wet cooling pad is replenished with water from the water reservoir. The effectiveness of this system is defined as the rate between the real decrease of the dry-bulb temperature (DBT) and the max. theoretical decrease that the dry-bulb temperature could have if the cooling were 100% efficient and the outlet air was saturated (Xuan et al. 2012). Practically, wet porous materials or pads provide a large water surface in which the air moisture contact is achieved and the pad is wetted by dripping water onto the upper edge of vertically mounted pads (Wei, Geng 2009) which drips down by gravity. In the tropics large amount of fruits and vegetables is lost after harvest due to high temperature which causes wilting of vegetables and assists in mould development in fruits. Some of them were even fade to animals or converted to farmyard manure. The fruit and vegetable farmers and sellers rush to sell their produce to avoid these problems, even at a ridiculous prize, which results in high financial losses if not quickly sold immediately after harvest. Because in most tropical countries, vegetable and fruits are sold in exposed trays, preserving them in the compression refrigeration is avoided because keeping tropical products too cool can pose a serious problem like chilling injuries. It is important to avoid chilling injury, since symptoms include failure to ripen (banana and tomatoes) development of pits or sunken areas (orange, melons and cucumbers), increase in respiration and susceptibility to quick decay once out of the refrigerator and development of off-flavours (Shewfelt 1994; Irtwange 2006). Any method that can delay the rate of deterioration of these products and maintain their quality and appearance, even in a short term, will help the farmers and sellers in orderly marketing of them. Therefore technologies that allow for a two or three fold extension of the shelf life are very important to decrease the food losses (Irtwange 2006); moreover, minimally processed fruits and vegetable are in high demand. Since 1983, the Food and Agricultural Organization of the United Nations has advocated the use of evaporative cooling in short term preservation (FAO 1983). This technique is yet to gain serious footing in developing countries despite the poor and costly electricity supply. Most developing countries depend on the use of mostly low power generator (about 1 kW) which can hardly energize a sizeable refrigerator but can power a sizeable active evaporative cooling system. The above socioeconomic problems have brought to the fore the alternative use of evaporative cooling system. Direct contact with farmers and sellers of vegetables and fruits has shown skepticism on the effectiveness of this method in preservation of products in a tropical environment like Nigeria. This research is therefore presented to douse this skepticism and highlight the effectiveness of this system in short term preservation of these products in a tropical environment, which can enhance the income of the operators in this area by preventing panic sales with attendant slash in prize. The research also shows the usefulness of this system in keeping products fresh and therefore can be integrated with good sanitation, proper handling and proper packing along the marketing channel from the harvest point until the consumption point to attain high quality level of fresh products at a small loss.

MATERIAL AND METHODS

Material. The products stored in the evaporative cooler were pumpkin, amaranth, water leaf, fairly ripped paw-paw and orange. The samples were immediately harvested from the farm and washed to remove dirt. Proper care was taken to avoid any mechanical injury which would hasten deterioration. The samples were weighed and it was ensured that each sample weighed more than two kilogrammes to have considerable quantity for evaluation. Visual pictures of the samples were also taken with digital camera (Canon, USA) to record the appearance before and after storage. An active evaporative cooler

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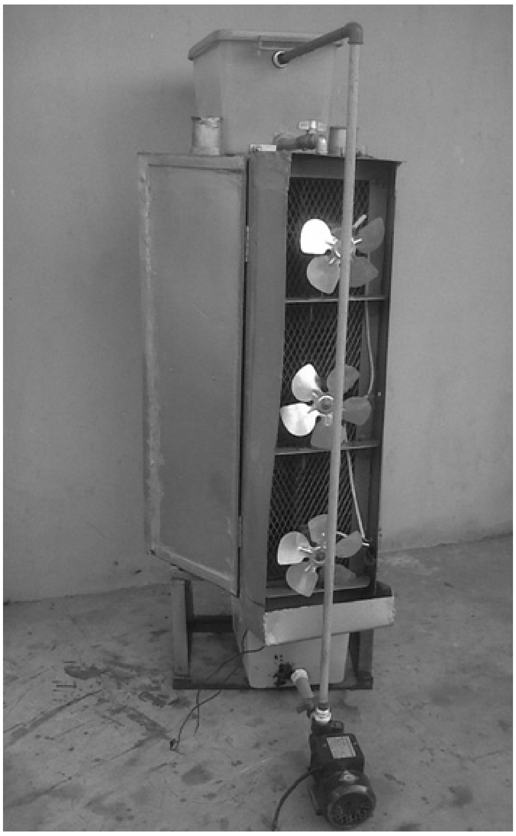

