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Zero Energy Cool Chamber for Extending the Shelf-Life of Tomato and Eggplant

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Abstract

A zero energy cool chamber (ZECC) consisting of a brick wall cooler and a storage container made of new materials has been developed. The ZECC requires no electric energy. The brick wall cooler made of bricks with a mixture of moistened sand and zeolite allows low inside temperature and high relative humidity to be maintained based on the principles of a natural evaporative cooling mechanism. Several types of storage containers coated with different antibacterial materials were applied to reduce decay. For example, silver-ion-coated storage containers were used to reduce decay. Heat treatment was also applied to the commodities in order to maintain freshness. Generally, tomato and eggplant had a shelf life of 7 and 4 days at room temperature, respectively, as compared to 16 and 9 days when stored in the ZECC. Tomato and eggplant treated with hot water reduced the percentage of rotting. Tomato treated with hot water at 60°C for three minutes and eggplant treated with hot water at 45°C for an hour when stored inside silver-ion-coated containers in the ZECC showed extended shelf life of up to 28 and 15 days, respectively.

Discipline: Food
Additional key words: inside temperature, postharvest loss, relative humidity, shelf life, storage

Introduction

Fresh fruits and vegetables generally need proper postharvest management to reduce loss and maintain quality. Today, the postharvest handling practices regarding vegetables throughout the marketing channels in most developing countries remain inadequate. The growers have no storage facilities, while the transport and marketing channels also lack storage facilities. As a result, most harvested fruits and vegetables are usually stored in the open, exposed to high temperatures and low relative humidity conditions, until a middleman, wholesaler or retailer purchases those commodities.

The quality of fruits and vegetables, and related shelf life are reduced by the loss of moisture, decay and physiological breakdown, and such deterioration is directly related to storage temperature, relative humidity, air circulation, mechanical damage, and improper postharvest sanitation[13]. For example, the rate of postharvest loss regarding tomato and eggplant taken from farmers' fields to the consumer in Bangladesh is as high as 26 per cent[1,30]. Despite the recent trend toward the increased production of vegetables in Bangladesh where the average national per capital consumption of leafy vegetables is 23 g, along with 89 g of non-leafy vegetables, and 14 g of fruits, the average Bangladesh only consumes a total of 126 g of fruits and vegetables daily. This is far below the minimum daily consumption of 400 g of fruits and vegetables as recommended by FAO and the World Health Organization[17]. World food prices have also recently increased due to natural disasters worldwide. Thus, preserving the fruits and vegetables produced is now a common issue in most developing nations. High food prices are a major concern especially for low-income food deficit countries that may face problems in financing food imports, and for poor households that spend a large portion of their income on food[12].

The combination of higher humidity and lower temperature facilitates extended shelf life. These conditions can be achieved by using a semi-underground storage system with moistened walls. The use of a shading curtain is also an effective means of reducing temperature. Higher humidity and lower temperature inside the ZECC offers a unique advantage for maintaining the firmness of fruits and vegetables by lowering the physiological loss in weight (PLW) and other metabolic processes[26].

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However, higher humidity inside the cool chamber enables the growth of microbial activities and also adversely affects the quality of stored fruits and vegetables[25,26].

Many types of antibacterial and antifungal containers have recently been developed to inhibit the deterioration of fruits and vegetables during storage. Silver and copper have been widely used since ancient times to fight infection and control microbial contamination[5,24]. The antibacterial activity of silver depends on the release of Ag ions. Some studies have reported that silver ions cause irreversible structural changes in bacterial cell membranes, thereby drastically affecting the functions of permeability and respiration[8,21]. Therefore, the use of a new storage container coated with an antimicrobial such as Ag^{+} will reduce the spoilage of storage fruits under higher humidity in the ZECC.

Heat treatment has been also reported to improve product quality and shelf life due to the effect of heat shock proteins[25,26,27,31]. Heat treatment inhibits ethylene synthesis, cell wall degradation, and insect pests[5,22]. Hot water treatment is suggested for eggplant and tomato to kill anthracnose and other bacteria or pathogens[15,16]. A comparative study was conducted to determine how to improve the shelf life of tomato and eggplant using silver-ion-coated containers, hot water treatment, plastic crates, and copper grain. It was found that after hot water treatment, tomato and eggplant stored inside silver-ion-coated containers in the ZECC could increase their shelf life longer than those stored inside copper grain or plastic crates. A ZECC using this new storage method will give farmers an opportunity to obtain fair prices from the middleman, and also improve their household nutritional and economic conditions by storing fruits and vegetables for a longer time.

In this study, a ZECC consisting of a brick wall cooler and a storage container coated with antimicrobials was developed, and then tomato and eggplant were stored inside it for extended shelf life by controlling watering and the shading curtain.

