THE UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION
INSTITUE OF SCIENCE AND TECHNOLOGY

DESIGNING AN EVAPORATIVE COOLING SYSTEM TO STORE THE SUMMER VEGETABLES IN THE DESERT CONDITIONS

MASTER THESIS

ALYAA ABDULLAH AL-RUBAYE

ID: 1403730061

INSTITUTE OF SCIENCE AND TECHNOLOGY

MECHANICAL AND AERONAUTICAL ENGINEERING DEPARTMENT

MASTER THESIS PROGRAM

NOVEMBER 2017

THE UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION
INSTITUE OF SCIENCE AND TECHNOLOGY

DESIGNING AN EVAPORATIVE COOLING SYSTEM TO STORE THE SUMMER VEGETABLES IN THE DESERT CONDITIONS

MASTER THESIS

ALYAA ABDULLAH AL-RUBAYE

Ref.No: 10171923

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE IN MECHANICAL AND AERONAUTICAL ENGINEERING

Supervisor: Assist. Prof. Dr. MUNİR ELFARRA
Co. Supervisor: Assist. Prof. Dr. AYAD AL-KHAFAJI

الاية

بسم الله الرحمن الرحيم

وَمَا تَوْفِيقِي إِلَّا بِاللَّهِ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْه أُنِيبُ

(صدق الله العظيم)

بسم الله الرحمن الرحيم

الله لا اله الا هو الحي القيوم لاتأخذه سنه ولانوم له مافي السموات وما في الأرض من ذا الذي يشفع عنده الا بأذنه يعلم مابين ايديهم وما خلفهم ولايحيطون بشئ من علمه الا بما شاء الله وسع كرسيه السموات والارض ولايؤده حفظهما وهو العلي العظيم.

(صدق الله العظيم)

Türk Hava Kurumu Üniversitesi Fen Bilimleri Enstitüsü'nün 1403730061 numaralı Yüksek Lisans öğrencisi "**Alyaa AL-RUBAYE**" ilgili yönetmeliklerin belirlediği gerekli tüm şartları yerine getirdikten sonra hazırladığı "DESIGNING AN EVAPORATIVE COOLING SYSTEM TO STORE THE SUMMER VEGETABLES IN THE DESERT CONDITIONS**"** başlıklı tezini, aşağıda imzaları bulunan jüri önünde başarı ile sunmuştur.

Tez Danışmanı: **Yrd. Doç. Dr. MUNİR ELFARRA** ………..

Eş Danışmanı: **Yrd. Doç. Dr. AYAD AL-KHAFAJI**
Kufa Üniversitesi. Ziraat Fakültesi

Jüri Üyeleri: **Yrd. Doç. Dr. MOHAMED S. ELMNEFİ** ………..
Türk Hava Kurumu Üniversitesi

Yrd. Doç. Dr. TAHSIN ŞIŞMAN ..………
Türk Hava Kurumu Üniversitesi

Yrd. Doç. Dr. MUNİR ELFARRA ………
Ankara Yıldırım Beyazit Üniversitesi

Tez Savunma Tarihi: 23.11.2017

STATEMENT OF NON-PLAGIARISM PAGE

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Alyaa AL-RUBAYE
23/11/2017

ACKNOWLEDGEMENTS

After a trip of research and effort by accomplishing this research, we thank God on his grace which is upon and he is Almighty. Also, we express our sincere gratitude and appreciation into my supervisor Dr. Munir Elfarra according to his valuable help and decrease all of the difficulties and facilitate the procedures. As well as, I would like to express my sincere gratitude to my co-supervisor Dr. Ayad Al-Khafaji according to what he has provided of effort and advice during the period of accomplishing this research.

To the bounty of love, honesty and hope his first credit after God to achieve my dream in study my husband dear. To the heartbeat of affection, loyalty and patience dear mother. To my liver and my loved ones, my children Bashir and Amir.

To all those who paved the way for me through the knowledge and knowledge of support and prayer, and from whom the most beautiful family and relatives. I give you all my research this.

NOVEMBER 2017 **Alyaa Abdullah AL-RUBAYE**

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

SECCRW	: Evaporative cooling system**.**	
LSD	: Least Significant Difference	
DC	: Direct Current**.**	
AC	: Alternative Current.	
TSS	: Total Soluble Solids.	
F	: Fan**.**	
F1	: The first speed of the cooling fan.	
F2	: The second speed of the cooling fan.	
Q0	: Without pumping water.	
Q1	: Pumping water with the first discharge.	
Q2	: Pumping water with the second discharge.	
P1	: Submersible Pump 0.1	L/s
P2	: Submersible Pump 0.15	L/s
P3	: Submersible Pump 0.22	L/s
C.ef	: Cooling Efficiency	%
P.L.W	: Percentage of loss in weight	%
Tout	: External Temperature	ºC
Tin	: Internal Temperature	ºC
Tw	: Wet Temperature for External Air	ºC
T.r	: Thermal Reduction	ºC
E.E.R	: Energy Efficiency Ratio	%
Qc	: Cooling capacity	KW
EP	: Electrical Power Consumed	KW
Q	: Air Flow Rate	m^3/s
Cp	: Specific Air Temperature	kJ/kg.k
p	: Air Density at 27 co	kg/ m
W1	: First weight	gm
W2	: Second weight	gm
P	: Power	kw
V	: voltage V	Volt
A	: Current	Amp

ABSTRACT

DESIGNING AN EVAPORATIVE COOLING SYSTEM TO STORE THE SUMMER VEGETABLES IN THE DESERT CONDITIONS

AL-RUBAY, Alyaa

Master. Department of Aeronautics and Mechanical Engineering

Thesis Supervisor: Assist. Prof. Dr. Munir ELFARRA

November 2017, 54 Pages

The evaporative cooling systems are used for storing fruits and vegetables due to their low cost and low electricity consumption. This research aims to design and test a desert cooling room which operates by the solar energy with the cooled walls in order to store the summer plant products in the desert conditions. The used data is the air data of the desert farm which is located in Karbala City - Iraq.

An evaporative cooler is used which consists of clay basin where inside it we placed a metal basin that close from up with an open inside it and the distance between the two basins is filled from three sides by water. The system consists of ventilation fan, cooling pillow and water pumps in order to humidifying the cooling pillow and the clay wall. Measures have been made to the temperature, thermal reduction of air, the cooling efficiency, the performance factor and the relative humidity inside the system. Also, the measurement of the electrical power which calculated for the work of the system. Moreover, some typical agricultural characteristics have been measured when storing the fruits inside the evaporative system where the temperature of the stored fruits, the hardness of the fruits, total dissolved soluble solid, the percentage of loss in the fruits weight and the validity of storing the tomatoes fruits which used in the experiment.

The results clarified that the, manufactured system gave less temperature inside the cooling room (27.5 ° C) when the temperature of outside was 50° C. As well as, the highest thermal reduction is registered where it is about 45% and also the efficiency of the cooling for the system is increased where the cooling efficiency which has been obtained is about 86% whereas the performance factor of the system which has been obtained is amounted 49.7 because of increasing the cooling energy of the system. Furthermore, the system achieved high efficiency by increasing the humidity as compared with the humidity of the air where the humidity inside the system is amounted 84% while the external humidity was 10%. Besides, the results clarified that the use of the evaporative system led to the superior of the temperature for the tomatoes fruits which stored inside. Also, it led to keep its good hardness and strength during the storing periods and the results showed also the superior of the stored tomatoes fruits inside the manufactured system in terms of the number of days and the total dissolved soluble solids from the rest of the fruits which have been stored outside the system.

Keywords: Adiabatic cooling system. Heat Exchanger. Evaporative wall. Cooling and storage basin

ÖZET

YAZ SEBZELERİNİ ÇÖL KOŞULLARINDA SAKLAYABİLMEK İÇİN BİR BUHARLAŞTMALI SOĞUTMA SİSTEMİ TASARLAMA

AL-RUBAY, Alyaa

Yüksek Lisans Tezi, Makine Mühendisliği Anabilim Dalı

Tez Danışmanı: Yrd. Doç. Dr. Munir ELFARRA

Kasım 2017, 54 sayfa

Buharlaştırmalı soğutma sistemleri, düşük maliyetli olması ve düşük elektrik tüketimi nedeniyle meyve ve sebzeleri depolamak için kullanmaktadır. Bu araştırma, çöl koşullarında yaz bitki ürünlerini depolamak için soğutulmuş duvarlı ve güneş enerjisiyle çalışan bir çöl soğutma odasını tasarlamayı ve denemeyi amaçlamaktadır. Kullanılan veriler, Irak'ın Kerbela şehrinde bulunan bir çöl çiftliğinin hava verilerinden elde edilmiştir.

İçine içeriden açık olan ve yukarıdan kapatılan bir metal havzası yerleştirdiğimiz kil havza içeren bir buharlaştırmalı soğutucu kullanılmış olup, iki havza arasındaki boşluk üç taraftan su ile doldurulmuştur. Sistem havalandırma fanı, soğutma yastığı ve soğutma yastığı ile kil duvarı nemlendirmek için kullanılan su pompalarından oluşmaktadır. Sitem içerisindeki sıcaklık, havanın termal indirgenmesi, soğutma verimi, performans faktörü ve bağıl neme ilişkin ölçümler yapılmıştır. Ayrıca, sistemin çalışması için hesaplanan elektrik gücünün ölçümü de yapılmıştır. Bunun yanında, buharlaştırmalı sistem içerisinde meyveler depolanırken bazı tipik tarımsal özellikler de ölçülmüştür. Bunlar; depolanan meyvelerin sıcaklığı, meyvelerin sertliği, çözünür katıların toplam çözünme oranı, meyve ağırlığındaki kayıp yüzdesi ve deneyde kullanılan domates meyvelerinin depolama geçerliliğidir.

Sonuçlar, imal edilen sistemin, dış ortam sıcaklığının 50° C olduğu durumda soğutma odasında daha az sıcaklık (27.5° C) bulunduğunu göstermiştir. Buna ilaveten, en yüksek termal indirgeme yaklaşık %45 olarak kaydedilmiştir. Ayrıca,

sistem için soğutma verimliliği artmış ve soğutma verimliliği yaklaşık %86 olarak ölçülmüştür; buna karşın, sistemin soğutma enerjisi arttığı için sistemin performans faktörü 49.7 olarak elde edilmiştir. Dahası, sistem havanın nemi ile karşılaştırıldığında nemi artırarak yüksek verim göstermiş, dış ortamdaki nem oranı %10 iken, sistem içindeki nem oranının %84 olduğu bulunmuştur. Bunun yanı sıra, sonuçlar buharlaştırmalı sisteminin kullanılmasının içeride depolanan domates meyveleri için sıcaklık üstünlüğü sağladığını ortaya koymuştur. Ayrıca, meyvelerin depolandığı süre içerisinde meyveler sertliklerini ve mukavemetlerini muhafaza etmiş ve sonuçlar üretilen sistem içerisinde depolanmış bulunan domateslerin gün sayısı ve çözünür katıların toplam çözünme oranı bakımından sistemin dışında depolanmış diğer meyveler ile karşılaştırıldığında üstünlük sağladığını göstermiştir.

Anahtar kelimeler: Adiyabatik (ısı geçişi olmayan) soğutma sistemi, Isı Eşanjörü, Buharlaştırmalı Duvar, Soğutma ve Depolama Havzası.

.

CHAPTER ONE

INTRODUCTION

1.1 Evaporative Cooling

Air and other liquids can be cooled with wet surface heat exchangers by the use of indirect evaporative coolers. The spray waters which are also called recirculation water can be used on wetting the surface of the cooling air. Therefore,, the temperature of the wetted surface can be decreased by the water film which evaporate into the cooling air. The main air or other process fluid streams in the alternate passages and is cooled by indirect interaction with the spray water film during the heat exchangers splitting wall. Currently, in all parts of the world, the availability of the energy is considered essential issue for wellbeing and daily life. Thus, the energy consumption will be increased in spite of increasing the prices of fuel because of the population growth. Many problems must be taken into consideration including depending on sources, raise the cost or the environmental effect of the energy use and transformation which will be faced. Therefore, there is a necessity of finding new legislation which works on guaranteeing the sustainable energy at reasonable costs [1].

The environmental effect related to the energy use from the traditional fossil origin, the energetic dependency on non-renewable resources resulted to the importance of decreasing the consumption of energy; maintain present goals and requirements for each activity that need the energy use. The percentages related to the energy consumption clarify that about 20% to 40% from the total energy demanding in the developing countries is in the houses because of the climatic condition change [2]. Furthermore, because of the high number of users who work in the construction sector, the enhancement on the energy effectiveness of the systems leads to a significant decrease in the energy consumption. Therefore, the building sector is considered one of the most important fields to emphasis the activity to enhance the energy competence. Nevertheless, consider the energy efficiency use must not be considered from the economic way only but also the environmental impacts and misuse of the natural resources [3]. In spite of the reality that the importance of the new dispositions presented for energy management, new devices and generators between others, is to decrease the consumption of energy in buildings, they must guarantee a appropriate ease level and wellbeing for the users [4]. Therefore, in order to obtain a suitable thermal environment inside the buildings, the system which must be entered should permit the hydrothermal environment of the rooms and preserve the quality of the air in the closed places which consist with the requirements of the low energy.

1.2 History of Evaporative Cooling

This method is succeeded in the dry and hot climates and thus, it has been applied firstly in the Near East. Therefore, in images from Ancient Egypt (2500 B.C.) it can be illustrated how slaves fanned big vessels filled with water, which were porous adequate to authority this water in order to permit during the ceramic wall and preserve the surface humid, evaporating to the air [5].

