NARP VEGETABLE RESEARCH PROJECT

EFFECT OF IMPROVED STORAGE UNIT ON THE SHELF-LIFE OF TOMATO

FINAL REPORT

Food Research Institute (CSIR)

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Executive Summary

This report covers work carried out to develop a portable storage coolant for increasing the shelf-life fresh either in at the farm-gate or at a marketing centre. The storage structure works on the principles of passive evaporative cooling.

In this work, a rectangular wooden storage coolant measuring 1.22 m long, 0.68 m wide and approximately 1.00 m high was evaluated. The cooling unit consisted of a pad and an overhead water trough. The pads which were two rectangular chicken wire frames housed either pieces of charcoal or cover of jute cloth. The latter two served as absorbents for the water dripping from the overhead water tank.

The coolant was designed to hold approximately 1718 or 82.5 kg of medium-sized fresh tomatoes to be stored at a given time. The coolant was designed to remove two sources of heat, field and respiratory heats of the amounts 657 kJ and 0.43 kJ, respectively.

The coolant is able to achieve an average of 80 to 85 % RH and relative lowering of 6 °C during its operation.

Unfortunately because of the drought in the Greater-Accra Region for much of 1998, it became extreemely difficult to come by matured-green tomato to carry out the evaluation of part of the study.

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INTRODUCTION

The tomato fruit is one of the most commercially important fruits in Ghana because of its rich source of vitamins A and C. Though records indicated that annual production of tomato was reasonably high (Ghana Agricultural Policy, 1985), there was always a perennial shortfall in the supply of the fruits. This is because of the lack of storage facilities on farms and at the marketing centres from the farm-gate, and also that during transportation and at the marketing centres there is usually a time lapse of two to seven days before all fresh tomatoes are sold off (Johnson & Adjei, 1990). In addition, a recent survey conducted under the NARP Vegetable Project established that most farmers usually do not harvest their tomato until the arrival of the trader and/ or vehicle mainly because of lack of storage facilities. Thus part of the solution to improving the post-harvest sector of the tomato industry in Ghana would be the provision of some temporary storage facility at the farm-gate before the arrival of traders. FAO (1980) recommends that a storage structure based on the evaporative cooling can be used as a temporary storage facility at the farm-gate by the small-scale farmer in the tropics to increase the keeping qualities of perishable food-crops. Johnson & Adjei (1990) also established that most tomato retailers in Accra said they would like to have a simple, but economical storage unit for improving the keeping quality of tomato fruits remaining at the end of marketing day.

When dry air is blown across a wet surface, water is evaporated and dry air is cooled due to loss of the latent heat of evapoartion. A high humidity is also maintained (Walker & Abernathie, 1964). This process is known as evapoartive cooling. Most of the previous work done with this system has been in the cooling of greenhouses during the summer in temperate and sub-tropical countries where temperatures both inside and outside the greenhouses are usually high. The wet pad and fan system, in which a fan on one side of the greenhouse draws air through the wet pad at the opposite end of the house, is the most popular form of evaporative system used. Water trickles down through the wet pad and is collected at the bottom, being returned to a sump for re-circulation. Usually air-circulation in the evaporative coolant is facilitated by the use of a fan. In its absence, air circulation will have to depend of wind which impinges on the surface of the pad and manages to go through the coolant. In situation the evaporative cooling is said to depennd on passive air circulation and therefore the process is described passive evaporative cooling.

A small-scale structure which works on the principles of evaporative cooling and which is capable of holding 80 kg fresh tomato fruits was found to be able to extend the shelf-life of matured-green tomato by 8 days (Johnson, 1986). Babarinsa & Nwangwa (1984) also demonstrated that even under tropical conditions of humidity of 75 % and average ambient temperature of 29 °C, the ripening of mature tomato was delayed for 7 days in a passive evaporative coolant.

