# Development of an Ambient Control Method for Tomatoes Preservation

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**ABSTRACT**
The quality of tomatoes depends on post harvest handling, transportation and storage techniques. Tomatoes cannot be kept for a long period of time due to their perishable and seasonal nature, it is therefore necessary to preserve it in seasons when available in other to ensure constant supply throughout the year with their nutritional value still retained. However, a 0.22 cubic metre capacity storage facility that operates on the principle of evaporative cooling, which is to increase the shelf life of stored tomatoes was designed, fabricated and tested. Data were observed twice daily and Results of the transient performance tests revealed that 117W is the cooling capacity of the produce (tomatoes) at 29.5$^0$C. Also, it was observed that the dry bulb (21-30$^0$C) and wet bulb (14.5-24$^0$C) temperatures are inversely proportional to the relative humidity (39-56%) of the cooler, which in turn show inverse relationship between the saturation efficiency (0-74.42%) and by-pass factor (0.26-1.00)**.** An evaporative cooling system should be utilized to preserve tomatoes and other forms of vegetables at their minimal storage temperature in fourteen days relative to ambient storage. Thus, it has the prospect of being used for short term preservation of tomatoes soon after harvest and it will be very useful in helping the farmers most especially in a developing economy like Nigeria.
**Key words:** Evaporative cooling systems, tomatoes, preservation, temperature, relative humidity, cooling efficiency, cooling capacity.

## 1.0 INTRODUCTION

Tomatoes are agricultural products that are known for their rich vitamins, high concentration of moisture and low fats. They are highly perishable due to excess moisture present in them especially at harvest time. It is therefore important that they are preserved in seasons when available in other to ensure that constant supply throughout the year with their nutritional value still retained (CFNEU, 2003). The quality of tomatoes depends on post harvest handling, transportation and storage. Compared with several temperate fruits and vegetables; tropical and sub-tropical vegetables (such as tomatoes and carrots) present greater storage and transportation problems because of their perishable nature (Mitra and Baldwin, 1997).
Kader (1992), estimated the extent of post harvest losses in fresh tomatoes at 5% to 28% in developed countries and 20% to 50% developing countries. In Nigerian alone, up to 50% of harvested tomatoes get spoilt annually (Musa-Makama et al, 2005) causing seasonal shortage and fluctuations in supply and price. Tomatoes can be successfully preserved by reducing their moisture content to a level that will discourage the activities of micro-organism and fungi deteriorating them. Microbial activities are not active when the moisture content of a product is below 10%. Therefore, preservation of tomatoes is of great importance because it makes provisions for delayed used and eliminated wastage (Aremu, 1975).

### 1.1 Methods of Tomatoes Preservation

Past research has shown that there several methods of preserving tomatoes. This includes ***Canning, Drying, Boiling, Cooling, mechanical refrigeration, controlled atmosphere, hypo baric storage and other sophisticated technique***. The techniques are highly capital intensive and for most developing countries, the required man power is either lacking or in-adequate. Although, refrigeration is very popular but it has been observed that several fruits and vegetables, for example banana, plantain, tomato etc. cannot be stored in the domestic refrigerator for a long period as they are ***susceptible to chilling injury*** (Shewfelt, 1994; Olosunde et al. 2009). Apart from this, the epileptic power supply and low income of farmers in the rural communities' makes refrigeration expensive. The injurious effects this has on stored tomatoes products are often very severe, hence, one of the major reasons for the low efficiency of this system in extending the shelf life of fresh tomatoes. Low temperature and high relative humidity can be achieved by using less expensive methods of evaporative cooling

(Seoyoum and Woldetsadik, 2000; Seyoum and Woldetsadik, 2004). Thus, cooling through evaporation is an ancient but effective method of lowering temperature.

**1.2 Principle of Evaporating Cooling**

Evaporative cooling is a physical phenomenon in which evaporation of a liquid, typically into surrounding air, cools an object or a liquid in contact with it. Evaporative cooling occurs when air, that is not too humid, passes over a wet surface; the faster the rate of evaporation the greater the cooling. Different designs of evaporative coolers have been reported in literature for the preservation of fruits and vegetables (Redulla, 1984a,b; FAO, 1986; Roy 1989; Thompson and Scheureman, 1993; Acedo, 1997, Noble 2008). The design ranges from straw packing house to some sophisticated design.

Thus, this work is aim at developing an ambient control method for tomato (Lycopersicum esculentum) preservation, which could be achieved through:

• Design, construction and testing of a 0.22m$^3$ storage facility to preserve tomatoes using the principles of evaporative cooling.