The idea of cooling by evaporation is used at the societies from a long time by wetting a portion of the cloth and places it at the open of the tight or window as a way to reduce the temperature and thus, air conditioning the atmosphere. The cooling by evaporation method is used by the plants in the evaporation-transpiration process and some animals which use the same idea of cooling by evaporation when they leave the water to the air. As well as, the human gets ride from the extra temperature in his body according to the vital operations and the extra effort through the evaporation of the sweat which formed in his body and then the temperature of the skin surface is reduced.

The cooling systems by the water evaporation are considered of the most cooling systems spread in the agricultural organizations in the desert areas according to decrease their costs and less consumption of the electrical energy which difficult to be offered at these areas if compare with the compressibility cooling systems. In addition, they increase the moisture content of air inside the storages and the cooling and storage systems which decrease the water effort on the stored crops and fruits. Thus, the probabilities of the crop damage at early time will be decreased and the cooling by evaporation methods are considered with high efficiency in cooling and humidifying the air especially in the regions with hot and dry atmosphere according to the high ability of the air on evaporating the water where the cooling process is implemented through the contact method between the air with a water where its temperature degree equal to the humidified temperature of the air and the physical temperature of the air on the evaporation of water which lead to decrease the dry temperature of the air and increase its humidifying content [6]. There are many ways for ventilation and cooling for the agricultural and cooling organizations as mentioned by Fang [7].

The researcher studied many methods in order to find the best method of ventilation and cooling for cooling and preserving the storages and he found that the fan and pillow method is considered one of the best used methods. As well as, she mentioned that the use of the mechanical cooling increase the operating costs. The quantity of the evaporation is proportional with surface area of the wood chips with the surface area. The evaporation depends on the quantity of air which passing above the wetted surface. So, if the speed of air is high, the quantity of evaporation will be increased (Farag, 1999). Also, the amount of evaporation is affected by a number of factors including the temperature, dryness of air and increase the water temperature. The efficiency of cooling by the use of desert air-condition cooling depends on the difference between the temperature of the entering and leaving dry air. The degree of cooling can be concluded by applying the equation of cooling efficiency. Moreover, there is a study applied on the poultry buildings in the regions of desert and dry climate. The study is concentrated on these buildings in terms of the construction, ventilation, cooling and self-control characteristics and it is found that all of these farms have been cooled by the evaporative cooling with fans and pulses [8]. The pulses material are the pillows with papery follicles (cellulose) and these buildings include fans with ability of pulling the air per one and one and half time each minute as advised [9].

There are attempts to use proud materials in the pulse of the evaporative cooling chambers such as paper, wood, metals, glass, plastic and cement. The pillows with papery grooves and the wood carpentry pillows are considered of the best used materials in the chamber pulses [10]. Moreover, it is found that the average of consuming the waters in the cooling process by the use of papery pillows with grooves when reducing the temperature from 45 degree to 25 degree at relative humidity of 10% reaches to about 24 L/h for each square meter from the area of the cooling pillow [11].

1.3 Theory on Evaporative Cooling

It can be imagen that the evaporating cooling as the process of transferring the heat and mass depending sensible heat transportation to latent heat. The non-saturated air decreases its temperature, supplying the practical heat that converts to latent heat in order to evaporate the water.

If the operation is developed in optimal adiabatic circumstances, the temperature of the dry bulb air reduces as the alterations is developing and increase its humidity. Until the reaches of the air to the saturated status, the heat exchanger will continue. So, if the temperature of water and air reached to the same value which is called “adiabatic saturation temperature”, the process is called “adiabatic saturation”.

In order to determine the temperature, a long adiabatic tunnel can be supposed where the air which includes humidity is introduced in specific circumstances whereas the water is sprayed inside the tunnel. Later, the water will be recalculated in a way where the air becomes saturated. In general, the waters gain some exterior practical loads in the pipes, tank and pumps. Furthermore, the water provided temperature in order to support the evaporated part and purges is not necessary to be the adiabatic inundation temperature of cove air. Therefore, the conception of “adiabatic saturation” in the evaporative cooling process is the unique theoretical limit up to which water or air complicated could be preferably cooled.If the water temperature is significantly above the air adiabatic saturation temperature,the process will be similar to the one feature of a cooling tower, where both air and water are cooled concurrently. The direct evaporative coolers for example this what is called “spray in air stream system” is heating the water through the pump or by advantages from non-insulated pipes. When the issue is associated with air, both of them supply heat and cold when it converts to latent heat where the water evaporates eradicating the heat from the environment in order to authority the stage changes from the liquid to vapor, moistening the air. The greatest percentage of the direct spray system is using non-recalculated water because they allow to decrease incrustations and corrosion. Nevertheless, these systems must always avoid the generation of aerosols, and generally includes an infrared radiation system. The adiabatic saturation includes limits in the cooling which must be accomplished. The total of practical heat detached is not surpassing that of the latent heat essential in order to saturate the air. Therefore, the possibility of cooling is highly depending on the humidity of air. Thus, this operation is not very efficient when the relative humidity is very high. The evaporative cooling introduces the following theoretical and real processes:

1.4 Conventional Evaporative Cooling Systems

The direct systems, indirect system or the combination of these two systems can achieve the evaporative cooling in various stages [12].

A. **Direct evaporative cooling systems:**

   The water is evaporating directly in the air stream through the direct systems and creates heat exchange adiabatic process where the air dry bulb temperature declines when its humidity raises. Therefore, the heat transfer quantity from the air to water is similar to that which employed in the water evaporation.

B. **Indirect evaporative cooling systems**

   The indirect evaporative cooling technique evaporates the water through a secondary air flow that exchanges the piratical heating with the preliminary one in the heat exchanger. At this technique, the flow of the external air will be cooled when keeping in contact with the surface during which the heat exchange is created without adjusting its total humidity. While the other side of the surface, the flow of the secondary air is being evaporative cooled. Therefore, this method which is called indirect is generally used in the applications where the humidity addition is not permitted in the provision air. Since there is no mass exchange is allowed between the streams of the two airs, it does not include contamination possibilities.

1.5 Thesis Objectives

1. The beneficial from the thermometer in the evaporative cooling which give high efficiency and better cooling.
2. Reach into a simple cooling method which is inexpensive economically, ease to maintain and suit with desert regions and its special circumstances for the farm products.
3. Reach into a design which give less possible temperature and decrease the electrical consumption by using local materials which consist with purchase ability of the farmer.
4. Publish the importance idea of the evaporative cooling inside the agricultural society.

1.6 Thesis Outline

Chapter 2: It includes the theoretical background of the evaporative system, methods used to preserve fruits, methods used for cooling and the conventional cooling systems.

Chapter 3: Description about the methodology used and the experimental setup and design parameters.

Chapter 4: Results and discussion

Chapter 5: Conclusion and recommendation

CHAPTER TWO

THEORETICAL BACKGROUND

2.1 Introduction

One of the most important problems which effect on the human being is the desertification phenomenon where it has negative effect on the different human activities including the agricultural activities and especially in the countries which suffer from the dry or semi-dry especially in Iraq. This problem has direct relationship with people life because it effects on the environment elements such as its effect on the food resources and the atmosphere pollution [1].

The oil is considered one of the most important resources that drive the life wheel and it is considered one of the sources of energy depleted because there are many technical problems in order to open new channels for oil production. Moreover, Iraqi environment includes a large quantity of pollutants which effect negatively on the agriculture and industrial activities especially which locate far from the electrical energy such as the far villages and desert areas [2].

Thus, this phenomenon must be studied deeply by the researchers in order to understand its real reasons and decrease its harmful impacts. This chapter provides a theoretical study about its real reasons in order to find solutions to its real causes and state the problems cause by the desertification for the human and environment.

2.2 Tomato

Tomato (Lycopersiconesculentum Mill.) is considered as one of the must produce vegetables during the world and the production of this vegetable is taking to increase day by day. The diet and healthy food can be obtained by the tomatoes. This vegetable includes a large quantity of vitamins, sugars, minerals, essential amino acids and dietary fibers [3]. In 2001, the cultivated area of tomatoes is approximated about 3.9 million hectares and produced more than 105 million tons [4]. The cultivated area of this vegetable is increasing by day and it is economically attractive. The tomatoes consist of phosphorus, vitamin B and C and iron. The fresh tomatoes are consumed in salads or cooked in sauces, soup and meat or fish dishes. It is considered an annual plant, its color varies between yellow to red and its shape differ per cultivar [5]. The fresh tomatoes are popular in the markets and versatile fruit vegetable which have important contributions to human nutrition through the world because of their content of vitamins, sugars, minerals, acids, lycopene and carotenoids, among other constituents [6].

2.2.1 Methods for Preserving Tomatoes

In general tomatoes are considered acidic while the degree of its acidic differs depending on their diversity and ripeness. The pH value increase when increasing the ripeness of the tomatoes. The pH value of the full ripe tomatoes ranging between 4.3 to 4.9 which put some tomatoes in the range of low-acid range (defined as a pH greater than 4.6) [7].

It is possible to froze the tomatoes in the form of sliced, chopped, or puréed. In addition, the tomatoes can be frozen in raw or cooked, as juice or sauce, or organized in the recipe of your selection. Any recipe cook tomatoes can use the thawed raw tomatoes. Nevertheless, it is not good to substitute the fresh tomatoes because the freezing make its texture soft. Tomatoes must be seasoned just before attending rather than before freezing. Freezing may be strengthen or weaken seasonings for example herbs, onion, and garlic [7].

2.2.2 Impact of Storage Conditions on Tomato Quality

The recommendations of storage and ripening are well known for everybody but the quality problems related to the bad temperature is continuing to arise through the distribution process. The tomatoes of cherry and grape are also known as snacking tomatoes [8]. There are post-harvest recommendations states that the tomatoes including the cherry and grape tomatoes must be stored at 10°C or higher in order to avoid chilling injury [9, 10]. However, even 10°C may hurt the flavor quality of tomatoes. The symptoms of chilling injury consists the failure to ripen and develop full color and flavor, crooked color development, extreme tempering, surface pitting, and amplified decay [11]. The existing of high levels of carbon dioxide (>5%) lead to damage the tomatoes while the low oxygen (3-5%) atmospheres lead to delay the tomatoes ripens. The injuries of carbon dioxide are characterized as uneven ripening and off-flavors because of increase in ethanol and acetaldehyde. If the concentrations of carbon dioxide increase than 5%, they lead to many problems such as softening, unequal coloration and surface discoloration [12, 13].

2.3 Cooling

One of the basics to protect the quality of the production is the cooling. The cooling works on increasing the shelf life of fresh produce by decreasing the physiological change rate (respiration, ethylene production, enzymatic processes and waterloos) and by reducing the microorganisms' growth. Every form of cooling is suitable in order preserve the quality of the product because cooling work on pulling the surrounding heat to the product and then increase its life period. It is possible to use simple cooling techniques in order to preserve the product better than not to use any cooling techniques at all. Cooling is considered the unique tool which is used to protect the product after the harvest especially those that quickly expose to damage [14].

2.3.1 Principles and Importance of cooling

Reduce the temperature of fresh products delay the metabolic activity and increase the period of life (Figure 2.1.a). The least temperature which is necessary to achieve the maximum validity period to preserve the product varies from one element to another according to its chilling sensitivity. The microbial activity can be blocked through cooling where it prevents the spread of proliferation which yields decay (Figure 2.1.b). Ice or water can be used in order to cool the fresh products in direct way or the use of cold air to protect the products in indirect way [15].

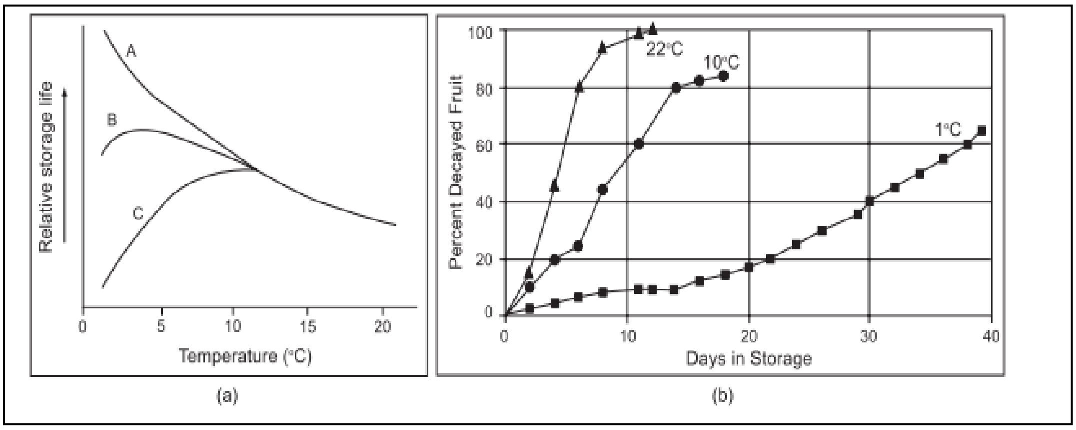

Figure 2.1. Storage life of produce and effects of temperature on fruit decay

The importance of precooling [14]

1. **Importance of lag time between harvest and cooling:** after the harvest of the product, the field temperature must be removed from the product because they cause quick deterioration for some horticultural crops.
2. **Influence of cooling on the respiration rate:** decrease the respiration rate after the harvest is essential issue to preserve the product quality where the deterioration rate after the harvest is directly associate with the respiration rate of the harvested products.
3. **Influence on metabolism:** the metabolic process of the crops determine the increase or decrease in the deterioration of product. The averages of deterioration process of crops within the plants increase when the temperature increases.
4. **Effects of rapid cooing on ethylene:** reduce the temperature degree provide additional features to the crops where it works on decreasing the productivity and sensitivity of ethylene which fasten the ripening and senescence. Thus, the quicker and more prompt the field heat and therefore, temperature is decreased after harvest.

