A Review of Porous Evaporative Cooling for the Preservation of Fruits and Vegetables.

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ABSTRACT

The review of a porous evaporative cooler for the preservation of fruits and vegetables are reported in this paper. The different types of evaporative cooler designs under review include: pot-in-pot, cabinet, static, and charcoal cooling chambers. The gap between them is either filled with a jute, damp cloth, or sand. Water is linked to the cooler at the top, thus keeping the chamber cooled. The result of transient performance of the cooler revealed a depression in temperature in the storage chamber. Thus, the evaporative cooler has prospect for use for short term preservation of vegetables and fruits soon after harvest.

(Keywords: pot-in-pot, cabinet, static, charcoal cooling chambers, fruit, vegetable, food preservation)

INTRODUCTION

Cooling through evaporation is an ancient an effective method of lowering temperature. Both plants and animals use this method to lower their temperatures. Trees, through the method of Eva transpiration, for example, remain cooler than their environment.

The basic principle relies on cooling by evaporation. When water evaporates, it draws energy from its surroundings which produces a considerable cooling effect. 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. The efficiency of an evaporative cooler depends on the humidity of the surrounding air.

Evaporative cooling is dependent on the conditions of the air and it is necessary to determine the weather conditions that may be encountered to properly evaluate the possible effectiveness of evaporative coolers (Menzer and Dale, 1960). On the other hand, the amount of water vapor that can be taken up and held by the air is not constant: it depends on two factors: the first is the temperature (energy level) of the air, which determines the potential of the air to take up and hold water vapor. The second involves the availability of water: if little or no water is present the air will be unable to take up very much.

The operational effectiveness of an evaporative cooler is made up of a porous material that is fed with water. Hot dry air is drawn over the material. The water evaporates into the air raising the humidity and at the same time reducing the temperature of the air.

FACTORS AFFECTING EVAPORATION

There are four major factors that impact the rate of evaporation. It is important to keep in mind that they usually interact with each other to influence the overall rate of evaporation, and therefore, the rate and event of cooling.

Factor 1 - Relative Humidity: This is the amount of water vapor in the air as a percentage of the maximum quantity that the air is capable of holding at a specific temperature. When the relative humidity is low, only a small portion of the total possible quantity of water vapor that the air is capable of holding is being held. Under this situation, the air is capable of taking on additional moisture, and if other condition are also met, the rate of evaporation will be higher. On the other hand, when the relative humidity is high, the rate at which water evaporates will be low, and therefore cooling will be low.

Factor 2 - Air Temperature: Evaporation occurs when water absorbs sufficient energy to change from a liquid to gas. Air with a relatively high temperature will be able to stimulate the evaporative process and also be capable of holding relatively great quantity of water vapor. Therefore, areas with high temperatures will have higher rates of evaporation and more cooling will occur. With lower air temperature, less water vapor can be held, and less evaporation and cooling will take place.

Factor 3 - Air Movement: The movement of air, either natural or artificial, is an important factor that influences the rate of evaporation. As water evaporates from a surface it tends to raise the humidity of the air that is closet to the water surface. If this humid air remains in place, the rate of evaporation will start to slow down as humidity rises. On the other hand, if the humid air and the water surface is constantly been moved away and replaced with drier air, the rate of evaporation will either remain constant or increase.

Factor 4 - Surface Area: The greater the surface area from which water can evaporate, the greater the rate of evaporation.

MAXIMUM COOLING POTENTIAL

The extent to which evaporation can lower the temperature of a container depends on the difference between the wet bulb and dry bulb temperatures. Theoretically, it is possible to bring about a change in temperature equal to the difference in these two temperatures. For example, if the dry and wet bulb temperatures were 35°C and 15°C, respectively, the maximum drop in temperature due to evaporative cooling would theoretically be 20°C. In reality, though, while is not possible to achieve 100 percent of the theoretical maximum temperature drop, a substantial reduction in temperature is possible.

METHODS OF EVAPORATIVE COOLING

The two general methods include direct and indirect evaporative cooling.

Direct Cooling

Direct cooling involves the movement of air past or through a moist material where evaporation, and therefore cooling, occurs. This cooled moist air is then allowed to move directly to where to where it is needed. In contrast to this process, indirect cooling uses some form of heat exchangers that use the cool moist air produced through evaporative cooling, to lower the temperature of drier air. This cool dry air is then used to cool the environment, and the cool moist air is expelled.