Fig. 1. Active evaporative cooling system

(Fig. 1) that uses palm fruit fibre as humidifier and incorporates automatic water recirculation system with a rated power of 0.37 kW, designed and fabricated at the engineering workshop of the Federal University of Technology Akure in the south Western Nigeria was used in the storage and evaluation of the various products. The evaporative cooler can be powered by 1 kVA generator.

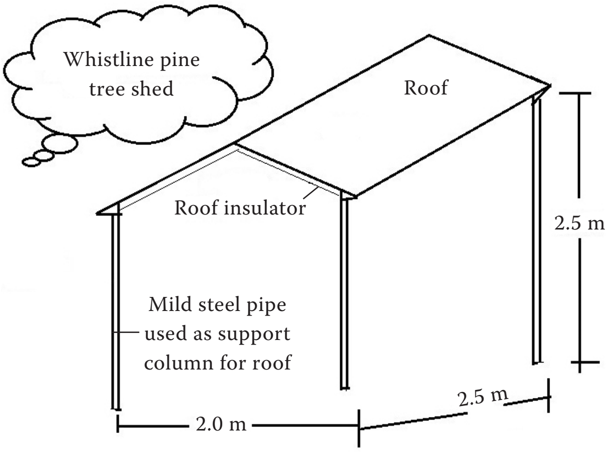

Fig. 2. Implement shed

Experimental procedures. The equipment used for the experimental evaluation:

- relative humidity sensor (ABS Humidity and temperature clock; DTH-82; TLX, Guandong China),
- temperature sensor (k-type thermocouple connected to omega data logger HH1147; Omega, Stanford, USA),
- air speed sensor (vane microprocessor AM-4826; Landesk, Guangzhou, China).

Vegetable and fruit storage. The evaporative cooler was located inside an implement shed (Fig. 2) built under a whistling pine tree. The implement shed consists of only the roof without walls but supported with mild steel pipes (Fig. 2). The roof of the shed was insulated with fibre from raffia palm. The shed and the tree protected the cooler from direct solar radiation and acted as a pre-cooler to the draft air before coming in contact with the humidifier.

The tests were carried out from January to June 2013; this period presented the extremes of the temperature within the year. At this period, there was rain for some days with high relative humidity. Also the period presented extremely low humidity of 28% and very high temperature of 45°C. Temperature and humidity clock was placed inside the shade. Before loading each product into the cooler for a test run, the water was allowed to re-circulate for 24 h with the fan switched on to make sure that the palm fibre is completely wet, otherwise it will create a hot spot were dry and hot air will enter the cooler. The test run for the vegetables was done differently from that of fruits because of the production of ethylene which is a ripening agent and may have an effect on the product, though this effect was not ascertained. Another set of experiment was mounted inside the shed as a control to look at visual and biological deterioration of the product. Measurement of dry and wet bulb temperature and relative humidity for the inside and outside of the cooler were made. A thermocouple measuring at four points was positioned through the hot wire terminals inserted into the cooling chamber. One of the terminals was covered with cotton wool soaked in the water to measure the wet bulb temperature (Anyanwu 2004). The inlet air speed was measured with vane microprocessor (AM-4826) digital anemometer (±0.1 m/s) placed between the fan and the pad at five different points across the pad. The average mass flow rate of the air across the pad calculated with continuity equation was 0.5 kg/s. The temperature and humidity clock

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(±0.1°C and 1.0%) was positioned inside the shed to record the temperature and humidity of the ambient air before it comes in contact with the cooling pad. Two analogue thermometers were inserted inside the tanks to measure the water temperature and ranged from 22 to 23°C. The data were logged every one hour. The relative humidity of the cooler was obtained from the psychrometric calculator. In addition, the wet bulb temperature of inside the shed and the ambient were calculated also from the psychrometric calculator (CYTsoft psychrometric calculator 1.0; CYTSoft Technology Inc). Visual image of the product was captured in the morning and evening each day of the experiment with a digital camera. Each experimental run lasted for one week in which the pad is removed washed and easily replaced in the pad holder to prevent mould growth and deterioration of the pad.

