# PROLONGED PRESERVATION OF TOMATOES USING THE EVAPORATIVE COOLING METHOD

**A MINOR PROJECT - III REPORT**

***Submitted by***



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**BACHELOR OF ENGINEERING**

in


**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING**

**M.KUMARASAMY COLLEGE OF ENGINEERING**

(Autonomous)

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## M.KUMARASAMY COLLEGE OF ENGINEERING, KARUR

## BONAFIDE CERTIFICATE

Certified that this **18ECP105L - Minor Project - III** report "**PROLONGED PRESERVATION OF TOMATOES USING THE EVAPORATIVE COOLING METHOD"**is the bonafide work of "**VISHWA S (927621BEC243), SHANJAY RK (927621BEC195), SIVARAMAKRISHNAN M (927621BEC201), SUBASH S (927621BEC214)"** who carried out the project work under my supervision in the academic year **2023 -2024 - ODD SEMESTER**.

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This report has been submitted for the **18ECP105L – Minor Project - III** final review held at M. Kumarasamy College of Engineering, Karur on ____________________

**PROJECT COORDINATOR**

## INSTITUTION VISION AND MISSION

**Vision**

To emerge as a leader among the top institutions in the field of technical education.

**Mission**

**M1:** Produce smart technocrats with empirical knowledge who can surmount the global challenges.

**M2:** Create a diverse, fully -engaged, learner -centric campus environment to provide quality education to the students.

**M3:** Maintain mutually beneficial partnerships with our alumni, industry and professional associations

## DEPARTMENT VISION, MISSION, PEO, PO AND PSO

**Vision**

To empower the Electronics and Communication Engineering students with emerging technologies, professionalism, innovative research and social responsibility.

**Mission**

**M1:** Attain the academic excellence through innovative teaching learning process, research areas & laboratories and Consultancy projects.

**M2:** Inculcate the students in problem solving and lifelong learning ability.

**M3:** Provide entrepreneurial skills and leadership qualities.

**M4:** Render the technical knowledge and skills of faculty members.

## Program Educational Objectives

**PEO1:** **Core Competence:** Graduates will have a successful career in academia or industry associated with Electronics and Communication Engineering

**PEO2:** **Professionalism:** Graduates will provide feasible solutions for the challenging problems through comprehensive research and innovation in the allied areas of Electronics and Communication Engineering.

**PEO3:** **Lifelong Learning:** Graduates will contribute to the social needs through lifelong learning, practicing professional ethics and leadership quality

## Program Outcomes

**PO 1: Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

**PO 2: Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

**PO 3: Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

**PO 4: Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

**PO 5: Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

**PO 6: The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

**PO 7: Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

**PO 8: Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

**PO 9: Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

**PO 10: Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

**PO 11: Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

**PO 12: Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

## Program Specific Outcomes

**PSO1:** Applying knowledge in various areas, like Electronics, Communications, Signal processing, VLSI, Embedded systems etc., in the design and implementation of Engineering application.

**PSO2:** Able to solve complex problems in Electronics and Communication Engineering with analytical and managerial skills either independently or in team using latest hardware and software tools to fulfil the industrial expectations.

| Abstract | Matching with POs, PSOs |
|---|---|
| Evaporative cooling system, Tomato preservation, Relative humidity, Cooling efficiency, Temperature reduction, Agriculture technology. | **PO1, PO2, PO3, PO4, PO5, PO6, PO7, PO8, PO9, PO10, PO11, PO12, PSO1, PSO2** |

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# ABSTRACT

The proposed solar-powered evaporative cooling unit to extend the freshness of stored vegetables, particularly tomatoes. This evaporative cooling apparatus functions by employing the principle of evaporative cooling to raise the relative humidity (RH) inside the storage chamber. The storage structure is primarily composed of 1mm thick aluminum sheets, with one side featuring a jute pad that becomes moist as water flows through a series of perforated pipes originating from a reservoir situated atop the storage unit. The flow of water is facilitated by gravity. Statistical analysis of the RH and weight loss of tomatoes was carried out using a Student's T-test. The findings revealed a significant difference between using the evaporative cooling system for tomato storage compared to ambient conditions. The average cooling efficiency was determined to be 83%. The temperature inside the system experienced a significant drop compared to ambient conditions, ranging from 6 to 10°C, while the relative humidity in the cooling chamber increased substantially to 85%. Furthermore, testing of the evaporative cooling system demonstrated that tomatoes could be stored for an average of five(5)days with minimal alterations in weight, color, firmness, and decay, in contrast to ambient conditions where decay began after three (3) days. Therefore, it is recommended that farmers, homeowners, and tomato processing facilities consider adopting such evaporative cooling systems for storing fresh tomatoes to prolong their shelf life.