2.3.2 Methods for Cooling

The fresh products can be cooled by the use of seven main principles as follow:

- **Room cooling**: this method consists the exposure of the product to the cold air inside refrigerated room. This technique is considered slow process. The room cooling is effective in terms of energy consumption. This method is not enough for the crops which stored in large containers including bulk bins or pallet loads because heat is gradually removed from the crops near the margin of the container while at the center of the container, there is not enough cooling degree [16]. This technique is old and efficient technique for small amount of products or for the products which are not deteriorating quickly [17].

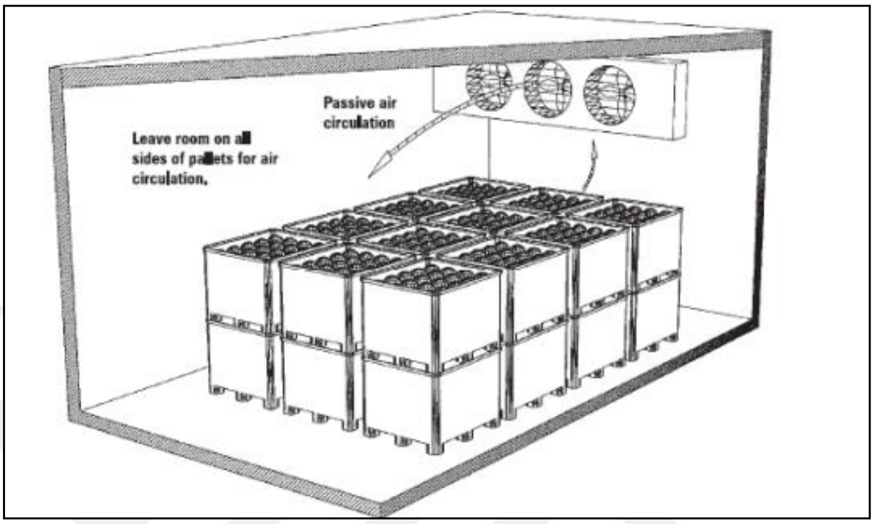

Figure 2.2: Room Cooling

- **Forced-air cooling:** this cooling technique is commonly used. The technique depends on the use of fans which raise the cooling rate in the refrigerated room through the pull of air by packed produce, therefore, picking up heat and significantly increase the heat transfer (Figure VII.4.2). The efficiency of this method is better than the room cooling where the forced air cooling is usually 75 to 90 percent more effective than room cooling. The cooling ratio relies on the air temperature and the rate of air flow over the packages. In order to achieve effective forced air cooling processes, it is necessary that containers which include vent holes be placed in the moving air direction and packing materials that would interfere with free movement of air over the containers must be decreased. This will result in excellent heat transfer and the air movement is good and thus, the cooling process is faster [17].

Figure 2.3: Forced-air Cooling

- **Hydro cooling:** this type of cooling technique is suitable for crops which are not sensitive towards wetting such as celery, peas, beet, Chinese cabbage, Brussels sprouts, cucumber, broccoli, asparagus, pomegranate, carrot, eggplant, squash, radish, green onions, cauliflower, cassava, spinach, sweet corn, cantaloupe, kiwifruit, leek and orange. The cooling process lies in operating the cooling waters (dip or spray) above the crops or products in order to guarantee the removal of temperature rapidly (Figure 2.4). The efficiency of this type of cooling is only about 20 to 40 percent while the efficiency of forced-air cooling is about 70 to 80 percent. The hydro coolers capacity which existed at this type of techniques is smaller as compared with the traditional hydro coolers and thus, they are less expensive [18].

Figure 2.4. Hydro cooling

- **Ice cooling:** this cooling technique uses the fine granular or crushed ice for the cooling process. This cooling technique is effective particularly with dense packages which cannot be cooled by the use of forced air. The heat is removed quickly by the ice when primarily applied on the product unlike the other cooling techniques that continuing absorbs the temperature as it melts. Due to this residual impact, the icing works efficiently with products which characterize to have high respiration ratios including broccoli. In terms of energy effectiveness, icing is particularly energy efficient. The of one pound of ice can cool around three pounds of products from 29.4°C to 4.4°C. Nevertheless, the ice must not include an amount of physical, chemical and biological hazards. As well as, the fresh products can be cooled by the ice bottles. The paper warping prevents the direct contact which existed between the ice bottles and products (Figure 2.5). China uses the ice bottles in order to cool the products with high value [19].

Figure 2.5. Ice cooling using crushed or flaked ice (a) and ice bottle (b)

- Vacuum cooling: this cooling technique is used in order to cool the products with high surface to volume rates that is very difficult to cool by the use of forced air or hydro cooling. Example of fresh products which can be cooled by the use of vacuum cooling include Brussels sprouts, carrot, peas, cauliflower, snap beans, celery, spinach, Chinese cabbage, sweet corn, leek, and Swiss chard. Vacuum cooling is implemented by placing the products inside large metal cylinder which evacuated from air. Vacuum works to evaporate the water from the product surface quickly which reduce the temperature. The water can be applied through the vacuum operation in order to prevent the extreme loss of water. The basic vacuum process can be described as follow [20]:

1. The boiling temperature of water during the atmospheric pressure (1013 mbar) is 100^0C. The boiling point is changing as a saturation pressure function and thus, at 23.37 mbar the water boiling heat will be 20^0C and at 6.09 mbar, it will be 0^0C.
2. The surrounding medium must supply the latent heat of vaporization in order to change from the liquid to the vapor status. Therefore, the

reasonable heat of the product is decreased. The water vapor which emitted from the product should be impassive. A comparison between the different cooling techniques of the horticultural produce is shown in table 2.1.

Table 2.1: Comparison of cooling methods

Variable	Cooling method				
	Ice	Hydro	Vacuum	Forced-air	Room
Cooling times (h)	0.1-0.3	0.1-1.0	0.3-2.0	1.0-10.0	20-100
Water contact with the product	yes	yes	no	no	no
Product moisture loss (%)	0-0.5	0-0.5	2.0-4.0	0.1-2.0	0.1-2.0
Capital cost	high	low	medium	low	low
Energy efficiency	low	high	high	low	low

- Cryogenic cooling: The use of the latent heat of liquid nitrogen evaporation or solid dioxide carbon (dry ice) can yield `boiling' temperatures of -196 and -78^{0}C, correspondingly. This is the basic operations of cryogenic precooling. The products can be cooled by using this technique by carrying it through a tunnel in which the liquid nitrogen or solid dioxide carbon evaporates. Nevertheless, through the temperatures mentioned above, the product will be frozen and therefore, be ruined as a fresh market product. This issue can be avoided by the careful control of the evaporation ratio and conveyor speed. This type of cooling is expensive to operate and cheap to install. The main use of this cooling is to cool the products especially the soft fruits which include seasonal production period. Therefore, the use of this type of cooling, the farmer will not afford the high costs which associate with the alternative cooling techniques during the period of use. This process is considered the most suitable process because of the high cost of dry ice, liquid nitrogen and other appropriate non-toxic refrigerants [21].
- Evaporative Cooling: the product temperature can be reduced in an effective and low cost technique which is the evaporative cooling process. The dry air can be drawn through moist padding or a fine mist of water. Later, by the vented containers of product. When the water status change from the liquid status to the evaporative status, the heat of product will be decreased. The arriving air must be less than 65 percent comparative humidity in order to obtain operative evaporative cooling. It will decrease the temperature only,

10-15°F. This technique is appropriate for the summer season products which need warmer storage temperatures (45-55°F) including tomatoes, eggplant peppers or cucumbers [14]. The evaporative cooling can be defined as the process of heat and mass transfer depending on the transformation of practical heat into latent heat. The temperature can be reduced and obtain a reasonable temperature through the non-saturated air and then the reasonable temperature will be changed to latent temperature to evaporate the water. When this process is developing in optimal circumstances, the air temperature of dry bulb reduces where this transformation improves, increasing its humidity. The exchange of temperature remains until the air reaching to its saturated status when the temperature of air and water reach to the same value which is known as “adiabatic saturation temperature” and the whole operation is known as “adiabatic saturation”. It is supposed to design a long adiabatic tunnel in order to define this temperature which through the humid air is presented in definite circumstances, whereas water is spewed within the tunnel and then recirculate at this way that the air becomes saturated [21].

2.4 Conventional Evaporative Cooling Systems

It is possible to obtain the evaporative cooling by the use of direct, indirect systems, or by the combination of these two types of systems in numerous stages (mixed systems) [23].

A. Direct evaporative cooling systems

At this system, the water will be evaporated straightly in the stream of air and produce an adiabatic process of heat exchange where the air dry bulb temperature reduces as its humidity raises. Therefore, quantity of heat transferred from the air to water is similar as the system which employed in the water evaporation (Figure 2.6). [23, 24].

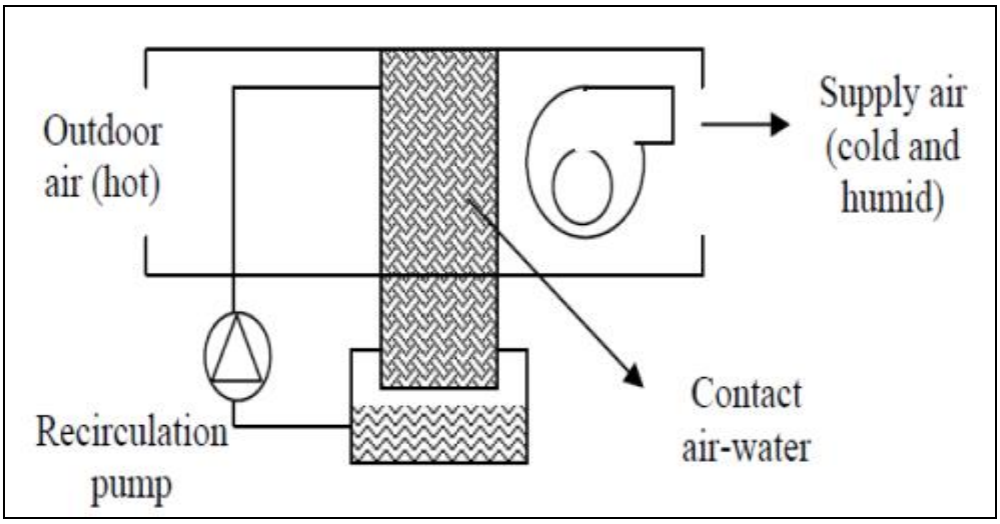

Figure 2.6: Direct evaporative cooler

B. Indirect evaporative cooling systems

At this system, the water will be evaporated in a secondary air flow that exchanges sensible temperature with the principal heat in a heat exchanger. As well as, the external air flow will be cooled when stay in contact with surface where the heat exchanges is created, without adjusting its total moisture. While in the other part of the surface, the secondary air flow will be evaporative cooled. Therefore, the above illustrated techniques is called indirect evaporative cooling technique and it is usually used where it is not allowed to add humidity in the provided air and also, no contamination dangers where no mass exchange is allowed between the two flows of air (Figure 2.7)[23,25].

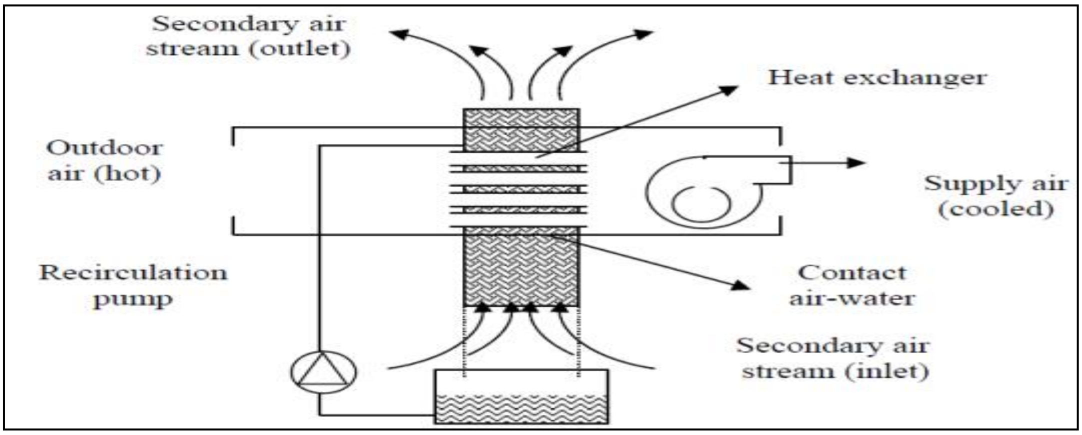

Figure 2.7: Indirect evaporative cooler

CHAPTER THREE

METHODOLOGY

3.1 The Location of Implementing the Experiment

The experiment is implemented in the summer season for 2017 in the Typical Desert Guidance Farm which belongs to the Iraqi Ministry Of Agriculture which locates in City of Karbala that locate 100 kilo meter to the south of Baghdad City. The climate of the region during the summer season is characterized as it is so hot and dry and clearly register the great contrast between the day and night in terms of temperature through this season and the upper temperature may exceed 50 Celsius degree in the shadow while the lower temperature does not decrease to less than 22Celsius degree. Also, the averages of the relative humidity reach to 10% or less. The rate of the monthly solar radiation is 27Mj/m2/m. At this region, the desert cooling system which operates by the solar energy to store the summer plants products that cultivated at the desert areas is designed, tested and studded.