A direct evaporative cooling is a line of constant wet bulb temperatures. In the course of direct cooling operation, wet bulb temperature and enthalpy remains unchanged, dry bulb temperature reduces while relative humidity and specific humidity increases (Babarinsa,1986).

Direct evaporative cooling is the most commonly used form of evaporative cooling used to cool water. This system usually uses either a porous clay container or a water tight canvas bag in which water is stored. These containers are then either hung or placed so that the wind will blow past them. The water in the container slowly leaks through the clay or canvas material and evaporates from the surface as warm dry air flow past. This process of evaporation slowly cools the water.

Limitations: The drop in temperature will generally be only a small faction of the total evaporative reduction that is possible. This is primarily due to the large volume of water that needs to be cooled by a relatively small evaporating surface area. Only a small number of items can be placed in large water containers.

Indirect Evaporative Cooling

The high level of humidity that is produced by direct evaporative cooling may be undesirable for some applications. Indirect evaporative cooling attempts to solve this problem by using the cool moist air produced through evaporation to cool drier air. The resulting cool air is then used to cool the desired environment. This transfer of coolness is accomplished with the help of a heat exchanger (Singh and Narayah,1999).

All methods of indirect evaporative cooling require power to run both water pump and fans. For this reason, indirect evaporative cooling will have limited applications. It is primarily used to cool dwellings and rooms. In such situations these cooling system are generally less expensive to buy or build and operate than conventional air conditioning systems.

On the other hand, indirect evaporative cooling cannot be used in all environments, and the reduction in temperature that can be achieved with this system is not as great as the reduction that can be achieved with conventional mechanical cooling systems. (Babarinsa, 2000).

The primary advantage of indirect evaporative cooling for increasing the comfort level of rooms are relatively low purchase or building cost and the relatively low operation expense, as compared with convectional air conditioning systems (Singh and Narayah,1999).

COMPARING ALTERNATIVES

Reduction in the temperature of fruits and vegetables to retard spoilage is an important benefit of evaporative cooling, though it is not the only one. Evaporation not only lowers the air temperature surrounding the produce, it also increases the moisture content of the air. This helps prevents the drying out of produce and therefore extends its shell life.

The principal alternatives to evaporative cooling systems are refrigeration and air conditioning. These technologies offer the user a wider range of applications. If electricity, natural gas, or kerosene are available, commercial refrigeration and air conditioning systems can be used in any environment regardless of the temperature or relative humidity. This is definitely not the case with evaporative cooling. Moreover, commercial systems allow the user to control the amount of cooling desired. Again, this is not possible with most evaporative cooling systems. Another advantage of commercial systems is that they usually require less day to day attention than comparative evaporative cooling systems.

However, where electricity or other commercial energy sources are either unavailable or very expensive, and the environmental conditions are favorable, evaporative cooling should be considered as a viable alternative to these more complex and costly commercial systems. (Babarinsa, 2000).

The primary advantage of evaporative cooling over cooling methods that involves commercial refrigeration is its low cost, less than $2. For example, an evaporative cooling system developed in the United States to cool fresh produce was able to produce 14 energy units of cooling while using only one energy units of electricity (Hutchisoon, 2000). Commercial refrigeration system only commonly produce only three energy unit of cooling for each energy unit of electricity consumed (Singh and Narayah,1999).

DESIGN CONSIDERATION/CHOOSING THE RIGHT TECHNOLOGY

Arriving at a decision on which type of cooling or refrigeration system to use is not an easy process. It is important to review carefully the cooling needs, weighing them against a range of other factors before making a decision. The following checklist may be useful in choosing the right design:

1. What are your cooling needs? Cooling different foods require different temperatures.

2. What is the average relative humidity of the area where cooling is needed? If the relative humidity is consistently high, evaporative cooling will not be a viable option, and therefore another system needs be considered. If the relative humidity is low, then evaporative cooling may be effective.

3. How windy is the area where the cooling is needed? If there is little wind evaporative cooling may not be the way to go.

4. Is there a good supply of water where the cooling system will be used? If this is readily available, evaporative cooling may be feasible.