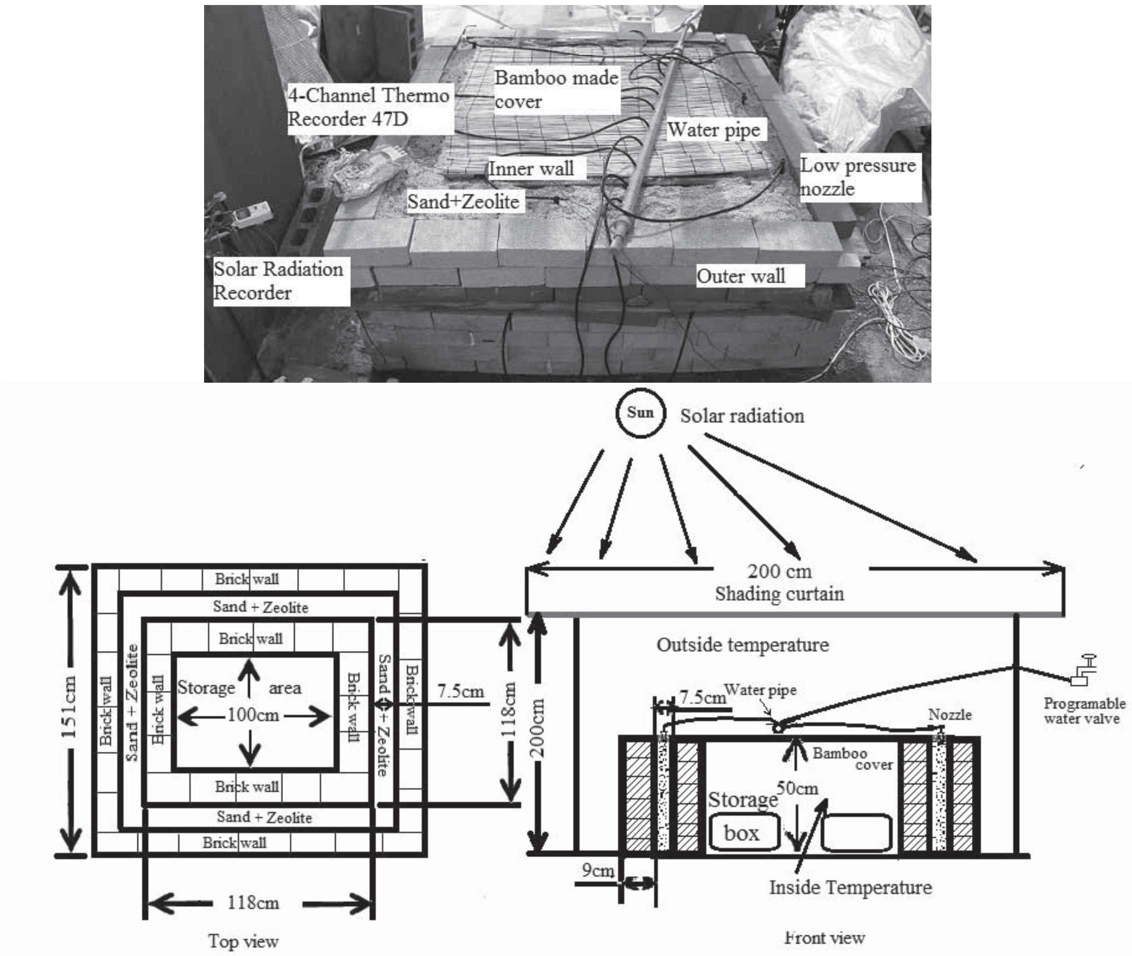


Fig. 1. Pictorial (top) and cross-sectional view (bottom) of the ZECC

(a) Silver-ion-coated plastic containe

(b) Copper container with copper

(c) Perforated plastic crates

Fig. 2. Several types of storage container used in the ZECC

Materials and methods

This experiment was conducted at Ehime University, Matsuyama, from May to June 2011. Two ZECCs were set up inside the greenhouse located at the Faculty of Agriculture, Ehime University. Average room temperature of 25°C was recorded. The load condition refers to tomato and eggplant stored inside the ZECC; the no load condition refers to when the ZECC is empty. In addition to considering the physiological loss in weight as an important indicator for qualitative evaluation, visual appearance in terms of tomato and eggplant color (from bright to deep dark color) was checked, along with surface observation (from glossy to a spotted surface). The observations were made at one-day intervals during the experiment period. The experiment used a total of thirty tomatoes and eggplants, and was repeated three times.

1. Structure of the ZECC

(1) Brick wall cooler

Figure 1 shows the complete randomized block design of the ZECC. The dimensions of the outer and inner brick walls were 151 (L) × 151 (W) × 50 (H) cm and 118 (L) × 118 (W) × 50 (H) cm, respectively. The 7.5-cm gap left between the outer and inner wall was filled with a mixture of sand (60%) and zeolite (40%), as the use of a porous material for a special type of evaporative cooler could reduce ambient temperature by as much as 15°C. Tap water was supplied to the sand area through drip irrigation using an electric valve. The cool chamber's storage area was 100 (L) × 100 (W) × 50 cm (H) in size. A bamboo made frame measuring 118 (L) × 118 (W) cm was used to cover the chamber.

(2) Shading curtain

Solar radiation causes the storage system temperature to rise significantly. Therefore, the use of a shading curtain effectively prevents an increase in ZECC temperature. In this experiment, a shading curtain with dimensions of 200 (L) × 150 (W) cm and capable of blocking out 60% of solar radiation was used.