Proximate food analysis and vitamin C test. The proximate food analysis was carried at the laboratory of Food Science Department of the University based on the AOAC (1995) standard while the vitamin C analysis was done by the titrimetric method. The PH value, titratable acidity, moisture content and percentage of total soluble solid were also determined for all vegetable and fruits for both the product inside and outside the cooler. More than 1 kg of each sample was used for the analysis.

RESULTS AND DISCUSSION

Analyses of temperature and relative humidity variation for inside and outside of the cooler (inside the shed)

The results on the observation of some air properties for a typical three consecutive days (January to February 2013) are presented in Figs 3 and 4. Fig. 3 shows the hourly air properties of ambient air and cooler air. It is clear from Fig. 3 that at 13:00 hours (GMT + 1), the ambient air of 32.8°C temperature with 36% relative humidity could be brought to 23.2°C temperature and 90.4% relative humidity at the first day. The max. temperature drop observed was 13°C.

The relative humidity of the cooler was observed around 85.6–96.8% throughout the experiment, which shows the max. possible level of saturation of air by humidification. Xuan et al. (2012) noted that 100% relative humidity was not achievable in direct evaporative cooling systems because 100% saturation is impossible. This is because the pad is loosely packed, and the process air can easily escape between the pads without sufficient contact with the water. In addition, the contact time between air and water is not long enough which results that heat and mass transfer might be insufficient (Ditchfield et. al 2006). The cooler temperature was maintained at 23.2–25.8°C. During this period, the ambient temperature of the shade ranged from 29.9–37°C while the relative humidity ranged from 34–73%. It was observed that the lowest temperature drop of 4°C for the cooler occurred when the ambient relative humidity was highest at 73%.

For the May–June period of the test, the max. temperature drop for the cooler was 6.4°C while the min. temperature drop was 0.1°C as shown in Fig. 4. This is a result of the high humidity of the draft air (61–78%) which made it difficult for much heat to be extracted from it by the waters. However the cooler humidity was observed around 81–99% which is very high and adequate for preservation of fruits and vegetables. The adoption of active evaporative cooling system instead of the passive system contributed to the relative success achieved in this time of the year which otherwise would have been

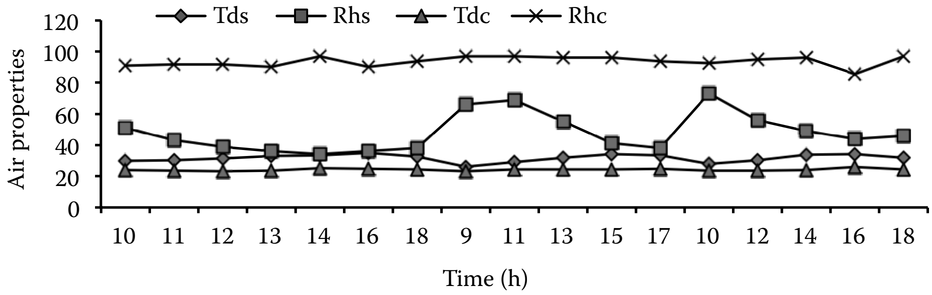

Fig. 3. Periodic variation in air properties for a typical three-day period in the cooler (January–February period)
Tds – dry-bulb temperature of air entering the pad (°C); Rhs – relative humidity of air entering the pad (%); Tdc – dry-bulb temperature of air leaving the pad (°C); Rhc – relative humidity of air leaving the pad (%)

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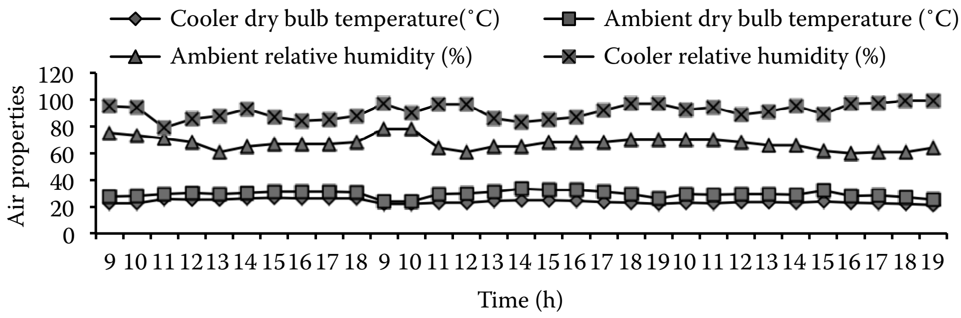