It follows therefore that a storage structure based on the principles of evaporative cooling could be used for temporary storage of freshly harvested tomatoes. The objective of this project was to design, construct and evaluate the performance of a storage coolant which works on the principles of passive evaporative cooling and which is capable of being used either in an on-farm situation or at the marketing centre for temporary storage of fresh tomatoes

MATERIALS AND METHODS

2.1 Design and construction of the passive evaporative coolant

2.1.1 Design Parameters

The parameters considered for the design of the storage structure were:

i. Quantity of fresh tomatoes to be stored at a given time.

The total storage space was estimated to be adequate enough to contain about one to two crates of tomatoes. Each crate weighs approximately 55 kg of tomatoes. This will be equivalent to about 1145 to 2290 of medium-sized tomatoes. An average number of 1718 or 82.5 kg of medium-sized tomato fruits was therefore used for the calculations. Tomatoes are to be stored not in crates, but spread out evenly on trays constructed in the storage structure.

ii. The ambient shade temperature was assured to vary from 27 to 33 °C.

iii. The ambient relative humidity was assumed to average from 65 to 80 %. These were expected to decrease during the harmattan season, between the months of December and February.

iv. The passive evaporative coolant was designed to remove two sources of heat; field and respiratory heats

2.1.2 Field Heat

This was based on methods by Bailey (1965) which is given as:

Field Heat = Weight of Fruits x Specific Heat x Temperature Difference

Specific Heat of Tomatoes = 3.98 kJ/ kg °C (Robinson *et al.*, 1975).

The mean ambient air temperature was assumed to be 30 °C and if the lowest temperature achievable within the storage structure was 20 °C, then there would be a fall in temperature of 10 °C (i.e when the structure is fully insulated)

Therefore, the Field Heat = (82.5 x 3.98 x 10) kJ = 3283.5 kJ

The recommended cooling time for tomatoes in a refrigerated room is normally about 12 h (Hobson, 1981). However in this investigation a 5h cooling period was assumed. The Field Heat would therefore be = **3283/ 5 = 656.7 kJ/h**.

2.1.3 Respiratory Heat

The respiratory heat of tomatoes is 5.25 kJ/ton/min (Robinson et al.,1975) and 82.5 kg of tomatoes is equivalent to 0.0825 tons. The respiratory heat loss would therefore be 5.2 x 0.0825 = 0.43 kJ/h

Total Cooling Load Required = Field Heat + Respiratory Heat

= **656.7 + 0.43**

= **657.13 kJ/h**

Thus when the structure is fully insulated, the total cooling load required will be equal to 675.13 kJ/h. However the type of materials used for insulation (as described below under material used for constructions) the efficiency of the insulation was considered to be about 50 % of the expected.

Hence, the Total Cooling Load Required will be = **50/100 x 657.13 = 328.6 kJ/h.**

Using the methods as explained by Walker & Abernathie (1965), the total cooling load of 328.6 kJ/h can be expected to achieve a relative humidity of 80 to 85 % within the structure.

2.2 Materials Used for Construction

2.2.1 Framework

The framework of the structure was rectangular, constructed out of emery (*Terminal ivorensis*). Scantlings of wawa (*Triplochiton scleroxylon*) were used for the construction of inside trays. The structure measures 1.22 m long, 0.68 m wide and approximately 1.00 m high. The main storage compartment is as shown in Fig. 1.

A door, measuring 0.93 high and 0.55 m wide was constructed at one of the dorsal ends of the structure. Inside the storage structure were three narrow trays, each 1.03 m long, 0.55 m wide and 0.17 m deep. The bottom parts of these were panelled with scantlings and covered with wire mesh. The gabs between the panels were to ensure that air could freely move through the stored tomato. The body of the framework was covered with half-inch plywood (Fig 1 and 2).

2.2.2 Insulation

The inside parts of the body of the unit were covered with 1 mm thick transparent polythene sheets (Fig. 2).