3.2 Experiment Design

The experiment is implemented as it is scientific experiment by two factors and by designing the Randomized Complete Block Design (RCBD) according to the design of dissidents' plants. The number of the experimental units is 18 experimental units $\{2 \times 3\} \times 3$ repeat for each treatment as follow:

1. Main plot which is the plot of velocity cooling fan:
   First: By the use of the first velocity F1.
   Second: By the use of second velocity F2.
2. Sub plot which is the plot of flowing waters on the external wall of the system and by two drainages:
   First: By first drainage Q1 0.15 L/S=450 L/S.

Second: By second drainage Q2 0.22 L/S=792 L/S.

Third: Without drainage.

The plots are distributed randomly according to the selected design where the obtained data have been collected, the experiment have been designed according to the used design, the differences between the plots are tested according to the (LSD) test on the probability level 5% according to the statistics program 12GenStat to test the significance of the differences and the medians of the different plots.

Table 3.1: The diagram of the farm experiment

Device type	Water drainage	Number of repetitions
Fan with first velocity F1	Without drainage Q0	3
		3
		3
	Primary drainage Q1 = 0.15 L/S	3
		3
		3
	Secondary drainage Q2 = 0.22L/S	3
		3
		3
Fan with second velocity F2	Without drainage Q0	3
		3
		3
	Primary drainage Q1 = 0.15 L/S	3
		3
		3
	Secondary drainage Q2 = 0.22L/S	3
		3
		3

3.3 The Way of Constructing and Installing the System

The storage and cooling system (Evaporative cooling system) and abbreviated by (SECCRW**)** consists of the following parts:

1. The external cooling water basin.
2. Internal cooling and storage basin.
3. Cooling fan and evaporative cooling window.

Each of these parts have been constructed, manufactured and configured by the following method:

3.3.1 The External Basin

A suitable place has been selected under an umbrella in the middle of the farm where the direct solar energy does not reach it and it is exposed to the farm air current in all of the directions. The basin is constructed on concrete land and its dimensions have been determined on this land which were $(120 \times 100 \times 60\ cm)$. The clay brick materials are used with dimensions $(20\ cm \times 20\ cm \times 3.5\ cm)$ as porous materials where it is installed by the use of the resistant cement. The porous material is graded in vertical way side by side and with the mentioned dimensions where the obtained basin is shown in Figure 3.1.

Figure 3.1: The External Basin

The basin has been filled by water in order to ensure that there is no leakage. As well as, a valve has been installed in the bottom of the basin for the purpose of emptying the basin when needed. Then, the walls and land of the basin are cleaned from inside and outside from the residues of the cement and building materials in order to take benefit from the largest possible porous area from the evaporative surface which is considered the work basic of the system. Moreover, a waterway is built to the bottom of the basin perimeter from outside which transfers the water coming down from the surface of the external walls to the small storage of the water which has been created beside the basin. Later, the water spray is installed on the upper wall of the basin where special pipes related to the drip irrigation are used and the nozzles of the drip are placed where there number is 36 nozzles which is approximately one nozzle for each 10 centimeter. This spray system is associated with submersible electrical water pumps operate by the solar energy and they are placed in the water collection tank which has been constructed.

3.3.2 Internal Storage and Cooling Basin

A metal basin is designed in one of the blacksmith workshops which locate at the industrial area in Karbala City where the basin is designed by the use of galvanized iron with dimensions $(100 \times 80 \times 90\ cm)$. A glass cover is placed to this tank and it consists of upper part for domestic freezing device. As shown in Figure 3.2, the benefit of this cover is to preserve the temperatures inside the cooling basin and also, the use of the glass gate in order to input and output the crops to be cooled and stored. It must be mentioned that a suitable cover must be placed above this glass in order to increase the thermal insulation.

Figure 3.2: Internal Storage and Cooling Basin

3.3.3 Evangelical Evaporative Cooling System

The process of air cooling is occurred during its pass from evaporative medium with specific velocity by the stabling of the air content which corresponds by the analytical side as it is evangelized process assuming that no heat transfer is transferring between the cooling device and the external environment during the cooling process [37]. Also, the temperature must be less than the temperature of dry onion for the air otherwise, the water will not be evaporated and thus, there is no air cooling.

The evaporative cooling system consists of the following:

- **Ventilating fan**
- **Evaporative cooling basin and gate**

Evaporative cooling system has been designed and implemented and consists of level of sawdust and its depth is about 7 cm and it is installed in vertical form with length of 40 cm and depth 30 cm. This level of sawdust is placed inside a gate of refrigerated evaporative cooler in order to allow the pulled air to enter by the ventilation fan. The passage of this air on the sawdust before its entering to the cooling basin and internal storage. As shown in Figure 3.3, the water is pumped through the water pump that is placed to the bottom of the basin in systematic way where the water reaches to the fibers through a pipe that installed on the gate. The water come out from the pipes on the upper cover of the gate and the container on regular openings in order to guarantee the optimal distribution of water on the fibers and make them continuously moist during the work period. Whereas the excess water comes out to the basin to the bottom of the gate. The basin is made from the same clay material where the external wall is designed and this basin can hold about 50 liter of the water and the reduced water is compensated continuously through a feeding pipe from the external cooling basin which composite with connected raft in order to adjust the level of the water.

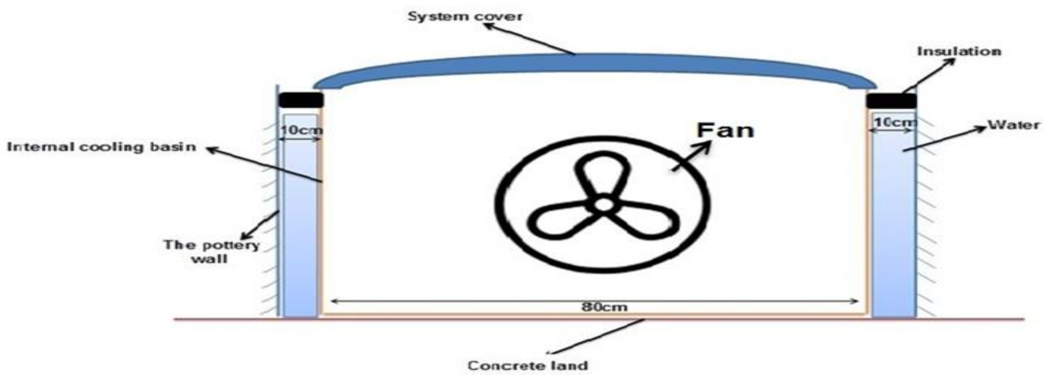

Figure 3.3: A Cross Section for the Evaporative Cooling System

3.4 Installation of the System

After completing the construction, design and preparing the storage and cooling basins which related to the system, the metal storage basin is placed in the middle of the basin which has been constructed. Since the dimensions of the metal basin is smaller than the clay basin, we get on a distance of 10 cm which separate between the clay basin and metal basin from three dimensions where this distance is filled by water as shown in Figure 3.4. While from the fourth side, an open in the upper wall and another open in the metal tank is installed with dimension of $25 \times 25\ cm$ in order to install the evaporative cooling system and the ventilation fan. A small basin which associates with the evaporative cooling system is left and an electrical pump is placed inside it in order to circulate the water inside the cooling system continuously. The interval distance between the metal basin and clay basin is covered from the upper by polystyrene heat insulating material for the purpose of thermal insulation of the basin water.

Figure 3.4: Installing the Metal Basin inside the External Basin and Fill the Interval Distance by Water

3.5 The Used Devices in the Experiment

3.5.1 Solar Energy System

This system consists of the following parts:

1. **Solar panels:** They are a set of associated cells with each other and composing panels with length of 1.20 meter and width of 70 cm and they perform a function of transforming the solar energy into electrical energy.
2. **Charger:** It performs the process of regulating the voltage comes from the panels to the transformer directly.
3. **Transformer**: It transforms the DC power comes from the panels across the charger into alternating current which suits the electrical devices which used in the experiment (from 30 volt to 220 volt).

The type of this system is LORNTZ with German origin and consists of number of the solar panels with energy of 30.4 volt, current of 8.2 amp and capability of 250 watt. This system is installed on fixed supports, strong and resistant to the wind conditions and various weather fluctuations. The silicon material is considered the basic in manufacturing these cells.

3.5.2 Waters Pumps Operate By the Electrical Energy Which Generated From the Solar System

Three pumps immersed by waters have been used where two different drainage water have been placed where the first one is (0.15 L/S) and the second one (0.22 L/S) these pumps transport the water from the water storage basin which related to the system and spray it on the clay wall of the basin which has been constructed. As well as, a third water spray with drainage capability of (0.1 L/S) is placed in the small basin which belongs to the evaporative cooling system as mentioned previously. Table 3.2 shows the characteristics of the pumps which have been used in the experiment.

Table 3.2: The Characteristic of the Electrical Pumps Which Used in the Experiment

Pump Type	Drainage L/S	Consumed Capability. Watt	Consumed Current. Amp
P1	0.1	66	0.3
P2	0.15	77	0.35
PF	0.22	85.5	0.39

3.5.3 Ventilation Fan

The ventilation system consists of pulling fan with variable velocity and its diameter is 30 cm that installed on the ventilation open of the system as shown in Figure 3.5. This fan operates by the electrical energy which generated from the solar system and pulling the air from outside to inside of the storage basin after passing the evaporative cooling system to be cold air. The work of this fan is cooling and humidifying the air entering to the storage basin. The volume of the entering air, velocity, capability, and consumed electrical current of the used fan is calculated as shown in Table 3.3. Moreover, the openings of the drainage air to outside is implemented from the basin of the internal storage by keeping an open in the glass gate which represented by the system cover with distance of 2 cm which through the air leave.

Table 3.3: The Characteristics of the Velocities Which Belong to the Fan used in the Experiment

The used velocity	The volume of entering air m^3/h	The velocity of air	The consumer capability watt	The consumed current amp
F1	0.25	3.6	66	0.3
F2	0.3	4.3	77	0.35

Figure 3.5: An Image Clarify the Used Fan in the Experiment

3.5.4 Evaporative Cooling Gate

It is a cooled gate and wood fiber is placed inside it and the measurement of the gate is (30×40) and its main work is cooling and humidifying the air entering to the storage and cooling system as clarified earlier.

3.5.5 Spray and Distributing Water System

A special pipes have been used by the drip irrigation system with size of 16 mm and drip nozzles with drainage of 5.5 L/H which distributed equally in the upper of the clay wall and its work is to humidifying the clay wall continuously during the work of the water pump which push the waters through these nozzles.

3.5.6 A Set of Thermometers

A set of electronic, mercury, and helical thermometers have been used and placed in the following positions:

- An electronic thermometer which measures the temperature inside the cooling storage tank (SECCRW) with the existing of wire with length of 150 cm linked by its head a sensor which is placed in the external basin water that related to the system and calculate the water temperature at the same time. As well as, this thermometer gives the current reading of the relative humidity inside the storage basin as shown in Figure 3.6.

Figure 3.6: Electronic Thermometer

- Mercury thermometer in order to measure the farm temperature and it is placed under the shadow near to the system.
- Mercury thermometer in order to measure the temapture of the system wall and it is installed on the evaporative cooling gate from outside.
- Helical thermometer in order to measure the entering air temperature and it is installed on the evaporative cooling gate from outside.
- Helical thermometer in order to measure the air which comes out and it is installed on the open of comes out air of the system.
- Helical thermometer and installed in the temporary storage.

Figure 3.7: Measuring the Temperature of the Cooling Wall

3.5.7 The System Cover

The cover of the system is made from a material which is a polyester yarns with slightly larger measures from the measurement of the clay perimeter of the aquarium. The cover is designed from three layers where the first layer consists of polyester yarns, the wood fiber layer and the third layer consists of polyester yarns. This cover is placed completely on the system from the upper and it is humidifying continuously. Its functions are to help in the cooling process and not to lose the temperature from inside.

3.5.8 Sensitive Balance

An electronic sensitive balance is used and contain on system for measurement in gram and kilogram which has been used in order to know the weights of the samples before and after the experiment and during the storage period after the experiment.

3.5.9 Total Soluble Solids Materials Tester

It is a device which is used to measure the percentage of the soluble solid materials "Total Soluble Solids" by measuring the refractive index of the material. Firstly, the device is calibrated by washing it and cleans the screen by a piece of soft cloth and then takes a reading of the Total Soluble Solids from the selected tomatoes samples and register the average of this reading.

3.5.10 Fruit Pressure Tester

It is a device which is used to measure the pressure of the plants fruit such as tomatoes, apple and pears where the pressure of the fruit is calculated after zeroing the device and small portion of the fruit crust will be scraped and measure its pressure and then the prop with (0.5 cm) will be inserted in vertical way in the fruit and for distance of (1cm) in order to register the pressure of the fruit directly where the reading appears on the counter of the device as shown in Figure 3.9.

Figure 3.9: Fruit Pressure Tester

3.5.11 Storage Baskets

A plastic made baskets have been used in order to place the fruits which related to the experiment where three baskets are placed inside the system and another three baskets are placed outside of the system

3.5.12 Fruit of Hybrid Tomatoes of Hatouf 1type

Tomatoes of type Hatouf 1 has been used in the experiment and it is one of the hybrid types and characterize by its tolerated to the salinity irrigation waters where there is adequate quantity of this type has been provided which cultivated under the plastic houses and by the plots ways. This quantity is secured for each day of the experiment days where these fruits are harvested at the early in morning from a tomatoes farm which near from the experiment location and reached to the location as fast as possible to guarantee the accuracy of the experiment which has been obtained. The best samples are selected for the experiment in terms of the shape, color and volume.