5. Are the materials and skills needed to build the cooler available?

6. Are commercial mechanical cooling or refrigeration systems available? Are they costly? If commercial systems are available, and not too costly, then they may maybe be a better choice of technology.

PREVIOUS TYPES OF EVAPORATIVE COOLER DESIGN

Large amounts of fresh produce and dairy products are lost due to spoilage in many tropical and sub-tropical areas of the world. If this food could be stored at relatively low temperatures until eaten or sold, much of this waste could be avoided. Different types of evaporative cooler have been reported in the literature, some of which include the following (Anyawu, 1995):

Pot-In-Pot

These are simple designs of evaporative coolers that can be used in the home. The basic design consists of a storage pot placed inside a bigger pot that holds water. The inner pot stores food that is kept cool. One adaptation on the basic pot design is the janata cooler, developed by the food and nutrition board of India (Roy,1985). A storage pot is placed in an earthenware bowl containing water. The pot is then covered with a damp cloth that is dipped into the reservoir of water. Water drawn up the cloth evaporates keeping the storage pot cool. The bowl is also placed on wet sand, to isolate the pot from the ground.

Mohammed Abbah (Longmone, 2003), a teacher in Nigeria, developed a small scale storage pot-in-pot system that uses two pots of slightly different size. The smaller pot is placed inside the large pot and the space between then is filled with sand.

In Sudan, the Practical Action and the Women's Association for Earthenware Manufacturing have been experimenting with the storage design of Mohammed Abbah. The aim of the experiment was to discover how effective and economical the Zeer storage is in conserving foods. Zeer is the Arabic name for the large pots used. The results are shown in the following table (Longmone, 2003). As a result of the tests, the Women's Association for Earthenware Manufacturing started to produce and market the pots specifically for food preservation (Longmone, 2003).

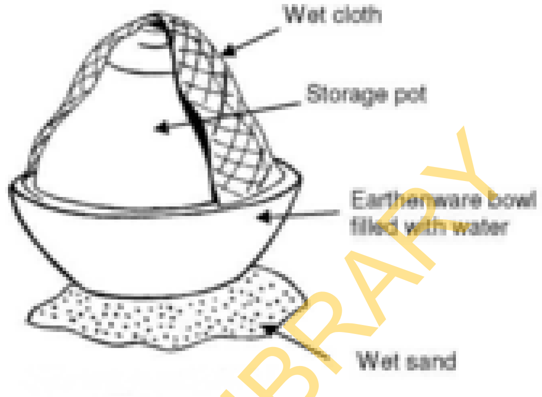

Figure 1*:* Pot-in-Pot *(Roy,1985).*

STATIC COOLING CHAMBER

The India Agricultural Research Institute develops a cooling system that can be built in any part of the country using locally available materials (Roy, 1985).

The basic structure of the chamber can be built from bricks and river sand, with a cover made from cane or other plant materials and sacks or cloth. There must be a nearby source of water. Construction is fairly simple, first the floor is built from a single layer of bricks, and then a cavity wall is constructed of bricks around the outer edge of the floor with a gap of 75mm (3") between the inner wall and the outer wall. This cavity is then filled with sand. About 400 bricks are needed to build a chamber of the size shown below. A covering for the chamber is made with canes covered in sacking all mounted in a bamboo frame. The whole structure should be protected from sunlight by making a roof to provide shade.

Table 1: Vegetable Shelf-Life (Longmone, 2003).

Produce	Shelf-life produce without using the Zeer	Shelf-life of produce using the Zeer
Tomatoes	2 days	20 days
Guavas	2 days	20 days
Rocket	1 day	5 days
Okra	4days	17 days
Carrots	4days	20 days

After construction of the walls and floor, the sand in the cavity is thoroughly saturated with water. Once the chamber is completely wet, a twice daily sprinkling of water is enough to maintain the moisture and temperature of the chamber. A simple automated drip watering system is shown in Figure 2.