• Evaluation of the facility

i. To examine the temperature at which the shell life of tomatoes would be expected

ii. To determine the thermodynamic properties (dbt, wbt, by-pass factor, relative, cooling capacity and cooling efficiency) of the machine.

## 2.0 MATERIALS AND METHODS

The following were considered during the design:

1. The evaporative cooler was designed with locally available materials to reduce cost.
2. The shape of the cooler is cuboids

### 2.1 Materials Selections

The selection on the type of materials used in the designed was based on the following conditions:

i) Porosity ii) Evaporation rate of the material iii) Availability iv) Cost v)Ease of construction

The materials used for the cooler were galvanized mild steel, stainless steel and polystyrene foam (insulated material), an extractor fan (with velocity 4.3m/s and 1250 rpm), Evaporator (jute of 0.06 thickness), Compressor (1/8 hp), Condenser, Capillary tube (2 yrds), Lagging material (polystyrene foam), Temperature control, Gas 134 (2ps), Butane gas (2 lines), Brass and silverous rod, Capillary 'D' oil, Filter drier, Electric wire (3yrds), Charging valve, Paints, Iron rod (1/2 length), Accumulator (5/8 inch), Bolts and nuts (6pcs- 14mm), Housing ( Galvanized steel of 1.03 m$^3$), Amaflex, PVC glue, Angle iron (25x25 mm), Fresh tomatoes (unripe- 1.020kg)

**2.2 Design Layout and General Description of the machine**

The evaporative cooler is made up of double jacket walls. The inside wall is a cuboids(550mm long x 510mm wide x 770mm deep) shaped galvanized steel storage structure with partitions for storage of tomatoes. The outside wall is also a cuboid (580mm long x 540mmwide x830mm deep) with a 30mm gap separating it from the inside wall. Galvanized steel was chosen because of its low conductivity of heat and is abundantly available.

The walls of the cooler were insulated with lagging materials (polystyrene foam) to reduce the heat transfer by conduction. The interior of the cabin was divided into three sections by a painted wire mesh. The shelves are of dimensions (320 x 520) mm$^2$, (150 x 520) mm$^2$ and (150 x 520) mm$^2$ respectively. The shelves are allowed to slide in and out for easy access and the removal of the produce. A detailed engineering drawing showing the front view of the complete assembly of the evaporative cooling system is shown in Appendix.

### 2.3 Sample Preparation

***Weighing of tomatoes*** → ***Shelving/preserving*** → ***Testing***

### 2.4 Experimental Procedure

Two tests were conducted everyday starting from September to October, 2012. The cooler was evaluated on the temperature drop between the ambient and the storage environment of the evaporative cooler, change in relative humidity between ambient and storage environment, cooling capacity and efficiency. The parameters monitored or calculated were; relative humidity, dry and wet bulb temperatures etc. Also evaporative cooling chamber relative humidity, dry and wet bulb temperatures were also determined.

### 2.5 Evaluation

- The cooling efficiency is calculated as follows (Lertsatitthanakorn et al. 2006):

$$\eta = \frac{T_{db} - T_a}{T_{db} - T_w}$$

- Yun (2008) provided an algorithm for calculating the cooling capacity of direct evaporative cooler as follows:

$$\text{Colcap} = 1.08 * Q * (Ts - \eta\,[\,T_{db} - T_w]\,)$$

Tdb = dry bulb temperature of ambient air (0C)

Tw = wet bulb temperature of the ambient air (0C)

Ts = temperature of cold air (0C)

Q = air flow rate ($m^3/s$)

$\eta$ = evaporative effectiveness (%)

$$\text{Weight loss} = \frac{\text{initial weight} - \text{final weight}}{\text{Initial weight}} \text{ X } 100\%$$

- **Saturating (Humidifying) Efficiency**

This is the ratio of dry-bulb temperature decrease to the entering wet bulb depression usually express as percentage.

$$\%\eta_{sat} = \frac{(t_{db1} - t_{db2})}{(t_{db1} - t_{wb})} \text{ x } 100$$

- **By-pass factor**

$$\%\eta_{sat} = 1 - BF$$

Where, BF is the by-pass factor.