3.5.13 Agricultural Climate System

The air system which belongs to the experiment location is used and the current readings for the climate are taken for each of the temperature, humidity and wind velocity for each day of the experiment and take benefit from these readings for the comparison and measurement.

3.6 Experimental Procedure

The practical experiment is implemented by the use of the system which has been created previously (SECCRW). Also, the devices and tools which prepared for the experiment are used and the system is prepared completely after ensuring from the water which exist in the basins related to the system and ensure from the operating of the fan, water pumps and prepare the fruits of the harvested tomatoes at the early morning, reached to the experiment location and prepare the thermometers belong to measure the temperature and place each one of them in the specialized place. As well as, prepare the pressure and soluble testers, electronic balance and the systems is operated before one day of starting the experiment to ensure the correctness of the system performance and then the following steps have been implemented:

First Step: The system is operated by initial velocity of the fan (F1) without pumping water on the external wall of the system and this plot is pointed by the symbol (F1Q0). In the morning of the experiment day, the plastic baskets are prepared and the fruit are placed after accomplishing the initial readings of the materials of Total Dissolved Solids (TSS) and the pressure of the fruits. Moreover, the weights and the temperature of the fruits are registered. A paper clip is inserted in each basket which holds the symbol of the treatment and the repeater for each basket and covers the system correctly as shown in Figure 3.10.

Figure 3.10: Place the Tomatoes in the Baskets Related to the Experiment after Registering Their Weights

Second Step: The measurements of the temperatures have been taken for all of the thermometers which placed in the experiment location and also, registering the relative humidity inside the cooling basin morning at the eight, ten and second o'clock as in Figure 3.11.

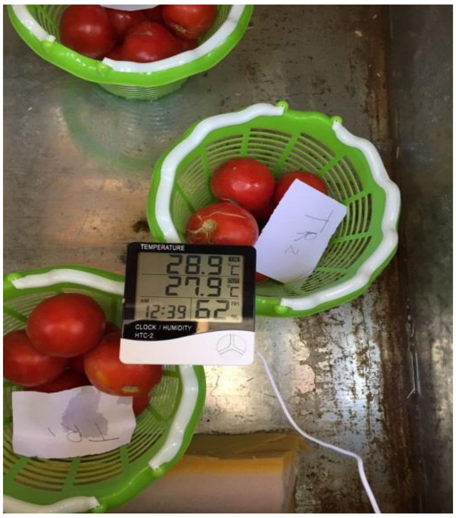

Figure 3.11: Take the Readings of the Temperature inside the System

Third Step: The weight of each basket is taken after the end of the experiment and registering the new weight in the main register of the experiment and also, registering the fruit temperature for the raised baskets. Then, the character of the Total Dissolved Soluble (TSS) materials is registered and the fruit pressure of each repeater. Later, these samples are transported into a temporary storage save with good ventilation inside the experiment farm and each group is placed in one side of the storage and far from each other in order to avoid the transfer of the pathological and fungal infections between the experiment samples. The registration of the weights and other studied characteristics are monitored every day for each repeater and also, the damaged fruits are raised until the damage of all of the fruits.

Fourth Step: The previous steps are repeated on the rest of the factors which belong to the experiment.

3.7 The Studied Characteristics

3.7.1 The Cooling Efficiency

The cooling efficiency is calculated by using the following equation [39]:

$$C.ef = \frac{\text{Tout} - \text{T}in}{\text{Tout} - \text{T}w} \times 100 \qquad (3.1)$$

Where:

$C.ef$= Cooling Efficiency (%).
Tout= external temperature (c^o).

Tin= internal temperature (c^o).

Tw=Wet wet temperature for external air (c^o).

It can be found by the use of Psychometric map depending on the reading of the dry temperature and the relative humidity to the atmosphere.

3.7.2 Energy Efficiency Ratio (E.E.R)

The energy efficiency ratio has been calculated by using the following equation:

$$E.E.R = \frac{\text{qc}}{EP} \qquad (3.2)$$

Where

$E.E.R$= Energy Efficiency Ratio

Qc=Cooling capacity KW.

$$qc = Q \times \rho \times Cp \times (Tout - Tin) \qquad (3.3)$$

Where

Q=Air flow rate (m^3/s).

Cp =Specific Air Temperature (kJ/kg.k)

ρ=Air density at 27 co (kg/ m)

Tout=External temperature (c^o)

Tin=Internal temperature (c^o)

3.7.3 Thermal Reduction of Evaporative Cooling

It has been measured in the dry temperature degrees of the external environment and the dry temperature degree inside the system.

$$T.r = Tout - Tin \qquad (3.4)$$

Where

T. r = Thermal reduction (c^o)

Tout=External temperature (c^o)

Tin=Internal temperature (c^o)

3.7.4 Percentage of Loss in Weight of Fruits

$$P.L.W = \frac{W1 - W2}{W1} \times 100\% \qquad (3.5)$$

Where:

P. L. W = Percentage of loss in weight %

W1= First weight (gm)

W2= Second weight (gm)

3.7.5 The Consumed Electrical Capability

$$P = V \times A \qquad (3.6)$$

Where:

P = Power kW

V = voltage V (Volt)

A = currentA (Amp)

3.7.6 The Temperature Degree and Relative Humidity

The temperature and relative humidity have been extracted and their change has been compared by the use of the electronic, mercury and helical thermometers.

3.7.7 Total Dissolved Soluble Materials

They are approximated by the use of the Manual refract meter of type Measuring rang according to what came in [39].

3.7.8 The Fruit Pressure (kgm/cm^2)

It has been measured in the fruit by the use of pressure degree with a diameter of (0.5 cm^2) and depth of (1 cm) [40].

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 The Mechanical Characteristics

4.1.1 The fridge heat and heat reduction

According to the research plan which aimed to exploit the external walls of the storage space as a mean of evaporative cooling that achieved from the water evaporation from the external surface of the clay wall which cause the reduction of the heat of water that existed in the storage space of the initial cooling and it is called the Solar Evaporative Cooling Chamber with Refrigerate Wall And Its Abbreviation is SECCRW. This works on heat pull from the internal wall of the metal which belong to the storage and this in its role decrease the heat inside the cooling space and contribute in achieving heat reduction that amounted about 9 ° C when the system operate without fan and without water pumping on the clay wall of the system (F0Q0) where the external heat was 47 ° C and became inside the storage 38 ° C.

Adding a desert cooling unit to the evaporative cooling storage achieved high increase in the characteristic of heat reduction where it is clarified from Figure 4.1 that the readings of heat degree and the internal and external relative humidity of the experiment (F1Q1) at the second o'clock, the cooling process starts from the point A until the air saturate with high percentage with water evaporation at B and the vapor pressure of the air equals with the vapor pressure on the water surface. Then, the heat is decreased from A to C and the relative humidity is increased from A to B.

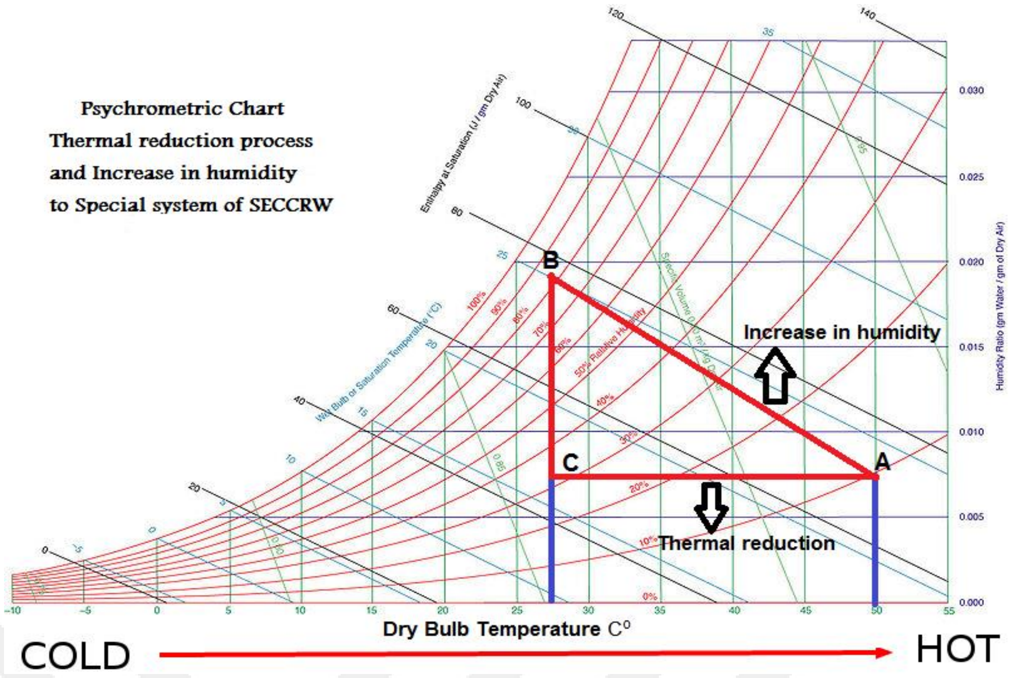

Figure 4.1: The evaporative cooling process on the schematic diagram

It is clarified the superior of the first fan velocity ($3.6 m.s^{-1}$) on the greatest velocity in general. As shown in Figure(4.2) where higher heat reduction is achieved when the fan operates by the first velocity and pumping the water on the clay wall with the first drainage (F1Q1) where the percentage of the heat reduction was (45% and the reason behind this is that the use of high velocity decreased the thermal exchange between the entering air and water that existed in the humidifying region (humidifying pillow) because of the decrease of the required time for heat exchange between the air and the cooling medium and at this case the vice versa. Therefore, the air velocity configures an important factor in increasing and decreasing the performance of the cooling system.

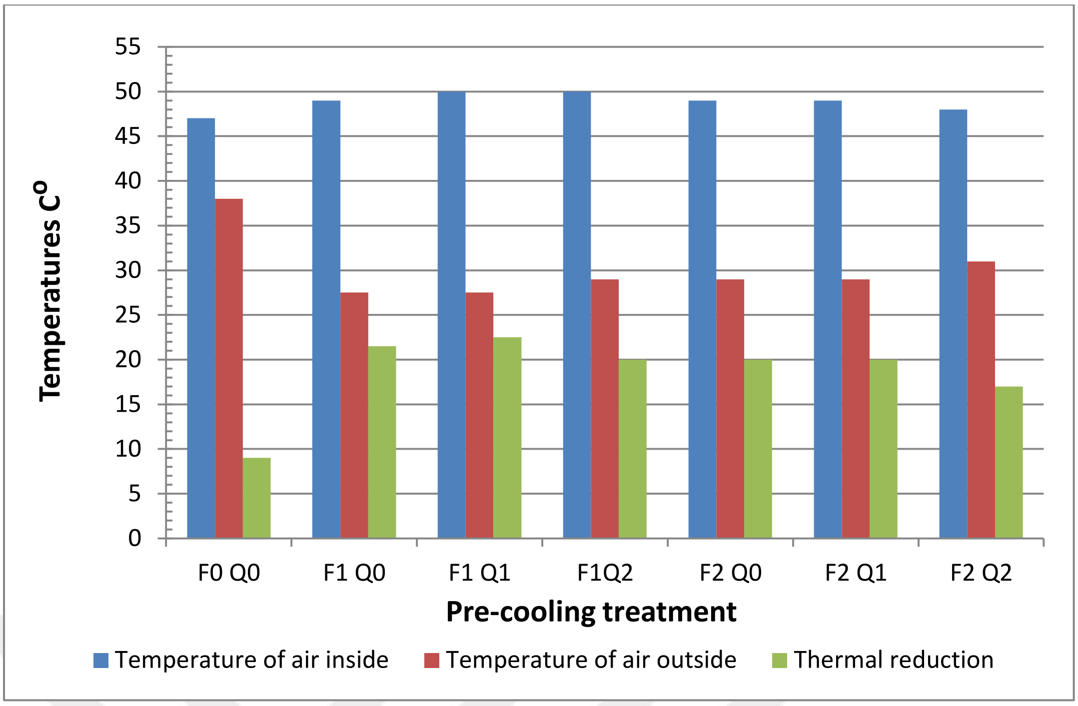

Figure 4.2: Heat reduction for the initial storage factors by using the SECCRW

Moreover, from Figure 4.2, it is clear that the water pumping to the external wall of the clay wall of SECCRW has effected in different ways where we find that the water pumping with the first drainage with less fan velocity (F1Q1) is achieved the highest thermal reduction as compared to the lack of water pumping but when increase the water drainage on the external surface as in (F1Q1), the heat reduction is decreased to 40% instead of 45% for the previous treatment. This matter is also happened with the high velocity. The reason of this is that increasing the quantity of water on the external surface than the optimal percentage which consist with the quantity of water which pass across the porous surface of clay decrease the opportunities of the water evaporation which pass across the clay wall because of the existing of added water level that separate between the external air and the passage waters across the clay surface and the heat of added water is higher than the heat of wall because the water is coming from the side collection basin of the fall waters on the system walls.