2. Storage container

(1) Use of Ag^+ coated plastic container

Silver ion (Ag^+) is well known to possess antibacterial properties and much research has been conducted on Ag^+ when used in nanosize form[11,17,20,22,23,34]. Tomato and eggplant stored inside the ZECC decayed due to microbial acitivities[19]. Figure 2 shows a silver-ion-coated container used to store tomatoes and eggplants subjected to hot water treatment (at 60°C and 45°C) inside the ZECC. Two commercialy available Passe Tight TW-100 silver-ion-coated containers measuring 35.6 (L) × 25 (W) × 16.5 (H) cm were used for the experiments. During each experiment, ten heat-treated tomatoes and eggplants were stored inside each silver-ion-coated container in a process repeated three times.

(2) Use of copper grain

It is also known that copper has antibacterial properties. Ten tomatoes and eggplants were used for the experiment, which was repeated three times. Both were placed in a copper container and then buried with copper grains (1 mmφ × 0.5 mm), as shown in Fig. 2 (c).

(3) Use of perforated plastic crates

Two fully perforated crates measuring 45 (L) × 35 (W) × 25 (H) cm in size and made from fine grade high density polyethylene capable of handling various types of fruits and vegetables were used to store eggplant and tomato not subjected to heat treatment (Fig.2). Ten tomatoes and eggplants were placed inside the perforated plastic crates and stored outside the ZECC for a qualitative evaluation. This experiment was repeated three times.

3. Qualitative evaluation

(1) Physiological loss in weight determination of tomato and eggplant

Physiological loss in weight (PLW) is one of the main factors in determining the quality of stored fruits and vegetables. Observations of PLW and the shelf life of tomato and eggplant were recorded periodically. The readings were made at one-day intervals during the experiment period. The shelf life of fruits and vegetables was determined on the basis of five percent PLW[16,33]. A decrease of only 5% in PLW often results in a loss of freshness and a wilted appearance[3,32]. The stored tomatoes and eggplants were evaluated daily by using the Shimazu high-precision BL-320S digital electronic balance until both decayed. PLW was measured by using the following formula:

$$\text{Physiological loss in weight, \%} = \frac{(X1 - X)}{X} \times 100 \quad (1.1)$$

where,

X1 = Initial weight, g

X = Weight (in units of g) at the end of storage time

(2) Hot water treatment of tomato and eggplant

Hot water treatment is commonly used for insect disinfestation and disease control[9,27]. Tomato and eggplant are often effected by *Alternaria rot Alternaria alternata* (f: fungus), *Buckeye rot Phytophthora sp.* (f), *Gray mold Botrytis cinerea* (f), *Soft rot Rhizopus stolonifer* (f), *Sour rot Geotrichum candidum* (f), *Bacterial soft rot Erwinia spp.* (b: bacterium) or *Pseudomonas spp.* (b), *Ripe rot Colletotrichum sp.* (b) and *Watery soft rot Sclerotinia sp.* (f), *Cottony leak Pythium butleri* (f), *Fusarium rot Fusarium sp.* (f), *Bacterial soft rot Erwinia sp.* (b), or *Pseudomonas spp.* (b), respectively. Some of these organisms that cause decay are repressed at higher temperatures. On the other hand, the efficacy of hot water treatment depends on the product and is restricted to a narrow range of temperatures and exposure time[13]. Moreover, the variety of crops, pre-harvest agronomic practices in the field, and climactic regions of crop growth could vary with hot water treatment efficiency[10]. During the past few years, there has been growing interest in the use of hot water treatment to control insect pests, prevent fungal rot, or retard or minimize commodity response to extreme temperatures[21]. The water temperature during hot water treatment was maintained within the set temperature by using a Fine Thermo-Indicator F-002DN (Tokyo Glass Instruments).

In each hot water treatment, tomato and eggplant were divided into two groups based on different temperatures (45°C and 60°C, respectively; 45°C for one hour; 60°C for three minutes). In the first group, tomato and eggplant were treated at a temperature of 45°C for one hour, and then cooled down to room temperature and dried before being stored inside the ZECC. In the second group, tomato and eggplant were placed in hot water at 60°C for three minutes, and then cooled down to room temperature and dried before being stored inside the ZECC.

4. Measurements of temperature, relative humidity, and watering

The temperatures at all places were simultaneously measured by using a digital thermometer (Sato Shoji, 47SD) with four thermocouples (Cromel-Alumel, 0.3 mmφ). Three thermocouples were placed in the top, middle, and bottom layers of the ZECC; another was placed outside the ZECC for measuring the outside temperature. The temperature at the middle layer was used as the inside temperature.