 

## 3.0 RESULTS AND DISCUSSION

Table 3.1: Results obtained for the $1^{ST}$ and $2^{nd}$ Week of preservation

| Days/ wk1 | TIME (hrs) | DBT ($^0$C) | WBT ($^0$C) | RH (%) | Days/wk 2 | TIME (hrs) | DBT ($^0$C) | WBT ($^0$C) | RH (%) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 12.00 | 27 | 20 | 53 | **1** | 12.00 | 25.5 | 20.1 | 50 |
| | 16.00 | 22 | 14 | 40 | | 16.00 | 23 | 18 | 62 |
| **2** | 12.00 | 34 | 24 | 44 | **2** | 12.00 | 24 | 15 | 38 |
| | 16.00 | 30 | 19 | 34 | | 16.00 | 22 | 14 | 40 |
| **3** | 12.00 | 28 | 20.2 | 47 | **3** | 12.00 | 25 | 18 | 50 |
| | 16.00 | 26 | 19.5 | 55 | | 16.00 | 25 | 19 | 57 |
| **4** | 12.00 | 26.5 | 19 | 49 | **4** | 12.00 | 30 | 22 | 50 |
| | 16.00 | 25 | 18 | 50 | | 16.00 | 24.5 | 18 | 52 |
| **5** | 12.00 | 26 | 15 | 29 | **5** | 12.00 | 27 | 18 | 40 |
| | 16.00 | 21 | 14.5 | 48 | | 16.00 | 21 | 14.5 | 48 |
| **6** | 12.00 | 27 | 20 | 55 | **6** | 12.00 | 25 | 17 | 45 |
| | 16.00 | 25 | 18 | 50 | | 16.00 | 25 | 18 | 50 |
| **7** | 12.00 | 28 | 19.5 | 45 | **7** | 12.00 | 28 | 20.5 | 50 |
| | 16.00 | 20 | 15 | 58 | | 16.00 | 24 | 19 | 55 |

The cooling efficiency is calculated as follows:

$$\eta = \frac{T_{db} - T_a}{T_{db} - T_w}$$

Where,

$T_{db} = 29.5$ $T_a = 24$ $T_{wb} = 18.1$

$$= \frac{29.5-24}{29.5-18.1}$$

$$= 0.4825 \text{ or } 48.25\%$$

The cooling capacity of direct evaporative cooler as follows

**Colcap = 1.08 *Q * (Ts – ʅ [ $T_{db}$ – $T_w$] )**

Since,

$$Q = A \times V$$

Where, A is the area of the inner chamber of the cooler and V is the speed of the fan.

Therefore, Q = (0.51 x 0.55) x 1250/60

Q = 5.844

Since Ta = Ts, therefore:

**Colcap = 1.08 *5.844* (24 – 0.4825 [29.5 – 18.1])**

**= 117 W**

Table 3.2: weight of the produce (tomatoes) in 14 days

| Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight (kg) | 1.020 | 1.0171 | 1.0142 | 1.0113 | 1.0084 | 1.0055 | 1.0038 | 1.0038 | 0.9997 | 0.9937 | 0.9910 | 0.9810 | 0.9805 | 0.9800 |

$$\text{Weight loss} = \frac{\text{initial weight} - \text{final weight}}{\text{Initial weight}} \times 100\%$$

$$W_L = \frac{1.0200 - 0.9800}{1.0200}$$

$$= 0.039 \text{ or } 4\%$$

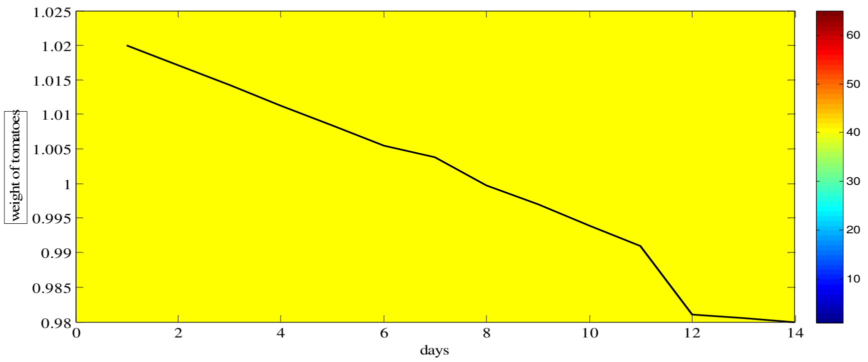


Fig. 3.1: Weight of Tomatoes in 14 days

Table 3.3: Average Relative Humidity of the produce (tomatoes) in 14 days

| Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg Rel. Humidity(%) | 46.5 | 39.0 | 51.0 | 49.5 | 38.5 | 52.5 | 51.2 | 56.0 | 39.0 | 53.5 | 51.0 | 44.0 | 47.5 | 52.5 |