4.1.2 Cooling efficiency

Figure 4.3 shows that the cooling efficiency is basically depending on the thermal reduction according to the mathematical equation between each of them. Whenever the thermal reduction is high, the cooling efficiency of SECCRW is increased as in equation (3.1) where the highest value of cooling efficiency is registered through the use of cooling fan with the first velocity and the pumping of water with the first drainage on the clay wall (F1Q1). This treatment is registered very good cooling efficiency and it is amounted about 86%. The reason of this is due that the value of the thermal reduction which occurred at this treatment was very high where the temperature of the air is registered 50 ° C and the internal temperature of SECCRW is 27.5 ° C. Thus, the value of the heat reduction is 22.5° C and it is very high value which resulted from the double cooling processes that happened inside the evaporative cooling systems which manufactured and represented by the operating of clay cooling system and the evaporative cooling system which through these good readings are produced. As well as, the least value of cooling efficiency is registered when using the SECCRW without operating the cooling fan and without pumping any quantity of water on the external wall (F0Q0) where the cooling efficiency was 37% and the reason of this belongs to the lack of heat reduction which happened when using this treatment because of the dry desert circumstances where the heat reduction is amounted at the least value which is 9° C as compared with the treatments which through the evaporative cooling is operated.

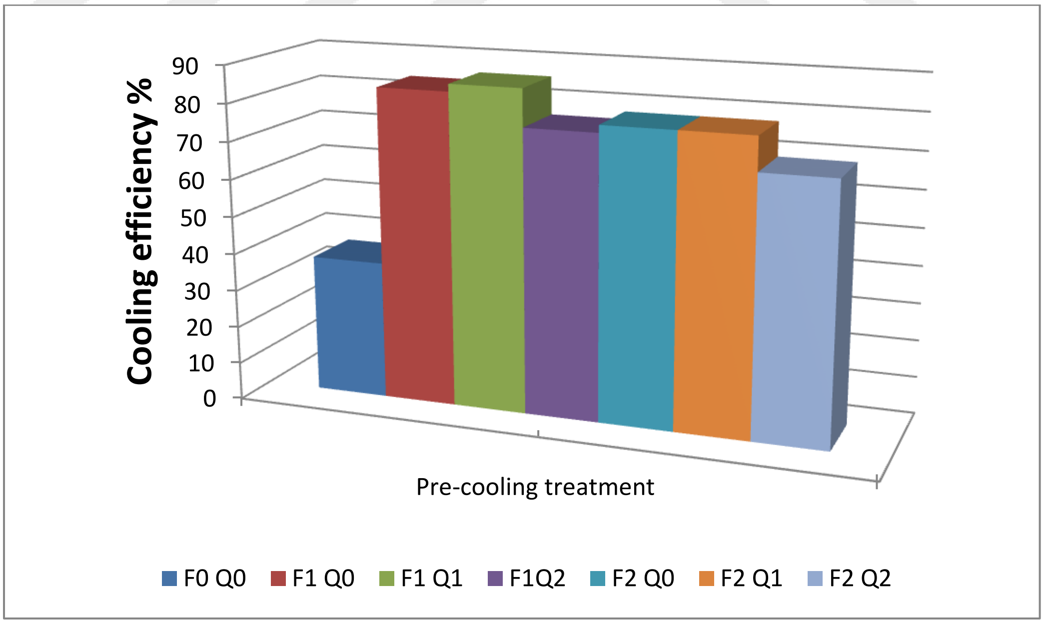

Figure 4.3: Cooling Efficiency

4.1.3 Energy Efficiency Ratio (E.E.R)

Figure 4.4 explains the effects of the studied factors in the efficiency ratio where it is noticed that it is proportional with the value of the cooling energy and it is inverse with the consumed electrical capability for each experiment. Therefore, the efficiency ratio will increase by increasing the cooling energy and decrease the consumed electrical capability as in equation (3.2). it is noticed from Figure 4.4 that the highest efficiency ratio which is obtained when using the stable velocity and without use the water pumping on the clay wall (F2Q0) and the reason of this because of increasing the energy value of cooling which is amounted 7.1 KW and decrease the consumed electrical capability at this experiment which is amounted 0.143KW. As mentioned in Table 4.1 and thus we got on the highest efficiency ratio which amounted 49.7 while that the least real efficiency factor for SECCRW at the operating is obtained when using the experiment (F2Q2) where the value of the efficiency ratio is (17.1). The reason of that is because of the cooling energy in its least value is 3.9KW and also, the consumed electrical capability was the highest value which is (0.228 KW) which led to decrease the performance factor of this experiment.

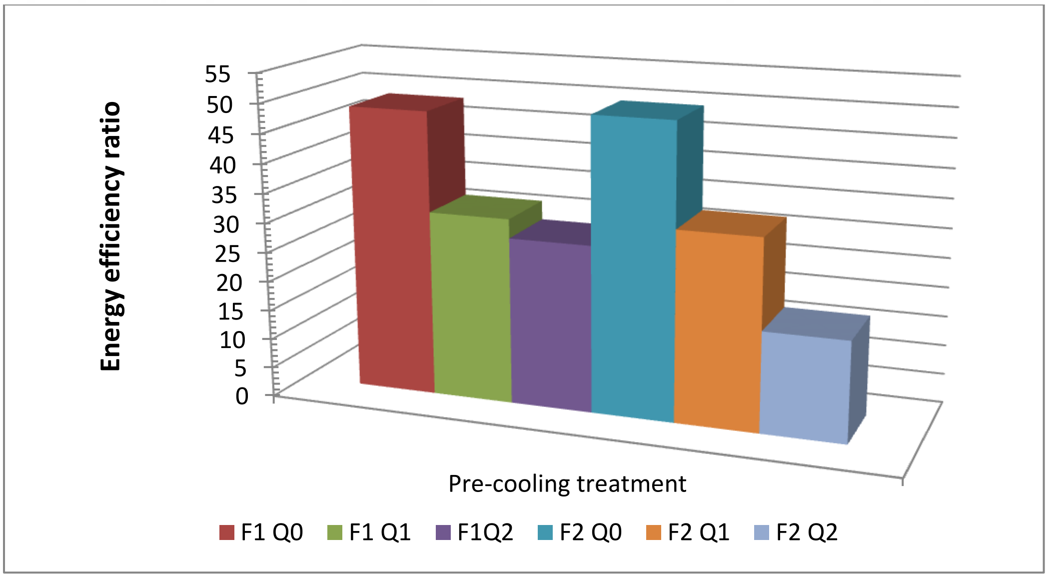

Figure 4.4: Energy Efficiency

4.1.4 Relative humidity of the cooling space

The results of SECCRW showed a significant superior in terms of its ability to increase the relative humidity in the cooling space which surrounding to the tomatoes fruit as compared with the relative humidity for the atmosphere of the desert areas with hot and dry nature in the summer season. The results clarified that the increase of the relative humidity from 11% to 35% for the treatment without operating the system of the desert cooling (F0Q0) and in spite of that this percentage is not enough to store the farm products which need into high percentages of relative humidity during the cooling in order to prevent the loss which occur in the weight fruits because of the breathing process which happen to the fruits during the store but is a good indicator and it is considered better that the store or preserve the fruits in the farm where the value of the relative humidity ranging between 9-11%. The reason of the increase in the relative humidity in spite of the lack of operating the cooling system to the relative decrease which happen by the temperature degree which resulted from the evaporative cooling of the clay wall of system which lead to raise the humidity inside the cooling basin.

The results clarified that the work of the desert cooling system gave high efficiency in terms of increasing the relative humidity as compared with the relative humidity of the atmosphere during the storing inside the system without its operating. Moreover, it is clarified that the relative humidity increased in general at the second velocity of the fan (4.3 s-1) as compared with the less velocity (3.6m.s-1) where the highest increase in the relative humidity is registered at the treatment (F2Q0) and (F2Q1) where the relative humidity to each one of them is amounted 84% and it is considered a good value to keep the vegetables cultivated at these regions. The reason behind increasing the humidity when using the high velocity of cooling fan that the air which pass quickly from outside to inside across the the humidifying pillow which saturated with cold water hold quantities of humidifying water with it to the cooling basin because the velocity of increasing the air pulling which lead to reach the spray of water inside the basin which in its turn causes the increase of the internal humidity to the cooling basin as in Figure 4.5.

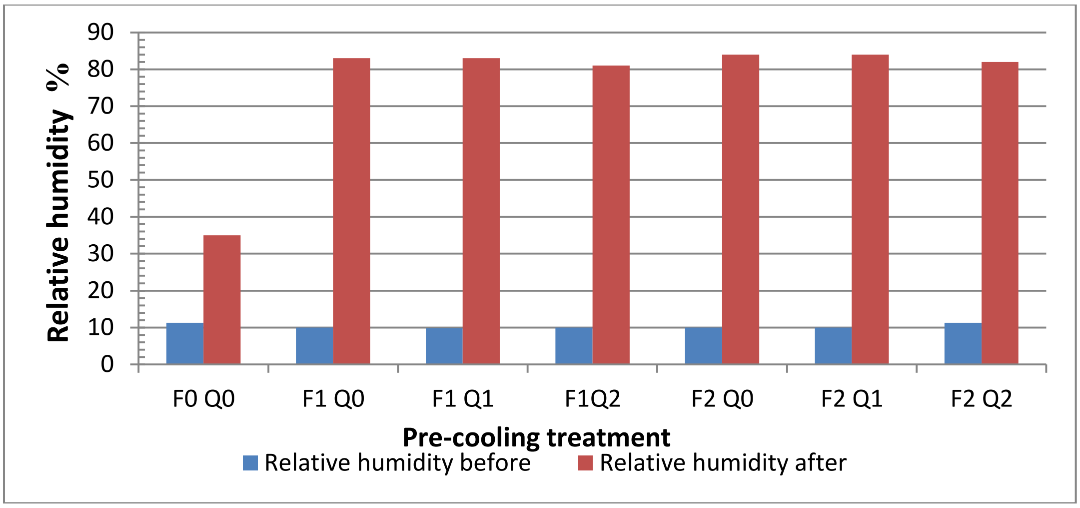

Figure 4.5: The relative humidity of the cooling space

4.1.5 The Consumed Electrical Power

The required electrical power to operate the SECCRW system is measured according to each factor of the experiment factors. It is clear from the results that the highest consumed electrical power is occurred when the system operates with the second velocity of the cooling fan and pumping water on the clay wall with the high drainage (F2Q2) and its value was (0.132 KW) as in Table 4.1. While the used solar system in the experiment consists of solar panels with length of 1.20 meter and width of 70 cm and the ability of each panel of them is (0.25 KW). One solar panel is enough to operate the SECCRW system and for all of the experiment factors which give an additional support to our results because the manufactured cooling system operates by the least electrical power and in the desert climates with least possible cost.

Table 4.1: The consumed electrical power for the factors of cooling storage

Experiment treatment	Electric Power KW
F0 Q0	0
F1 Q0	0.132
F1 Q1	0.209
F1Q2	0.2075
F2 Q0	0.143
F2 Q1	0.22
F2 Q2	0.2285

4.2 The Agricultural Quality Characteristics

4.2.1 The heat of fruits (the first in the characteristics of quality)

Increase or decrease the fruit temperature is considered an indicator on the storing efficiency of fruit during the storing periods. The results of ,measuring the temperature of fruit after one day of storing inside and outside of SECCRW clarified the superior of the factors which have been stored inside SECCRW on the rest of the experiment factors. The differences were significant between all the factors of SECCRW excluding the two factors of F1Q2 and F2Q0 where there was not any significant difference between each of them.

The least temperature of fruit is registered after one day of the storing when using the cooling factor with first velocity of the cooling fan and pumping water on the clay wall with the first drainage (F1Q1) where the temperature of the fruit was 21.67° C with significant factor between each of them and between all of the other factors. While the highest temperature of fruit is registered when using the storing factor in the farm under the shadow (FIELD) where the temperature of the fruit after one day of storing was 34.33° C. It must be known that the median of the surrounding atmosphere temperature was 49° C and the results of the fruit temperature came consistent with the storing temperature of the different factors. Also, the temperature of the storage is decreased whenever the temperature of the tomatoes fruit is decreased while the differences which existed between the SECCRW factors is because of the differences of the cooling and relative humidity efficiency for these factors as in Figure 4.8.

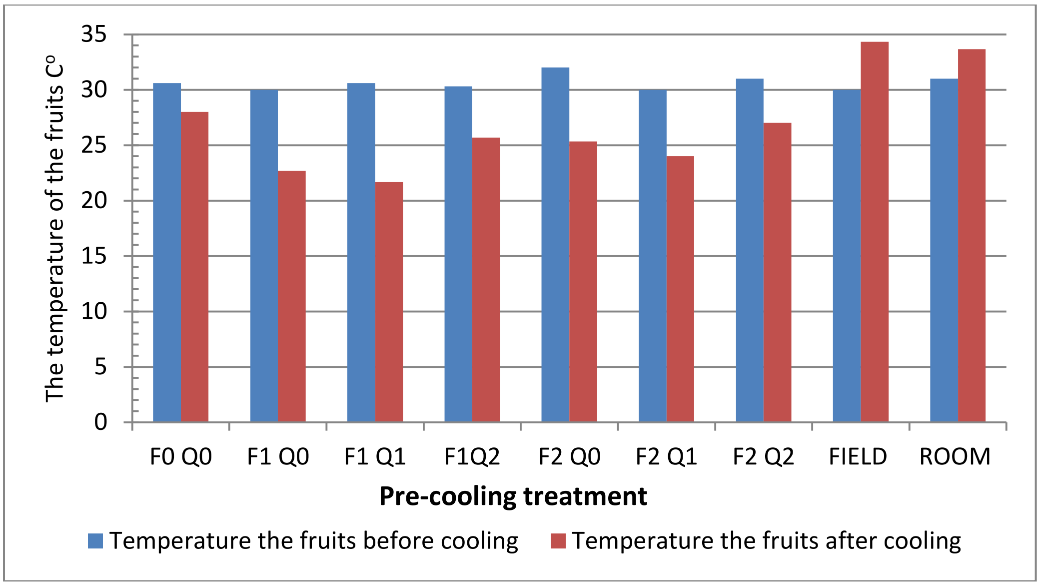

Figure 4.8: The heat of the fruit before and after the cooling

4.2.2 Harness of Tomatoes Fruits

The statistical analysis results clarified that the hardness of tomatoes fruits during the cooling and storing periods that all of the samples which have been treated inside the storage basin (SECCRW) have been kept in a good percentage of hardness and strength excluding the samples which have been kept in the storage without operating the cooling fan and humidifying the clay wall (F0Q) where the hardness results of these fruits were good as compared with the harness results of these fruits which have been stored under the shadow and in the simple store (FIELD) and (ROOM) where their hardness are decreased after one day of the store.