The relative humidity of the ZECC was measured

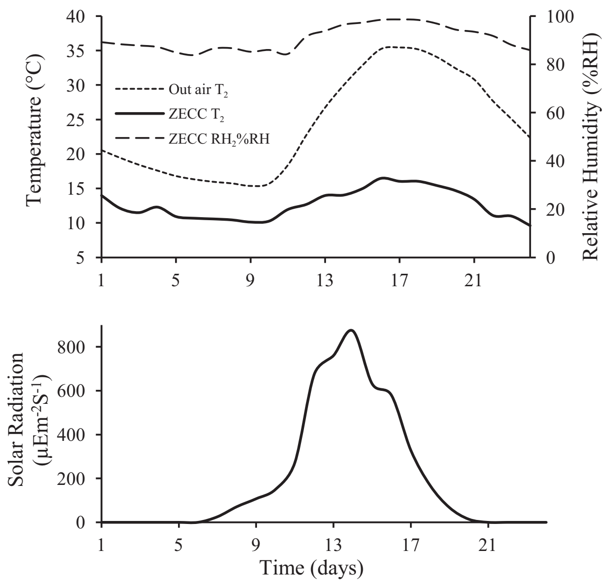


Fig. 3. Diurnal changes in solar radiation, outside temperature, inside temperature, and inside relative humidity in the ZECC under shading and watering conditions

simultaneously using a thermo hygrometer (Sato Shoji, HT-SD), which has data logger functions. The data were sampled at one-minute intervals for 24 hours. Thus, about 1440 points of data for outside temperature, relative humidity, watering interval with duration, and inside temperature of the ZECC were obtained.

In the ZECC, water is distributed from a water supply to twenty low-pressure drip nozzles through a programmable flow valve (Haikanbuhin VKK-15WAG) for wetting the layer of sand. The rate of watering was 50 *l*/day through the low-pressure drip nozzles. Excess water dripping from the ZECC was drained out.

Results and discussions

1. Performance of the ZECC

The fundamental performance relative to temperature and relative humidity inside the ZECC was first investigated from the standpoints of both dynamic and static characteristics. Figure 3 shows the typical diurnal changes in solar radiation, as well as the outside temperature, inside temperature, and inside relative humidity of the ZECC under no load, shading, and watering conditions. Solar radiation increased the outside temperature around the ZECC. An increase in outside temperature also increased the inside temperature of the ZECC. The shading curtain, however, protects the ZECC against direct exposure to solar radiation. For instance, under shading and watering conditions, the maximum values of the outside and inside ZECC temperatures were 35.4°C and 16.5°C, respectively. Conversely, the minimum values of the inside and outside ZECC temperatures were 9.6°C and 15°C, respectively. Under shading and watering conditions, the average value of relative humidity was recorded at 90.6% inside the ZECC, but maximum relative humidity of 98.6% was achieved under the highest outside temperature. This is because a higher outside temperature increases the evaporation rate from the sand and wet bricks of the ZECC.

Figure 4 shows the typical diurnal changes in inside temperature of the ZECC under watering, no watering, shading and no shading curtain conditions. The highest temperature (34.6°C) and lowest temperature (9.6°C) of the ZECC were recorded under no watering without the shading curtain and under watering with the shading curtain, respectively. Average inside temperatures of 12.7°C, 21.4°C, 23.8°C, and 26.8°C were recorded in the ZECC under watering with shading, watering without shading, no watering with shading, and no watering without shading, respectively. The inside temperature was thus found to be significantly affected by the shading curtain, outside temperature, and watering. Therefore, the combined use of watering and the shading curtain was found to provide the lowest inside temperature of the ZECC. This is probably due to the effects of the evaporative cooling mechanism by water and the reduction of solar radiation by the shading curtain. Here, the outside temperature around the ZECC and the vapor pressure of the moist sand-zeolite mixture and surrounding air attempt to equalize. Liquid water molecules of the moist sand-zeolite mixture gasify under the influence of outside air through a process that uses energy to change the physical state. Heat transitions from the higher temperature of the air and brick walls to the lower temperature of water, due to convection and conduction. During this conversion process, there is a drop in ambi-

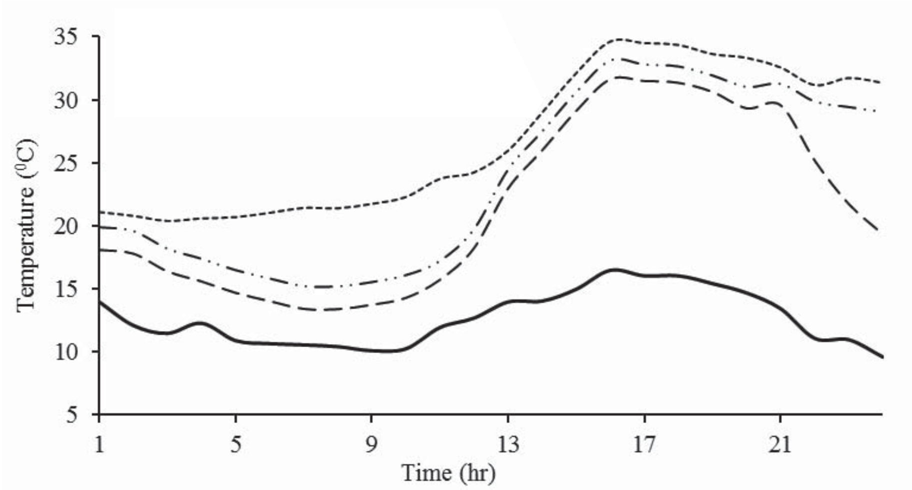


Fig. 4. Diurnal changes in inside temperature under shading and no shading curtains
——— : ZECC $T_2$⁰C (Watering with shading), – – – – : ZECC $T_2$⁰C (Watering without shading),
–·–·· : ZECC $T_2$⁰C (No watering with shading), - - - - - - : ZECC $T_2$⁰C (No watering without shading).