2.2.3 Pad and Cooling Unit

The cooling unit of the evaporative storage unit consisted of a pad and an overhead water trough. On the two long sides of the storage unit, facing the prevailing wind direction, were two rectangular chicken wire frames (Fig. 1). These housed the pad (Bailey, 1965) sections of the passive evaporative storage unit. These two frames were filled with either pieces of charcoal or cover of jute cloth. The latter two served as absorbents for the water dripping from the water tank as described below.

Water for the cooling unit of this system was held in an open trough made from 1 mm thick galvanised sheets on the top of the wooden structure (Fig. 3) Each trough measured 0.92 m long by 0.69 m wide. The depth of trough was 0.09 m at the ventral ends and 0.05 m at the mid section where it has been bent inwards and parallel to the sides. This was done to ensure easy flow of the water. Five equal distanced small holes, each aperture 0.8 ,mm diameter were made on either side of the bottom long ventral edges. It was through these small holes that water dripped onto the pad.

The whole storage unit is covered by a *Zana* mat to help reduce evaporation of water from the trough (Fig.3).

2.2.4 Rate of Water Flow

The rate at which water was dripping from the cooling unit was assessed as a measure of the flow of water through the jute cloth cover. The rate of water flow was measured by the help of a measuring cylinder and a stop-clock. The rate of water flow through the pad was found to be 0.38 mL/s. This works out to be 31 litres/day. Thus, the capacity of the through which is 42 litres is adequate enough to allow for continuos flow of water through the pad for a whole day whilst the fruits are being kept in the storage unit.

Fig. 1 Storage units (Passive Evaporative Coolants) showing the framework

Fig. 3 Storage Unit (Passive Evaporative Coolant) showing the water trough and *Zana* mat cover

3. Determining the Physical Conditions in and around the Coolant

Three physical conditions, temperature, relative humidity and airflow speeds in and around the evaporative coolant over a period of two week's duration, each time, in March, April and June were monitored. These three months were chosen because they coincided with periods of varying climatic conditions at the project site at the Pilot Plant of the Food Research Institute. In March the ambient day temperatures and the relative humidities averaged 35 °C and 60 % whilst during June, these conditions are usually around 31 °C and 75 %, respectively. The object was to study the effect of changing weather conditions on the performance of the coolant.

3.1 Temperature Measurement

Temperature changes in and around the evaporative coolant were monitored using a portable thermometer (model HTAB, Abbeomn Cal Inc.).

3.2 Relative Humidity Level

Calibrated thermohygrographs were used to record the relative humidity changes within the evaporative coolant and the immediate outside of the coolant. Two thermohygrographs were used within the coolant. One was suspended in the middle on the coolant and the second close the wall directly opposite the door of the coolant.

3.3 Air-Flow Rate

Two airflow rates were monitored, the air flow rate across the pad from inside the coolant and the wind speed around the coolant. The airflow rates was measured with the help of a portable anemometer air meter (Negretti & Zambra, London).

RESULTS AND DISCUSSION

4.1 Temperature Difference and Relative Humidity

Fig. 4 and 5 indicate that the highest level of cooling was best achieved in the afternoons both in March/April and June. The temperature difference between the coolant and the ambient was higher in March/ April than in June. This can be attributed to the fact that a much lower average ambient relative humidity achieved during the March/April, as shown in Fig. 4, ensured a much higher water vapour pressure deficit between the air outside and that within the coolant. As expected, the level of temperature lowering achieved within the coolant in June was less as compared to those achieved in March/ April. It was also noted on days when it was sunny, the temperature difference was much more than on days when there were clouds.

4.2 Air-Flow Through the Evaporative Coolant

The results of the air-flow rate through the coolant appeared to indicate that air movement through the coolant was fastest around midday, between 12.00 and 14.00 GMT (Table 1). This corresponded with periods when the ambient temperature was usually high (Fig. 4 & 5). As a result the relative humidity of the ambient air was usually low. Therefore, the density of the ambient air around the coolant was relatively less dense and therefore was able to move faster through the coolant.