The highest hardness of the fruits are registered after starting the experiment when using the cooling system with the first velocity and pumping the water on the clay wall at the second drainage (F1Q2). As shown in Figure 4.6 that the harness of the fruits at this treatment is (5.5 kg. cm^2) without registering any significant difference with the factor (F2Q2) with significant difference from all of the other factors. Whereas the least value of the fruit hardness is registered when storing the fruits in the simple storage directly this was (3.733 kg.cm2). the reason of making the tomatoes which treated by cold before the storing by its harness belong to decrease and consistency of the temperature inside the storing basin (SECCRW) and increasing the humidity inside it which effect on slowing the ripening the tomatoes fruit after harvest. These fruits still keeping their hardness and non-softening quickly as compared with the samples which have been stored in the farm and simple storage and from the samples in the cooling storage without using the desert cooling systems. These samples are effected by the climatic factors which represented by increase the temperature and decrease the relative humidity which cause the fasten in its ripening and the transformation of non-dissoluble pectin materials such as prospecting which make the fruit gains its harness into dissoluble pectin materials and the last one lead to decrease the hardness of the fruits and increase its softening.

As well as, the simulation results clarified that at the last day of storing the fruits, the hardness of fruits are decreased with high degree and the reason of this is that because of approaching the storing circumstances for all of the samples and their exposure to high temperature degree during the storing period and decrease the relative humidity which lead to ripen of these fruits and thus they lost their hard strength as we clarified. Also, the factors of SECCRW are kept significant superior for the hardness of the stored fruits as compared with the storing methods outside the SECCRW system. The reason of this is due to that the direct farm cooling process of the tomatoes fruit help to prolong the storing period of the fruits.

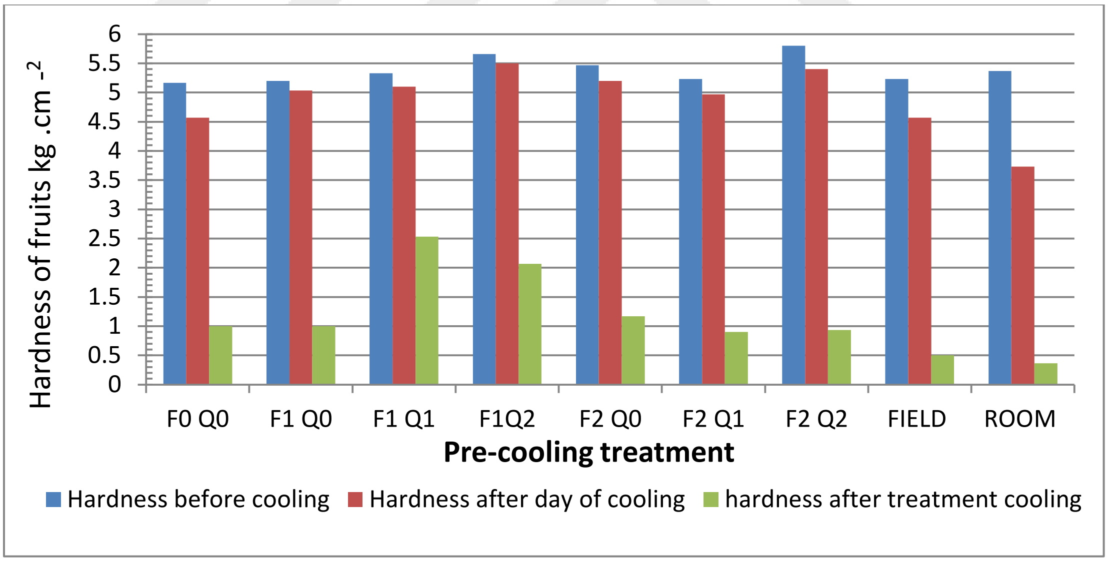

Figure 4.6: The hardness of tomatoes fruit

4.2.3 Total Soluble Solids (TSS)

The results of the statistical analysis which have been obtained from analyzing the percentage of the total dissolved soluble solids in the tomatoes fruits in the experiment showed that the total dissolved soluble solids presented with the highest percentage inside SECCRW in general where it is significantly superior on the fruits which have been stored in the shadow and in the simple storage. The differences varied between the different cooling factors where the factor (F1Q1) registered the least percentage (Tss) and it was 5.967% without any significant difference with the factors (F2 Q0), (F2 Q1) and (F1 Q0) where the percentage of the total dissolved soluble solids were 6.1, 6.1 and 6.16% respectively. The reason of this is due to the significance of the total dissolved soluble solids for the direct evaporative cooling factors of the fruits before the storing period on the shadow factors and simple storage for the same period of time and it is because of the lack of exposure to the fruits of these factors to the hard climatic conditions which represented by increasing the temperature and decrease relative humidity outside of SECCRW as the temperature degrees and relative humidity within the standard averages to store the tomatoes fruits inside the evaporative storing system which preserve on the lack of progress of the fruits ripen. Thus, the starch will be turned into dissolved sugars in the fruit which raise from the dissolved solids values as the case in the factors outside the cooling storage [41] [42].

The results of the statistical analysis showed that there is approaching to the percentage of the total dissolved soluble solids for all the factors of the cooling storage and the storage factors in the shadow and simple storage at the end of the storing period. The reason of this is because of the approaching of the storing circumstances at the end of the storing period because of the length of fruit preserving period under the same circumstances and gives a simple superior for some SECCRW factors as shown in Figure 4.7.

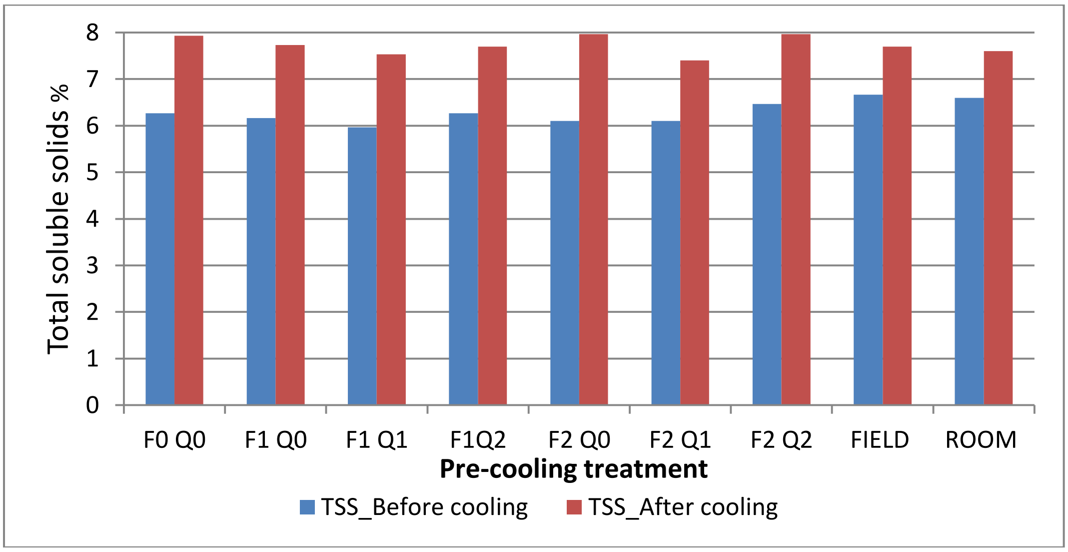

Figure 4.7: Total soluble dissolved solids

4.2.4 The percentage of loss in the fruits weight

Loss by weight occurs whether because of the water content of fruits through the evaporation from the fruit surface or because of the losing by the food inventory according to the consumption in the breathing process [43].

The use of SECCRW is achieved a significant superior in terms of the ability of decreasing the losing percentage by the weight fruit of tomatoes which superior on the traditional storing inside the traditional storage and the storing under the shadow in significant way. The least percentage in the weight (2.13%) is registered at the first velocity of the cooling fan without pumping water to the clay external wall of the cooling storage (F1Q0) as in Figure 4.9. The reason behind this is due to that the high efficiency of SECCRW system in the circumstances of this region and the suitability for each of the fan velocity and the evaporation average from the external wall of the required circumstances to decrease the temperature. As well as, it is noticed that all the factors of the first velocity are superior on the factors of the second velocity because of the high efficiency of cooling which have been obtained at the first velocity that gave the best indicator to decrease the temperature inside the desert cooling storage.

Moreover, it is noticed that storing in the farm and under the shadow led to loss high percentage ratio from the weight of the fruits which reached to about 29% during one day and it is a great loss in the weight. The reason of this is due to the high increase of the surrounding temperature which approached to 50° C with great decrease in the relative humidity to less than 10% that helped the velocity of liquids evaporation from the stored fruits in the farm under the shadow. It is clear that storing the tomatoes fruits in simple storage of bricks and include simple ventilation has contributed in decreasing the loss percentage in the tomatoes fruits to 12.24%. This percentage is still high percentage loss but it is better than the storing in the farm and the reason of this is that the simple storage decreases the dry air flows which cause the loss of humidity from the tomatoes fruits as in the farm circumstances. We notice that the farm cooling factors by the use of SECCRW is given the tomatoes fruits a good storing ability which helped the fruits to keep small losing percentage when they stored after the farm cooling in the simple storage. For all of the storing days, the least percentage is registered in the simple storage which amounted 11.94% at (F1Q0) in the last day of the storing as compared with the samples of the other fruits which have been kept in the evaporative cooling storage and also which have been stored directly outside the cooling storage.

It is also noticed that the percentage of the lost weight in general increase whenever the storing period is increased where it is noticed that it is raised from about 5% in the first day to about 20% in the last day of storing. As well as, it is noticed that the difference between the storing factors inside and outside the cooling start approaching with each other whenever the storing period is increased excluding the two factors of the first fan velocity (F1Q0) and (F1Q1) which are keeping with small percentages. The reason of this is due to the approaching of the storing circumstances in the simple storage with clear significance for the evaporative cooling factors with the first velocity which contributed in gaining the fruits a reduced temperature which helped on decreasing the percentage of loss for the humidity from the fruit.

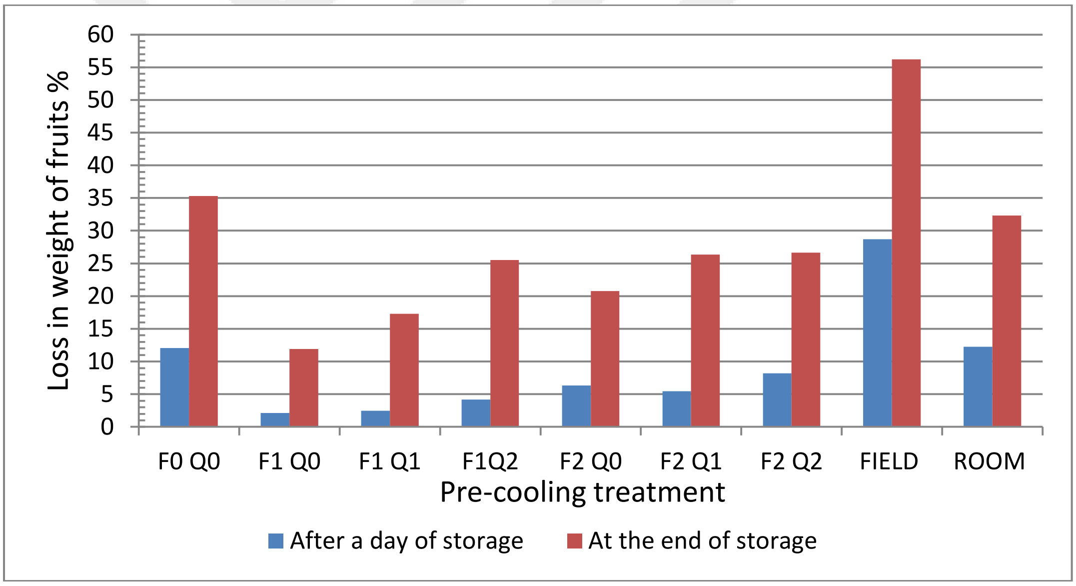

Figure 4.9: The percentage of loss in the fruits weight

4.2.5 Number of Storage Days for Fruits

Figure 4.10 explains the significance of the SECCRW system which significantly manufactured in terms of the validity of tomatoes fruit storage on storing these fruits in simple storing room and the storage under the shadow in the farm field. The results clarified that the SECCRW system gave higher storage validity to the fruits which helped to keep their form and strength without the deterioration of the fruits during the storage after the farm cooling in the storage and for all of the storing days. The average which registered by these factors inside the storage in terms of the number of days (four days) for storing the fruits before their deterioration excluding the experiment of (F1Q1) where this experiment gave significant differences with all of the other factors. The average of fruits storing validity at this experiment was 4.7 day according to the statistical data analysis for these factors. The reason for the superior of the SECCRW cooling storage factors than the storage under the shadow and in the simple storage is because of the storage efficiency or the storage factors of the desert cooling storage as the temperature inside the storage registered difference than the external temperature degrees and also, increase the humidity averages inside the cooling storage that give the fruits a storing ability for longer period of time because of preserving on their strength and not to loss liquids during the storing period as compared with the registration of the storing factors in the shadow and in the simple storage where the validity of the storing fruits were 3 days and 3.3 days respectively and without any significant differences between each of them. The reason of this deterioration is because of the exposure of the tomatoes fruits at these factors into high temperature degrees and reduced humidity which led to fasten the process of fruits ripen from the first day of the experiment and then its deterioration after that which decrease its storage ability during the storing period.