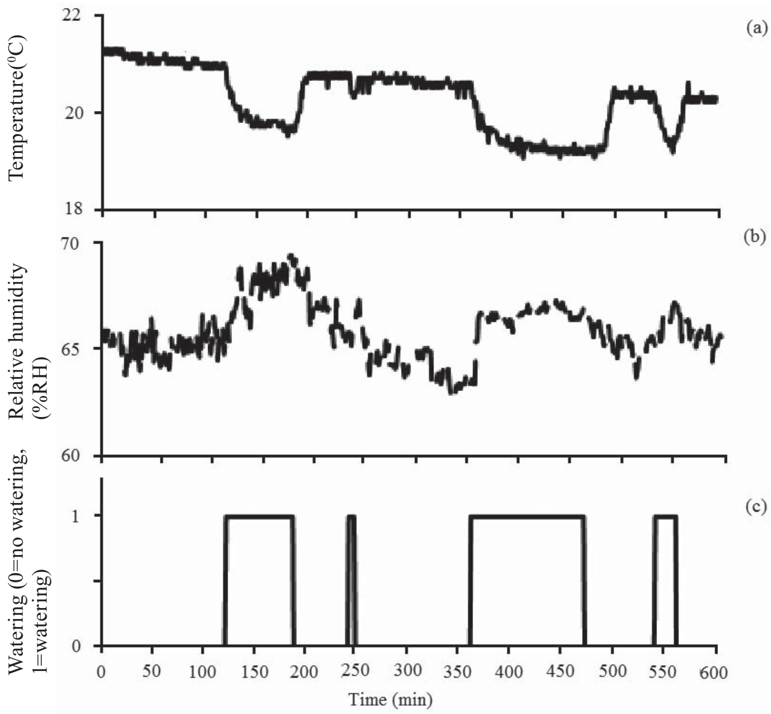


Fig. 5. Dynamic responses of inside temperature (a) and relative humidity (b) as affected by watering (c)

ent temperature. This cooling temperature caused by the effect of evaporation cools down the inside temperature of the ZECC below the dry-bulb temperature. This is the result of the combined effects of underground temperature, the moist inside walls, and watering. Consequently, the inside air temperature of the ZECC became cooler. On the other hand, the shading curtain blocked 60% of the sun's infrared rays, thereby lowering both the temperature inside the ZECC and that surrounding it.

Watering was also found to maintain a low inside temperature of the ZECC for a longer time. Under the shading condition, watering lowered the ZECC temperature for a longer duration, while under the no shading condition, watering slightly lowered the inside temperature of the ZECC for a shorter duration. This is because under the no shading condition, solar radiation directly striking the surface of the ZECC increased the inside temperature of the cool chamber. Under the no shading condition, the maximum relative humidity and minimum temperature inside the ZECC were 68% and 19°C, respectively.

Figure 5 shows the typical diurnal changes in the inside temperature and relative humidity of the ZECC, as affected by watering operation under no shading. Here, watering was performed four times. The responses of both inside temperature and relative humidity to the watering showed dynamic changes where a significant decrease in inside temperature and a marked increase in relative humidity were observed at watering. Therefore, the inside temperature and relative humidity can be modeled and controlled by the watering operation.

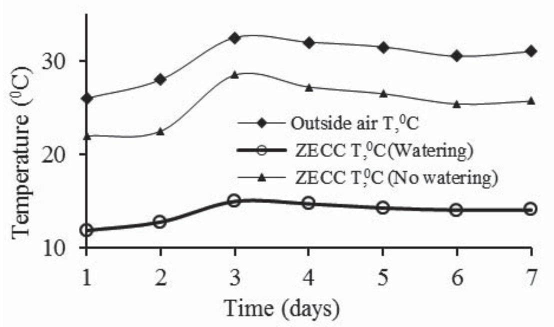
Figure 6 shows the daily changes in inside temperature and relative humidity of the ZECC over seven days. In Figure 6, (a) and (b) show daily average values of temperature and relative humidity at 13.8°C and 91.7%, respectively, under the shading curtain condition inside the cool chamber with watering, and at 25.4°C and 64.1%, respectively, without watering. The daily average values of temperature and relative humidity under the no shading condition inside the cool chamber were 27.8°C and 65.9%, respectively, with watering, and 29.4°C and 64.1% without watering. Outside average temperature of 30.2°C and relative humidity of 63.7% were recorded. From this experiment, we can see that the shading curtain can reduce the inside temperature of the ZECC, although its relative humidity remained virtually the same under both shading and no shading conditions.