Fig. 4. Periodic variation in air properties for typical three-day period in the cooler (May–June)

a difficult period for evaporative cooling application. At the time of the experiment in May–June large natural air movement, which passive coolers depend on, are not regular, therefore the fans helps to drive the air towards the cooling pads. Also the solar load at this period of the year was not so high and this minimal drop in temperature with the high humidity of the cooler was able to preserve the fruits and vegetables for more than ten days.

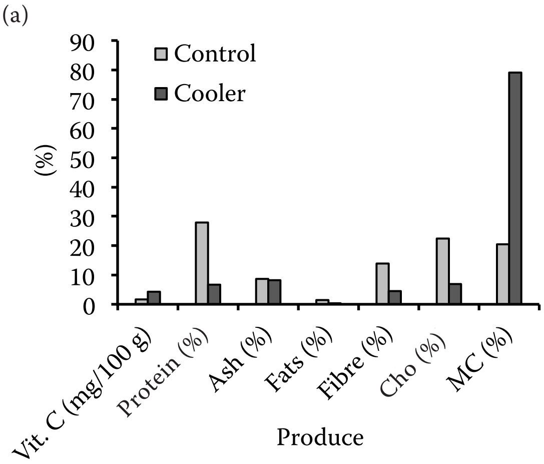
Freshness of preserved fruits and vegetables

The result of the food quality verification analysis for the vegetables in the cooler and the control is shown in Fig. 5 for January–February while that of May–June is shown in Fig. 6. In order to ascertain the quality of pumpkin leave and amaranths stored in the shed compared to those kept outside, food quality analysis was done on the seventh day of storage and the comparison was made on the moisture content, protein, carbohydrates, fat, fibre content and vitamin C as shown in Fig. 5 while the pH, acidity moisture content and percentage of total soluble solids was presented in Fig. 6.

The qualities of good vegetables are high moisture content, high vitamin C and low fibre content. Comparing these values for the stored products showed a great difference. For example the vitamin content for amaranths and pumpkin were 4.182 and 7.45 mg/100 g, respectively, while the corresponding control was 1.65 and 3.3 mg/100 g. It is a well-known fact that heat destroys vitamin C. Analysis of ANOVAs with two factors without replication shows a high significance at 5%. This shows there is a great difference for the two storage conditions.

However when the value of vitamin C is considered for fruits stored during May–June, the control has a higher value than those stored in the cooler as shown in Fig. 6. For paw-paw the value for the control was 60.774 ml/100 g while for the cooler it was 39.286 ml/100 g. This shows the delayed ripening of the fruits in the cooler as opposed to the overripen-

(a)



(b)

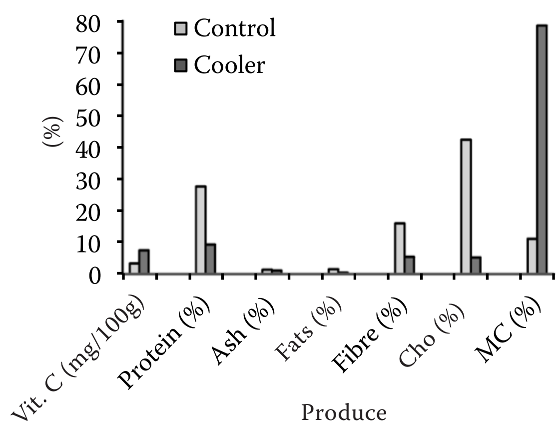


Fig. 5. Proximate food analyses and vitamin C of stored (a) amaranths and (b) pumpkin at 7 days (January–February)
Vit. – vitamin; Cho – carbohydrate; MC – moisture content