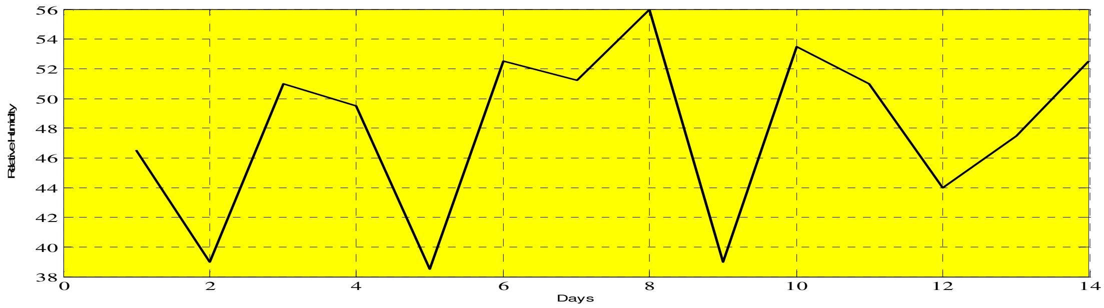


Fig. 3.2: Average Relative Humidity of Tomatoes in 14 days

Table 3.4: Weight of the produce (tomatoes) and Average Relative Humidity in 14 days

| Weight (kg) | 1.020 | 1.0171 | 1.0142 | 1.0113 | 1.0084 | 1.0055 | 1.0038 | 1.0038 | 0.9997 | 0.9937 | 0.9910 | 0.9810 | 0.9805 | 0.9800 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg Rel. Humidity(%) | 46.5 | 39.0 | 51.0 | 49.5 | 38.5 | 52.5 | 51.2 | 56.0 | 39.0 | 53.5 | 51.0 | 44.0 | 47.5 | 52.5 |

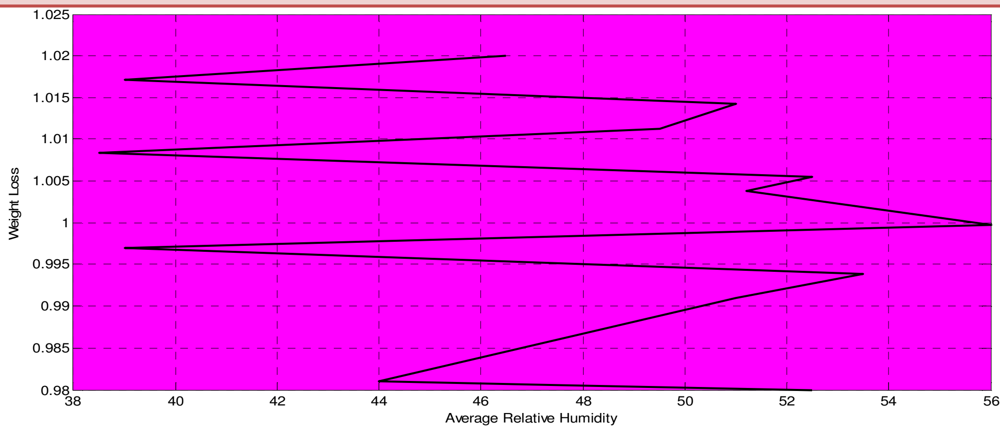


Fig. 3.3: Relationship between Weight and Average Relative Humidity of Tomatoes in 14 days

Table 3.5: Saturating (Humidifying) Efficiency and By-pass factor of the produce in 14 days

| Days | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Saturating Efficiency (%)** | **50.00** | **32.00** | **24.00** | **18.75** | **44.44** | **25.00** | **74.42** | **38.74** | **21.00** | **0.00** | **55.00** | **55.81** | **0.00** | **48.48** |
| **By-Pass Factor** | 0.50 | 0.68 | 0.76 | 0.81 | 0.56 | 0.75 | 0.26 | 0.61 | 0.79 | 1.00 | 0.46 | 0.44 | 1.00 | 0.52 |