2. Physiological loss in weight of fruits and vegetables in the ZECC

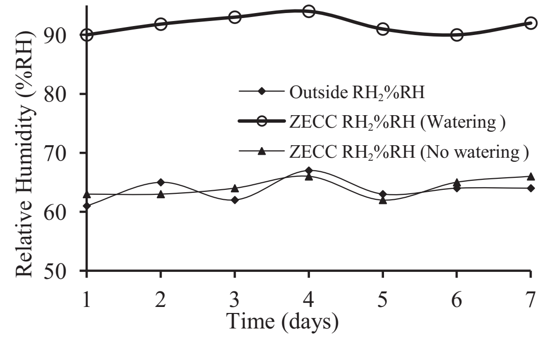
Next, the physiological loss in the weight of tomatoes and eggplants stored in silver-ion-coated containers and placed in the ZECC after applying hot water treatment was investigated.

(1) Tomato and eggplant without hot water treatment

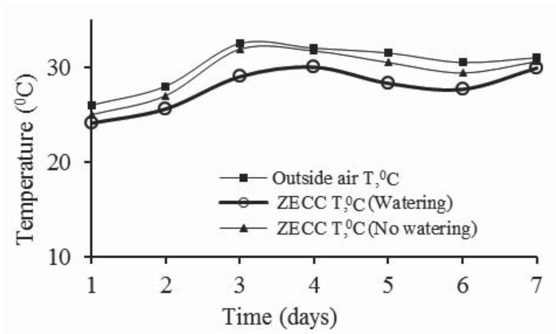
In Figure 7, (a) and (b) show daily changes in PLW



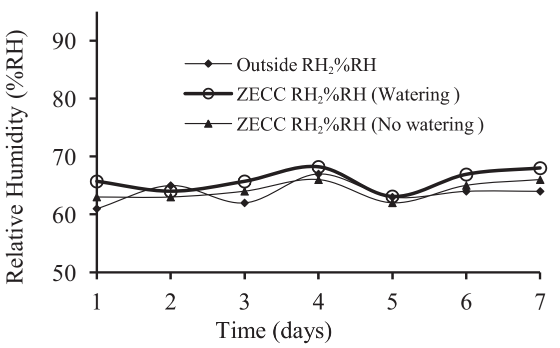
(a) Inside temperature with shading



(b) Inside relative humidity with shading

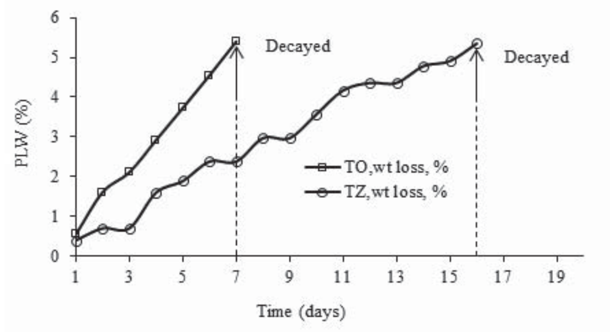


(c) Inside temperature without shading

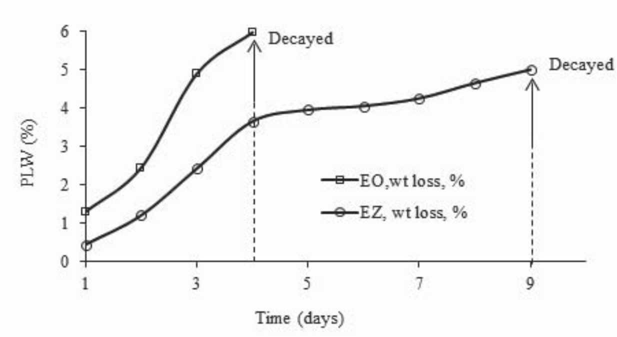


(d) Inside relative humidity without shading

Fig. 6. Daily changes in the inside temperature and relative humidity of the ZECC



(a) No heat-treated tomato



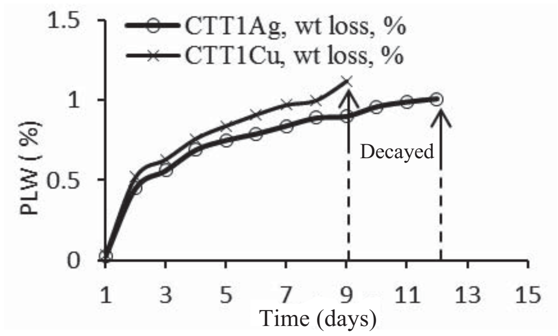
(b) No heat-treated eggplant

Fig.7. PLW of no heat-treated tomato (a) and eggplant (b)
TO: Tomato stored outside the ZECC in room temperature at 25°C
TZ: Tomato stored inside the ZECC at average 15°C
EO: Eggplant stored outside the ZECC in room temperature at 25°C
EZ: Eggplant stored inside the ZECC at average 15°C