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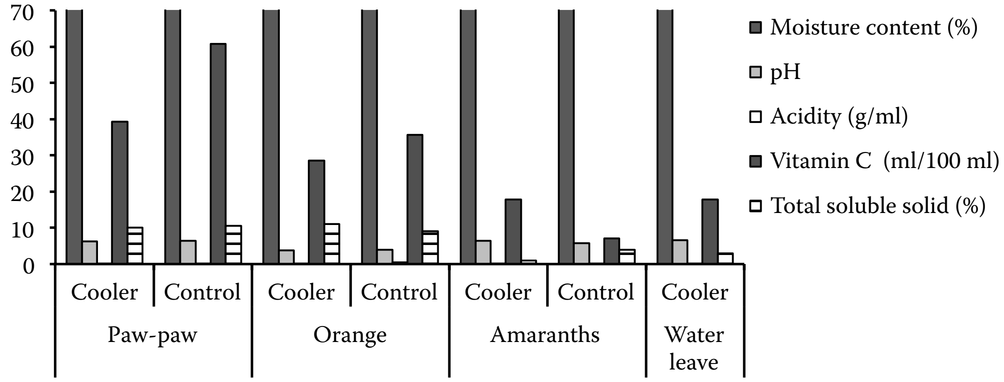

Fig. 6. Food quality analysis for stored products at 7 days (May–June)

ing of the control. This also showed that the cooler was able to reduce the rate of ethylene production which causes ripening and subsequent softening and deterioration in fruits. Also the vegetable in the cooler has higher vitamin C than the control. This is because of the wilting of the control as a result of heat which destroys vitamin C in vegetables. The values of titratable acid for the fruits are lower than those of the control while the reverse is the case for vegetables as shown in Fig. 6. The comparison of the palatability of the fruits and vegetables are shown on the moisture content values in Fig 6. The product in the fridge has higher moisture content than the control. Despite all the food verification analysis, the visual examination of the control experiment and the product stored in the cooler (Fig. 7) showed clearly the level of deterioration of the control experiment compared to the product in the cooler.

CONCLUSION

Vegetable and fruit products differ from other crops in terms of their physiology and respiratory activities. Maintaining their freshness even for a short period in a tropical environment is difficult. Fresh fruits and vegetables deteriorate faster than other products usually because they increase in respiration while in storage due to high moisture content which leads to a number of physical and physiological changes affecting the viability and quality of the products. Integration of evaporative cooling system with good sanitation along the marketing channel from the harvest point until the consumption point will help attaining high quality level of freshness for some period.

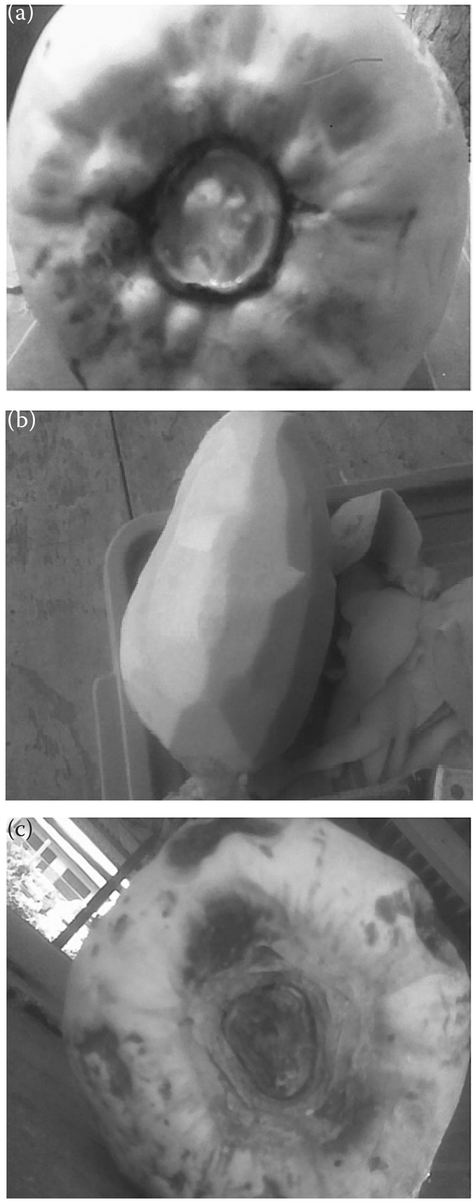

Fig. 7. Visual appearance of paw-paw at the 7th day of storage in the evaporative cooler (a) , (b) and (c) the control

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