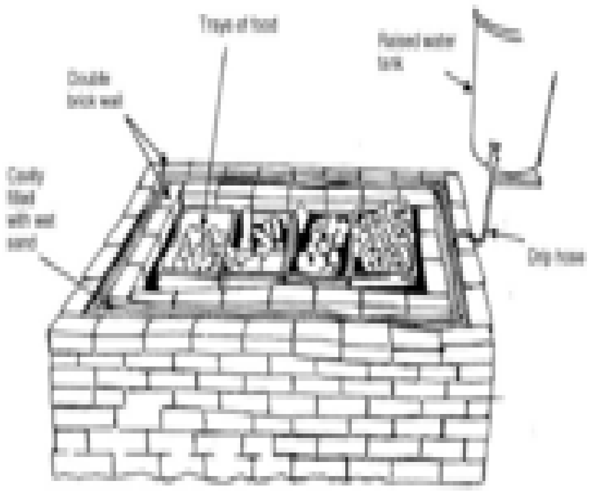

Figure 2: A Static Cooling System (Roy, 1985).

CABINET COOLER

A convenient cabinet is usually encapsulated by evaporating cool surfaces. In some cases, the cabinet is constructed from metallic materials with charcoal placed adjacent to the sides with the result that heat conduction takes place between the outer and inner metal container walls and combine radiative and convective heat transfer within the storage area. This results in little or no temperature difference between the evaporative cooler storage chamber and the ambient air temperature. In particular, seepage of water is inhibited by the non-porous container (Raha, 1994).

CHARCOAL COOLER

The charcoal cooler is made from an open timber frame of approximately 50mm x 25mm (2" x 1") in section. The door is made by simply hanging one side of the frame. The wooden frame is covered in mesh, inside and out, leaving a 25 mm (1") cavity which is filled with pieces of charcoal. The charcoal is sprayed with water and when wet provides an evaporative cooling. The frame work is mounted outside the house on a pole with a metal cone to deter rats and a good coating of grease to prevent ants from getting to the food (Sharma and Rathu, 1991). The top is usually solid and thatched, with an overhang to deter flying insects.

All cooling chambers should be placed in a shady position, and exposure to the wind will help the cooling effect. Airflow can be artificially created through the use of a chimney (i.e., using a mini electric fan or an oil lamp to create airflows through the chimney) the resulting draft draws cooler air into the cabinet situated below the chimney. The butch cooling cabinet uses this principle to keep its contents cool. Wire mesh shelves and holes in the bottom of the raised cabinet ensure the free movement of air passing over the stored food.

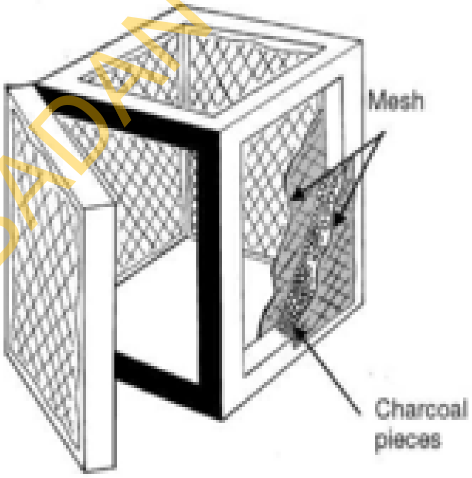

Figure 3: Charcoal Cooler (Sharma and Rathu, 1991).

ADVANTAGES OF EVAPORATIVE COOLER DESIGN

The main advantage of this unit is that it uses simple passive cooling features to achieve low temperatures for the preservation of fruits and vegetables. It requires no special skill to operate and therefore is most suitable for rural application.

Evaporation not only lowers the air temperature surrounding the produce, it also increases the moisture content of the air. This helps prevent the drying out of the produce, and therefore extends its shelf life (AP-Tech, 1980).

In general, evaporative cooling can be used where:

1- Temperatures are high
2- Humidity is low
3- Water can be spared for this use; and
4- Air movement is available (e.g., wind).

CONCLUSION

Evaporative cooler to some extent has influenced the rate of water loss by reducing the temperature in the storage chamber and increasing the relative humidity. Moreover, fruits and vegetables continue the life process that existed before harvest. They respire and in doing so use up oxygen and give up carbon dioxide and generate heat. Temperature and relative humidity have been established to be a major factor that causes the deterioration of foodstuff.

Since significant evaporative colling temperature depression from the ambient air temperature always occurs during the times of the day when cooling is most desired, the cooling condition achieved are suitable only for the short term preservation of vegetables and fruits soon after harvest.

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