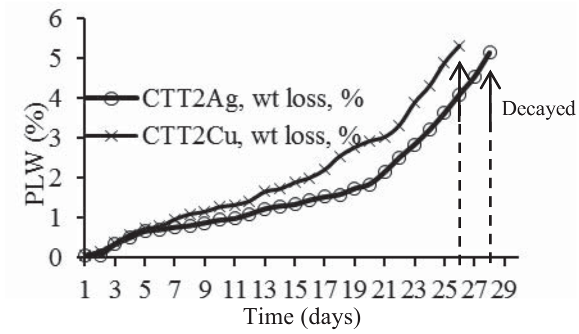
of tomato and eggplant without hot water treatment, respectively. In the experiment, significant differences were found in PLW (in percent) of tomato and eggplant stored in the ZECC (at average temperature of 15°C) and at room temperature (average of 25°C). The ZECC reduced the percentage of PLW of tomato and eggplant in contrast to those stored outside the ZECC. Tomato stored outside the ZECC showed PLW of 5.4% after seven days, while tomato stored inside the ZECC showed 5.35% after 16 days. Eggplant stored outside the ZECC showed PLW of 5.98% after four days, while eggplant stored inside the ZECC showed 5.01% after nine days. Thus, tomato and eggplant stored inside the ZECC showed lower PLW than those stored outside the ZECC.

(2) Tomato and eggplant stored in the silver-coated container with copper grains after hot water treatment

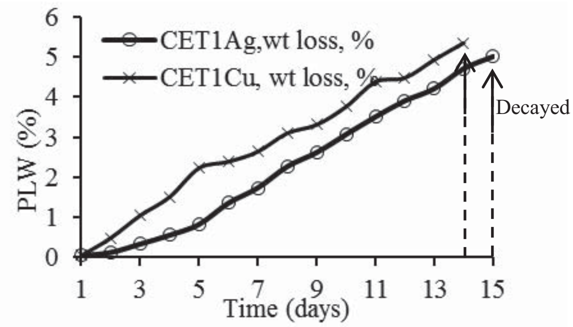
In Figures 8 and 9, (a) and (b) show daily changes in PLW of tomatoes and eggplants stored in the silver-ion-coated containers with copper grains after hot water



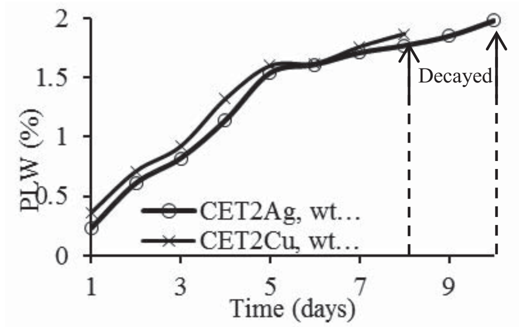
(a) Heat treated tomato



(a) Heat treated tomato



(b) Heat treated eggplant



(b) Heat treated eggplant

Fig.8. PLW of heat treated tomato (a) and eggplant (b) stored inside the ZECC at average 15°C

CTT1Ag: Tomato treated with 45°C hot water for 1hr stored inside the silver ion coated container
CTT1Cu: Tomato treated with 45°C hot water for 1hr stored inside the copper grain
CET1Ag: Eggplant treated with 45°C hot water for 1hr stored inside the silver ion coated container
CET1Cu: Eggplant treated with 45°C hot water for 1hr stored inside the copper grain

Fig.9. PLW of heat treated tomato (a) and eggplant (b) inside the ZECC at average 15°C

CTT2Ag: Tomato treated with 60°C hot water for 3 min stored inside the silver ion coated container
CTT2Cu: Tomato treated with 60°C hot water for 3 min stored inside the copper grain
CET2Ag: Eggplant treated with 60°C hot water for 3 min stored inside the silver ion coated container
CET2Cu: Eggplant treated with 60°C hot water for 3 min stored inside the copper grain

treatment. Table 1 shows the number of days until decay under different conditions. Here, decay of the fruit was evaluated from an outside view. Hot water treatment at 45°C for one hour was applied to the tomatoes and eggplants. Tomatoes treated in hot water and then stored in the silver-ion-coated container and copper grain lost only 1.01% of PLW after 12 days, 1.12% of PLW after nine days, and then decayed. Eggplants treated in hot water and then stored inside the silver-ion-coated container and copper grain lost 5.01% of PLW after 15 days, and 5.35% of PLW after 14 days without any decay. Tomatoes treated in hot water at 60°C for three minutes and then stored inside the silver-ion-coated container and copper grain lost 5.14% of PLW after 28 days, and 5.32% of PLW after 26 days without any decay. Eggplants treated in water at 60°C for three minutes and then stored inside the silver-ion-coated container and copper grain lost only 1.98% of PLW after 10 days, lost 1.87% of PLW after eight days, and then decayed.