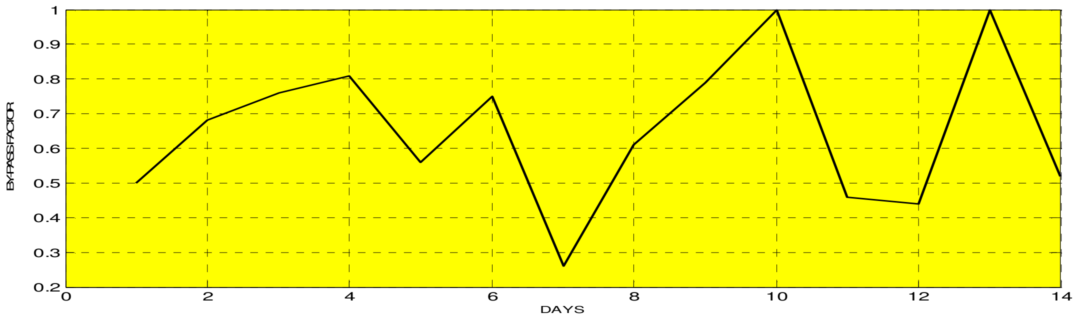


Fig. 3.4: By-pass factor of the cooler in 14 days

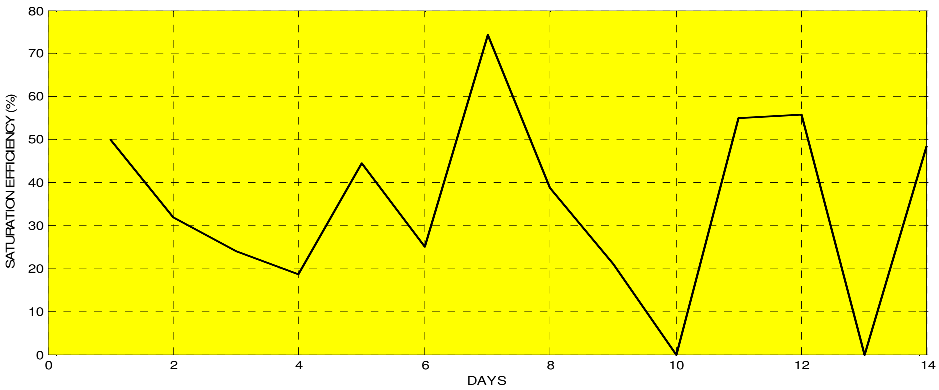


Fig. 3.5: Saturation Efficiency of the cooler in 14 days

 

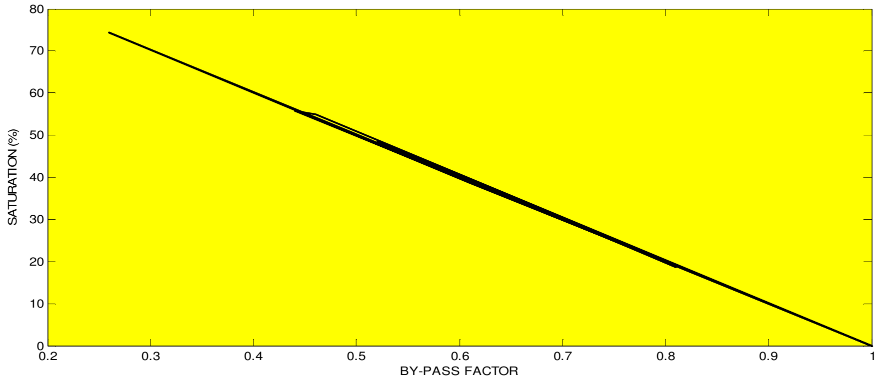


Fig. 3.6: Plot of Saturation Efficiency against the By-Pass factor of the cooler in 14 days

**Discussion**

The efficiency of the cooler during the load test was averagely 48.25 % and the percentage weight loss of the tomatoes was about 4%. The change in the firmness of the vegetable stored in the cooler was negligible when compared to the ones stored in the ambient. It was observed from the result evaluation that 117W is the cooling capacity of the produce (tomatoes) at 29.5$^0$C. Also, from table 3.1, it was observed that the dry bulb and wet bulb temperatures are inversely proportional to the relative humidity of the cooler.

The highest Average relative humidity of the produce (tomatoes) as observed in table 3.2 and fig. 3.1 was recorded in day 8. In table 3.3 and fig 3.2, the highest average relative humidity was recorded (day 8) where the weight loss is at the peak (difference of 0.0033). From fig. 3.3, it was discovered that the by-pass factor is at the peak in the 8$^{th}$ and 13$^{th}$ day, because the cooler has been working constantly without any power interruption. Fig. 3.4 shows that the saturation efficiency is at the peak in the 7$^{th}$ day. No saturation efficiency was recorded in day 8 and 13. Fig. 3.5 shows that there is inverse relationship between the saturation efficiency and by-pass factor.