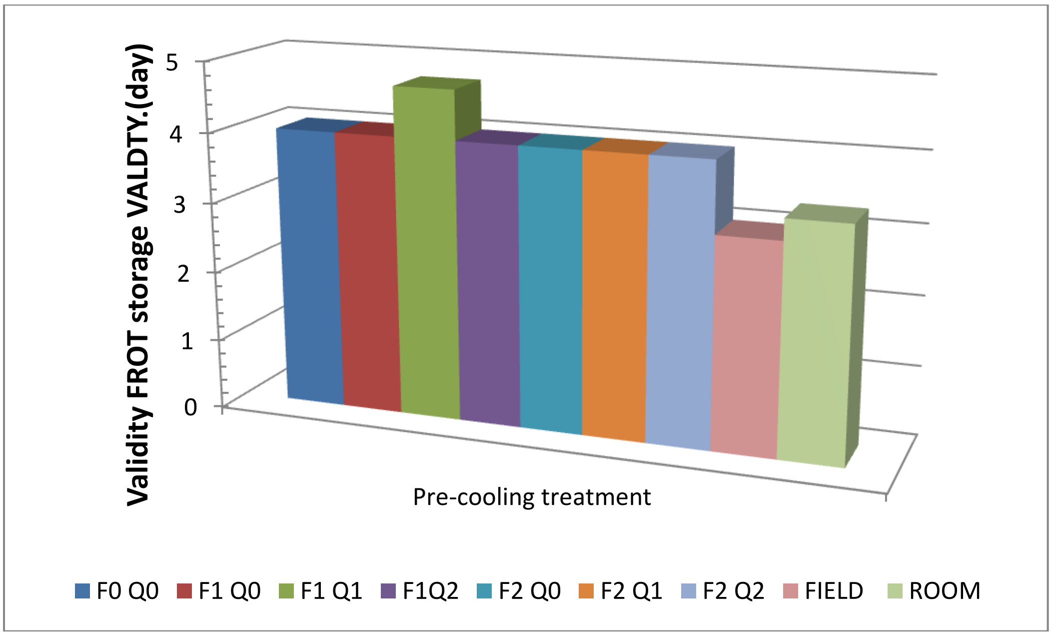

Figure 4.10: Number of Storage Days

4.3 Cost of the system

1. The price of the system with periodic for 20 years (life span) = 500$
2. Price of the solar system used to operate the system for 20 years with maintenance = 2000 $.
3. Cooling system capacity and storage = 100 kg / day
4. Period of use of the system 8 months/ year

4.3.1 Cost Analysis

Solar + system = 2000$ + 500$ = 2500$

System lifetime = 20 years

- Cost per year = 2500$ / 20 years = 125$ / year
- Cost of storage and cooling season = 125$ /8 months = 15.6 $/ months
- Cost per day = 15.6$ / 30 day = 0.5 $ / 100 kg
- Cost per kilo = 0.5 $ / 100 kg = 0.005 $

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

The evaporative cooling room has been manufactured with the cooling wall and it is called the name of SECCRW in order to keep the cultivated summer fruits products in the desert region. The effect of the different used factors for the tomatoes fruits in the system on the mechanical cooling and the agricultural characteristics have been studied. The results have been summarized as follow:

5.1 The Mechanical Characteristics

1. The use of SECCRW system has given the best internal temperature and also the best thermal reduction.
2. The cooling efficiency of SECCRW system is increased where the highest value of the cooling efficiency is obtained.
3. The highest performance factor of the SECCRW cooling system is obtained because of increasing the cooling energy of the system.
4. SECCRW is achieved high efficiency in terms of increasing the relative humidity as compared with the relative humidity of the atmosphere.
5. SECCRW system can work on simple electrical power where its value is (0.2KW).

5.2 The Agricultural Typical Characteristics

1. The temperature of the stored fruits inside SECCRW is superior on the rest of the experiment factors where the temperature gave a good indicator for the work on the storage system.
2. The stored tomatoes fruits kept inside the system preserved its hardness in good manner during the storing periods because of the direct farm cooling

3. Process of the fruits helped on increasing the validity period of the fruits during the storage.
4. The use of manufactured SECCRW system decreased the deterioration of the tomatoes fruits quickly according to increase the percentage of the total dissolved soluble solid and gave to the stored fruits inside the system a superior on the rest factors of the experiment.
5. The use of SECCRW achieved a significant superior in terms of the ability on decreasing the percentage of loss weight in the tomatoes fruit and superior on the storage inside the traditional storage and the storage under the shadow because of the high efficiency of the manufactured system.
6. Generally, the manufactured SECCRW system is superior in terms of the validity of tomatoes fruits store than the storage of these fruits in the simple storing room and the storage under the shadow in the farm field where the results showed that the manufactured system gave a higher storing validity to the fruits which helped to keep by their shape and hardness without deterioration of the fruit during the storage after the farm cooling in the storage.

REFERENCES

1. Energy 2020 – a strategy for competitive, sustainable and secure energy. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions; 2010. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?Uri=COM: 2010:0639: FIN: EN: PDF>.

2. Pérez-Lombard L., Ortiz J., Pout C. A review on buildings energy consumption information. Energy and Buildings 2008, (40) 394–398.

3. European Parliament and of the Council. Energy performance of buildings. Directive 2002/91/EC the of 16 December 2002.

4. EN ISO 7730:2005. Ergonomics of the thermal environment -- Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria.

5. Bowen A.B. Cooling achievement in the gardens of Moghul India. Proceedings of the International Passive and Hybrid Cooling Conference, Miami Beach, FL 1981.

6. ASHRAE.6987."Fundamentals Handbook published by the American Society of Heating, Refrigerating, and Air conditioning Engineers .New York.pp534.

7. Fang, W. 6995. Greenhouses cooling in subtropical regions. Acta Horticulture.

8. Alhilal, and Ibrahim 2003. Effect of shading on the efficiency of the cooling system by evaporation in green houses

9. Czarick, M .4009. Six inch pad systems will use more water than fogging pads. www.poultrytowday.com

10. Czarick, M. 4008. Evaporative cooling pad quality makes a difference. Poultry Housing Tips, 40(3): 1-5

11. Al-Hilal Ibrahim and Al-Tuwaiji 2001. The evaporative cooling efficiency of palm leaf pillows and cross-edged paper pillows under dry climatic conditions

12. ASHRAE Handbook. 2000 Systems and Equipment. Chapter 19. Evaporative air cooling equipment. 19.1-19.8.

13. Ali Sahib Talib,"the Local Relationship Between Climate and Human Characteristics and the Desertification and its Effects in Iraq", College of arts, Basrah, Iraq, 2013.

14. SawsanSabih, Climate Elements Available in Iraq and their Potential for Alternative Energy Production, Mustansiriya Journal of Arab and International Studies, 2014

15. Ayandiji, A, O. R., AdeniyiOmidiji, D , "Determinant Post Harvest Losses among Tomato Farmers inImeko-Afon Local Government Area of Ogun State, Nigeria", Global Journal of Science Frontier Research,2011

16. Naika S, Juede J, Goffau M, Hilmi M, Dam V,(2005). “Cultivation of Tomato” Production,processing and marketing, Agromisa/ CTA. Revised edition, 2005 Agrodok- series No 17.

17. Bodunde, J.G, Erinle, I.D,Eruotor, P.G., andAmans, E.B. (1993). “Recommendation for therelease of four heat tolerant Tomato varieties”.Paper approved by the Professional and AcademicBoard, IFRA, ABU, Zaria, Nigeria. Pp 165

18. Marita Cantwell, XunliNie, and GyunghoonHong,"Impact of Storage Conditions on Grape Tomato Quality", 6th ISHS Postharvest Symposium, Antalya, Turkey. April 8-12, 2009

19. TRACY L. PARNELL , TREVOR V., "Tomatoes: Safe Methods to Store, Preserve, and Enjoy", http://anrcatalog.ucdavis.edu,UNIVERSITY OF CALIFORNIA

20. Anon. 2008. Fresh facts on retail. Whole and fresh-cut produce trends: Q2 2008. United Fresh research and Education Foundation. 8 pp.

21. Jimenez, M., E. Trejo and M. Cantwell. 1996. Cherry tomato storage and quality evaluations. Dept. Vegetable Crops, University of California, Davis, and CA.Vegetable Research Report.

22. Roberts, P.K., S.A. Sargent and A.J. Fox. 2002. Effect of storage temperature on ripening and postharvest quality of grape and mini-pear tomatoes. Proc. Fla. State Hort. Soc. 115:80-84.

23. Maul, F., S.A. Sargent, C.A. Sims, E.A. Baldwin, M.O. Balaban, and D.J. Huber. 2000. Tomato flavor and aroma quality as affected by storage temperature. J. Food Science 69(8): S310-S318.

24. Leshuk, J.A. and M.E. Saltveit, Jr. 1990. Controlled atmosphere storage requirements and recommendations for vegetables. In: M. Calderon and R. Barkai-Golan (Eds.). Food Preservation by Modified Atmospheres. CRC Press, Boca Raton, FL. Pp. 315-352.

25. Sargent, S.A. and C.L. Moretti. 2004. Tomato. Postharvest Quality Maintenance Guidelines. In, USDA Agric. Handbook 66. Commercial Storage of Fruits, Vegetables and Ornamentals. K.Gross, M. Saltveit and C.Y. Wang, eds.).

26. Y. H. Hui‹E. ÖzgülEvranuz "Handbook of Vegetable Preservation and Processing, Second Edition",bool,2015

27. KMUTT. 2007. Post-harvest: a technology for living produce. Multimedia produced by the Division of Post-harvest Technology, King Mongkut's University of Technology Thonburi (KMUTT), Bangkok, Thailand.

28. Fernando, M.D. 2006. Country paper: Sri Lanka (2). In APO. 2006. Post-harvest management of fruit andvegetables in the Asia-Pacific region. Asian Productivity Organization (APO) and FAO. pp. 264–275.

29. Sullivan, G.H., Davenport, L.R. & Julian, J.W. 1996. Precooling: key factor for assuring quality in new fresh

30. Market vegetable crops. p. 521–524. In J. Janick, Ed. Progress in new crops. ASHS Press, Arlington,VA.

31. Sivakumar, D. &Korsten, L. 2007. Maintaining fresh produce quality during cold storage. In Horticultural chainmanagement for Southern and East Africa: theoretical manual. FAO and the Commonwealth Secretariat.

32. Jennifer R. DeEll; Clement Vigneault; Stephanie Lemerre.(2000). Water temperature for hydrocooling field cucumbers in relation to chilling injury during storage. Postharvest Biology and Technology, 18, 27–32.

33. Lijun Wang and Da-Wen Sun," Rapid cooling of porous and moisture foods by using vacuum cooling technology", Trends in Food Science & Technology 12 (2001)

34. TadhgBrosnan; Da-Wen Sun. (2001). Precooling techniques and applications for horticultural products - a review. International Journal of Refrigeration, 24, 154-170.

35. C.R.PATIL, K.G.HIRDE & P.R.M.I.T. &R., BADNERA "The Concept of Indirect Evaporative cooling", International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 2, Issue 5, September 2013

36. ASHRAE Handbook. 2000 Systems and Equipment. Chapter 19. Evaporative air cooling equipment. 19.1-19.8.

37. ASHRAE Standard Project Committee SPC 133; "Method of Testing Direct Evaporative Air Coolers", ASHRAE, Inc., Atlanta, 1997.

38. ASHRAE Standard Project Committee SPC 143; "Method of Testing for Rating Indirect Evaporative Air Coolers", ASHRAE, Inc., Atlanta, 1997

39. Gonzales , D.J. ; " The Scince and Application of Evaporative Cooling " , American Industrial Hygiene Association Journal , Vol.27,March – April 1966 , PP. 172 – 179)

40. The Iraqi journal for mechanical and mayerial engineering 2009 and [yuns ، 2006]

41. A.O.A.C. (1986). Association of Official Agricultural Chemists. Official and Tentative Methods of Analysis.13thed. Association of Official Agricultural Chemists, Washington, D.C., U. S. A.

42. A.O.A.C. (2002). International Official Methods of Analysis. 17th ed.

43. Tsuda, T., K. Chachin, and K. Ueda. 1999. Studies on keeping capacity of imported carabo mango fruit from the philippines. J. Jap Soc. Hort. Sci. 69(3): 669-674.

44. Winsor G. W, J. N. Davies, and D. M. Massey. 1967. Composition of tomato fruit juices from whole fruit and locales at different stages of ripens. J. Sci Agric. 13: 108-115.)

45. Shirikov,E.P.(1988)Technology of storage and processing of fruits and vegetables.Moscow,319PP.

PERSONAL INFORMATION

Name, Surname: **ALYAA AL-RUBAYE**

Date and place of Birth: Iraq – 7.10.1982

Marital Status: Married

Phone: 00905318256926 – 009647817239146

Email: aa495114@gmail.com

EDUCATION

Undergraduate: University of Kufa, College of Agriculture,

Department of Agricultural Mechanics.

LANGUAGE

English ،Arabic