In Figure 10, (a) and (c) show photographs of tomato and eggplant not treated in hot water after the experiment. Both were found to decay with dark color and spots. This is because microorganisms easily affect tomato and eggplant not treated in hot water, and uncontrolled ethylene production causes the fruits to ripen faster. In contrast, (b) and (d) in Figure 10 show photographs of tomato and eggplant treated in hot water and stored inside the silver-ion-coated container. Both were found to be bright in color. This is because hot water treatment slows down color development and the ripening process. Fruits subject to hot water treatment have lower levels of acidity and a higher content of soluble solids, glucose and sucrose, thereby achieving higher quality for consumption[21]. Epicuticular wax covering the eggplant is generally smoother than that of tomato. This epicuticular wax is a very important factor in preventing the growth of harmful microorganisms after heat treatment. For instance, mild-temperature hot water treatment (at 45°C for one hour) of tomato with a longer duration, and high-temperature hot water treatment (at 60°C for three minutes) of eggplant with a shorter duration damaged the layer of wax, but in both cases disinfected the surface. However, even such heat treatment in later stages could not prevent the growth of microorganisms that cause decay. At the same time, both high-temperature hot water treatment (at 60°C for three minutes) of tomato with a shorter duration and mild-temperature hot water treatment (at 45°C for one hour) of eggplant with a longer duration increase the thermo tolerance of plant cells and sterilize many types of bacteria.

Many researchers have demonstrated that hot water treatment between 35°C and 63°C effectively inhibits ethylene production, delays ripening[5,22], and reduces the water loss of fruits during storage[4,27]. Hot water treatment is also reportedly effective in preventing bacterial infection by activating the defense mechanism of cells[14,29]. It is well known that exposing living organisms to heat stress produces several types of heat shock proteins (HSPs) in their cells, which acquire a transient thermo-tolerance[7,18]. Therefore, acquiring thermo-tolerance and disinfection by heat treatment may reduce PLW and increase the shelf life for fruits during storage. It is thus logical to assume that hot water treatment reduces PLW.

Silver ions also have an antibacterial effect by emitting positively charged electric particles or ions. The silver ions penetrate the cell membrane and enter the body of bacteria. Silver ions (Ag^+) coming into contact with bacteria destroys the bacteria's proteins and interrupts the synthetic version of bacterial DNA. The bacteria loses the ability to divide and propagate, and thus eventually dies. Moreover, the higher redox potential of silver ions causes faster dissociation after bacteria is destroyed. It will then continue to destroy other bacteria. Many researchers have described the obvious antibacterial effect of silver ions and how silver ions prevent the growth of microorganisms on the surfaces of tomato and eggplant[10,15,16,18,21,27,28]. Therefore, said antibacterial effect is probably due to the disinfection effect of silver ions. At the same time, copper grain can inhibit the growth of fungi [2,6] that pose a great threat to fruits stored in moist and dark environments. The thermal conductivity of copper is greater than that of other materials, causes a faster decrease in fruit temperature, and reduces ethylene production.

Table 1. Number of days until decay of tomato and eggplant

Treatment	Packaged system	Normal room temperature (days)		ZECC (days)	
		Tomato	Egg-plant	Tomato	Egg-plant
No heat treatment	Outside the ZECC	7	4		
	Inside the ZECC			16	9
Treated at 45°C	Silver-ion-coated container			12	15
	Copper			9	14
Treated at 60°C	Silver-ion-coated container			28	10
	Copper			26	8

Conclusion

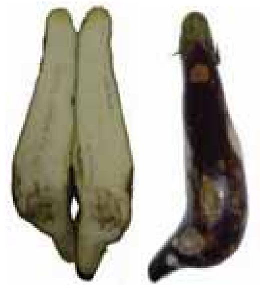
The ZECC can maintain relatively low inside temperature and high relative humidity as compared with outside temperature and relative humidity. Temperature inside the ZECC can be reduced through the process of an evaporative cooling mechanism and by using a shading curtain to protect the ZECC against direct exposure to solar radiation. The moisture condition on the walls in the ZECC and the ground condition also help to maintain higher relative humidity. The experiment revealed that when watering, the shading curtain reduced the inside temperature of the ZECC from 27.8°C to 13.8°C, and increased humidity from 65.9% to 91.7%. But under no watering and no shading conditions, the inside temperature and relative humidity of the ZECC were 29.4°C and 64.1%, respectively. However, there were few differences between the shelf life of tomato and eggplant as increased by the silver-ion-coated container and copper grain. Copper grain is very heavy in weight and might cause mechanical damage to fruits during the storage period. Therefore, a combination of lower temperature and higher humidity inside the cool chamber, along with hot water treatment and the use of a silver-coated storage container could prevent the decay of tomato and eggplant, while increasing the shelf life of tomato and eggplant.

Acknowledgments

This paper reported on results obtained in the Toyota Foundation's Asian Neighbors Program on "Improving food security and farmers socioeconomic condition in Bangladesh through the dissemination of a zero energy

(a) Tomato with no heat–treatments (Dark color and spots are clearly visible) after 7 days

(b) Tomato with silver coated container and heat treatments (60°C hot water for 3 min) after 28 days



(c) Eggplant with no heat–treatments (Dark color and spots are clearly visible) after 4 days

(d) Eggplant with silver coated container and heat treatments (45°C hot water for 1hr) after 15 days

Fig.10. Visual appaerances by color and presence of spots in tomato and eggplant

cool chamber."

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