## 4.0 CONCLUSION AND RECOMMENDATION

The performance of the evaporative cooling system depends on ambient temperature, humidity and Weight. It was observed that the temperature control for preservation of tomatoes must not exceed 29.5$^o$C with relative humidity between 34- 62%.

The system performed up to expectation as tested samples maintained their fresh condition for the 14 days within which they were tested. The required storage temperature for the preservation of the tomatoes samples was achieved at 24°C for the cabinet temperature at an ambient temperature of about 28°C. With respect to the quality of the stored items (tomato) results obtained showed that there is a tremendous improvement over the ambient control system. The system maintained a higher quality of preservation when compared to the mechanical multipurpose refrigerating system. Hence, the excessive chilling or freezing effects normally experienced with tomatoes stored using the former method were naturally eliminated by the operating conditions of this evaporative cooling system, as the stored products were only exposed to their required storage temperatures.

This work has elucidated a cost effective means of preserving fresh tomatoes, which if adopted will reduce post harvest losses, hence increase in income generated from agricultural produce. It is strictly recommended for preservation of tomatoes and other forms of vegetables at home, stores and offices.

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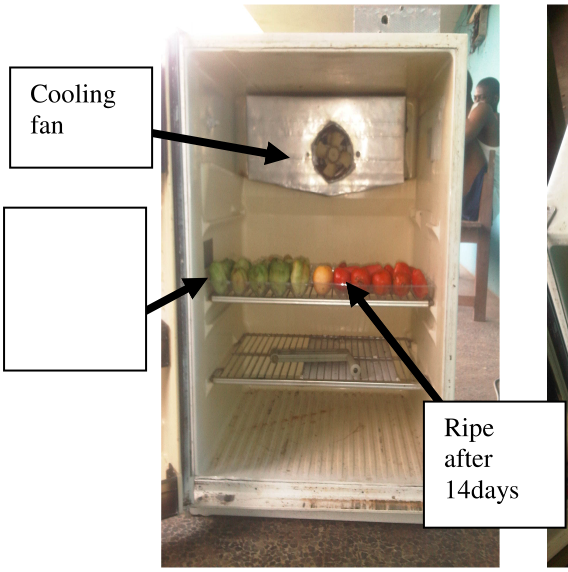
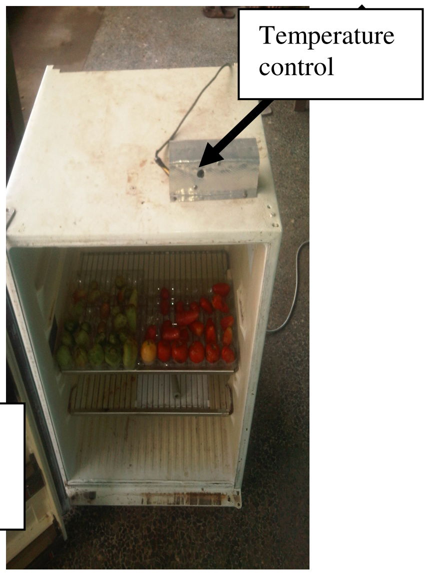
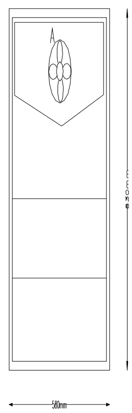
## Appendix



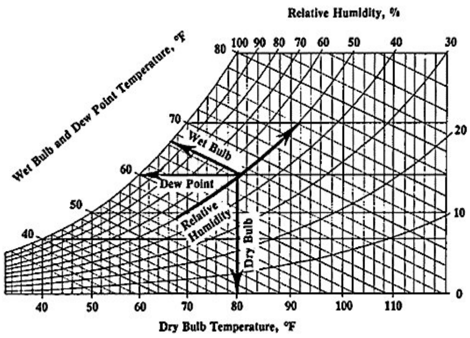



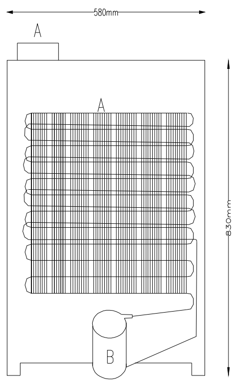

**Cooler**




**front view of the cooler**

## Psychrometric Chart




**Side view of the cooler**