Fig. 4 Differences in temperature between the inside and outside of the evaporative coolant during two 5 days in March/April, 1998

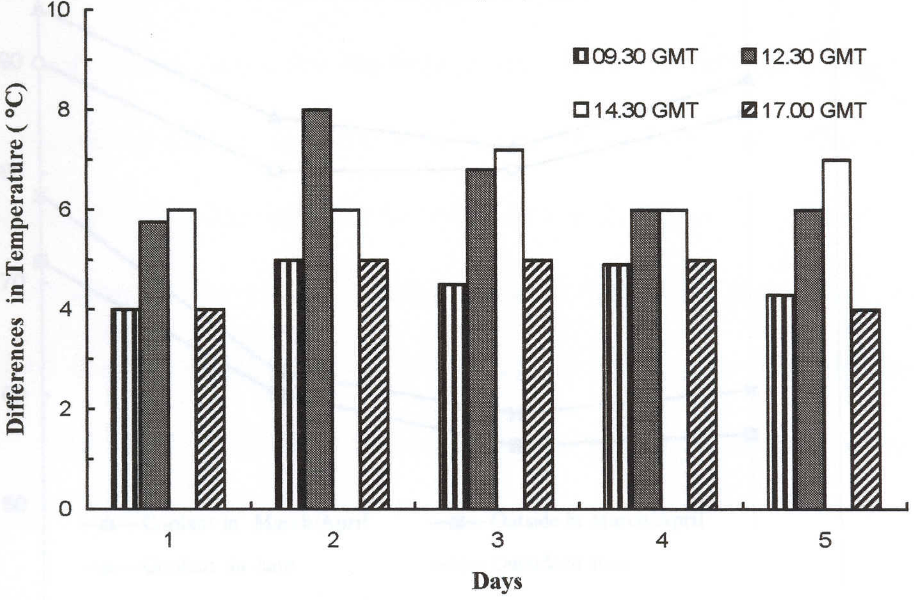

Fig. 5 Differences in temperature between the inside and outside of the evaporative coolant during two 5 days in May/June, 1998

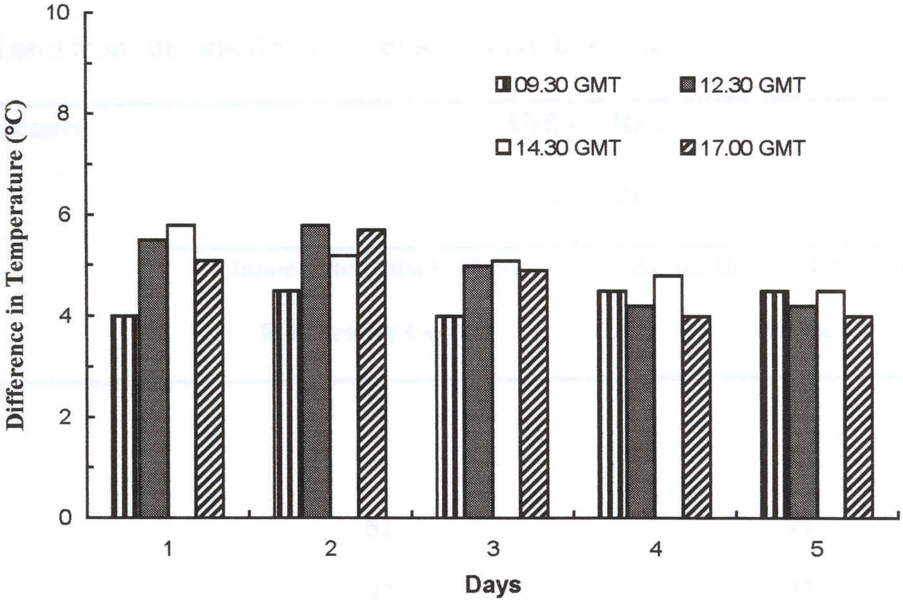

Fig. 3 Average relative humidity recorded during two 5 days inside and outside the evaporative coolant

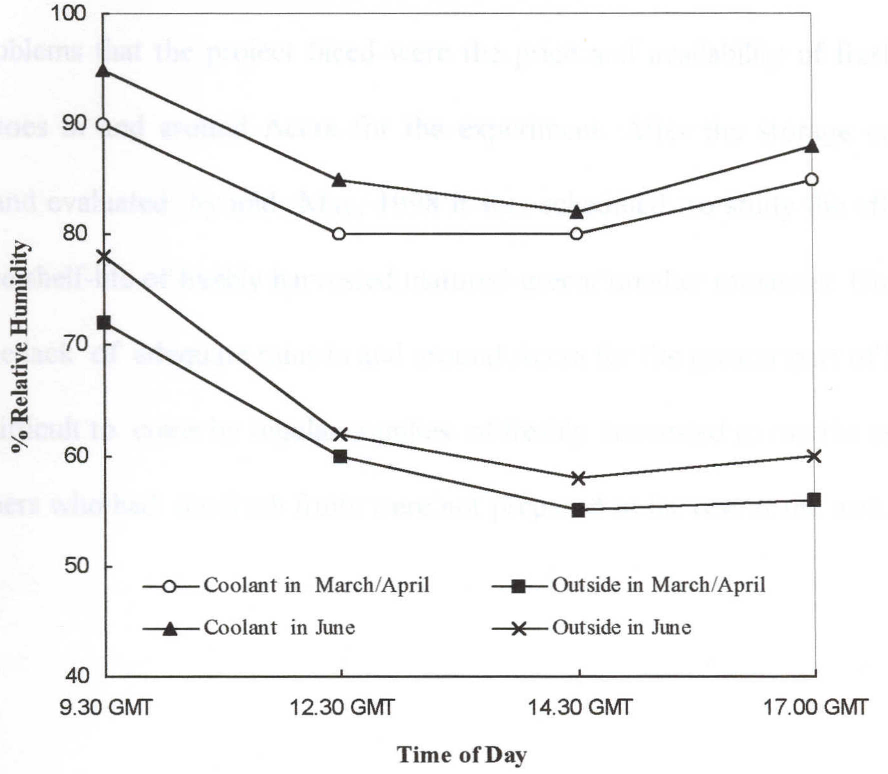

Table 1: **Average air-flow rates recorded in March / April around and across the pad end from the inside of the evaporative coolant**

Time of Measurement (GMT)	Airflow Rate (m/ min) Immediate Outside of the Evaporative Coolant	Airflow Rate (m/ min) Across the Pad End from the Inside
09.30	48	15
12.00	50	20
14.00	52	23
17.00	47	12

Problems Encountered

The main problems that the project faced were the price and availability of fresh matured-green tomatoes in and around Accra for the experiment. After the storage coolant was constructed and evaluated by mid May, 1998 it was scheduled to study the effect of the coolant on the shelf-life of freshly harvested matured-green/ breaker tomatoes. Unfortunately because of the lack of adequate rains in and around Accra for the greater part of last year, it was highly difficult to come by regular supplies of freshly harvested to run the experiment. The few farmers who had the fresh fruits were not prepared to harvest at the matured-green/ beaker stage.

Future Direction of Research Activity

In the immediate future, the main activity that needs to be carried out will be to test the performance of the developed storage coolant structute in respect of its ability to significantly increase the shelf-life of fresh tomato. Other studies that need to carried out alongside this main are:

- An investigation into the use of different materials in the construction of the cooling pad system of the storage coolant.
- An investigation into the scaling up of the storage coolant structure and yet being able to achieve the same or better levels of cooling.

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