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## LIST OF ABBREVIATIONS

| ACRONYM | | ABBREVIATION |
|---|---|---|
| IoT | - | Internet of Things |
| LCD | - | Liquid Crystal Display |
| LED | - | Light Emitting Diode |
| VCD | - | Vapor Compression Distillation |

# CHAPTER 1

## INTRODUCTION

Evaporative cooling is the process by which the temperature of a substance is reduced due to the cooling effect from the evaporation of water. The conversion of sensible heat to latent heat causes a decrease in the ambient temperature as water evaporated provide useful cooling. This cooling effect has been used on various scales from small space cooling to large industrial applications (Liberty et al., 2013). Several researches have been done on various forms of design of evaporative coolers (Rusten, 1985; Dzivama, 2000; Olosunde 2006; Sushmita et al., 2008). In developing countries, Storage has been observed to pose a greater threat to fruits and vegetables because information on the storage temperature, humidity requirements and the length of time they can be kept without a decline in market value is either inadequate or unknown to those who need the information . Deterioration of fruits and vegetable during storage largely depends on temperature. One way to increase the shelf life of fruits and vegetable is by lowering of the temperature. Too low temperature can cause damage to agricultural produce and as soon as the product leaves the region of controlled temperature, deterioration starts again, In order to maintain the quality of stored fruits and vegetables, they are normally kept in humid conditions . For most perishable crops, the higher the humidity the better it is in storage. However if the humidity is too high, water may condense on top of the vegetables thus increasing rotting . Deterioration of fresh tomatoes during storage depends partly on temperature . One way to slow down deterioration and thus increases the length of time tomatoes can be stored, is by lowering the temperature to an appropriate level. If the storage temperature is too low the product will be damaged and also as soon as the product over a wet surface so that the faster the rate of evaporation the greater the cooling and the leaves the cold store, deterioration starts again and often at a faster rate. It is essential that tomatoes are not damaged during harvest and that they are kept clean. Damaged and bruised tomatoes have much shorter storage lives and very poor appearance after storage. stated that keeping products at their lowest safe temperature (0°C for temperate crops or 10-12 °C for chilling sensitive crops) will increase storage life by lowering respiration rate, decreasing sensitivity to ethylene gas and reducing water loss. Much of the postharvest losses of vegetables in developing countries are due to the lack of proper storage facilities. Refrigerated cold stores are the best method of preserving vegetables, but they are expensive. Consequently, in the developing countries such as Nigeria and particularly in northern Nigeria where most vegetable crops are grown there is an interest in simple, low-cost alternatives, many of which depend on evaporative cooling which is simple as water evaporates, it draws energy from its surroundings which produce cooling effect. Evaporative cooling occurs when air, that is not too humid, passes efficiency of an evaporative cooler depends on the humidity of the surrounding air , Dry air can absorb moisture faster and no cooling occurs in the extreme case of air that is totally saturated with water . Generally, an evaporative cooler is made of a porous material that is fed with water. Hot, dry air is drawn over the material. The water evaporates into the air raising its humidity and at the same time reducing the temperature of the air. For fresh market produce, any method of increasing the relative humidity of the storage environment (or decreasing the vapor pressure deficit (VPD) between the commodity and its environment) will slow the rate of water loss. The best method of increasing relative humidity is to reduce temperature . However, the problem of inadequate storage facilities for fresh vegetables after being harvested in Nigeria, result to the reduction in the quantity that gets to the market; this also has a direct effect on the economic distribution and consumption of the needed quantity for human sustainability. Hence, the purpose of this work is to Design and Construct an Evaporative Cooling System that will temporarily store fresh vegetables to increase the shelf life before economical distribution, consumption and for processing.

# CHAPTER 2

## LITERATURE SURVEY

### 2.1. Evaporative cooling: water for thermal comfort

Chandra et al. presents evaporative cooling for a natural process that humans and animals use to cool themselves down. When water evaporates, it changes from a liquid to a vapor, absorbing heat from its surroundings in the process. This phenomenon is widely used in various forms to provide thermal comfort, especially in hot and dry climates. In evaporative cooling systems, water is allowed to evaporate into the air, which lowers the air temperature and increases humidity. This cooled and humidified air is then circulated indoors, creating a comfortable environment for occupants. Evaporative coolers, also known as swamp coolers, are devices that use this principle to cool the air in buildings. They consist of a fan that draws warm air through water-saturated pads. As the air passes through the wet pads, the water evaporates, cooling the air before it is circulated inside the building. One of the significant advantages of evaporative cooling is its energy efficiency compared to traditional air conditioning systems. Evaporative coolers use significantly less electricity because they do not require energy-intensive refrigeration cycles. However, they are most effective in dry climates, where the air is hot and humidity is low. In humid conditions, the cooling effect of evaporative cooling is limited because the air is already saturated with moisture, reducing the evaporation rate.

## 2.2. Thermal behaviour of a fruits and vegetables storage structure

Nanda et al. presented the thermal behavior of a fruits and vegetables storage structure is crucial for maintaining the freshness and quality of the produce. Such structures are designed to regulate temperature, humidity, and airflow to create optimal storage conditions. In these storage facilities, temperature control is essential as it directly affects the rate of respiration and ripening of fruits and vegetables. Different fruits and vegetables have specific temperature requirements for storage; some require cooler temperatures to extend shelf life, while others need slightly warmer conditions to prevent chilling injury. Proper insulation and ventilation systems are implemented to prevent temperature fluctuations and maintain a stable internal environment. Humidity control is another vital aspect of the thermal behavior of storage structures. Fruits and vegetables have varying moisture content levels, and excessive humidity can lead to mold and rot, while low humidity can cause dehydration. Therefore, the storage facility must have mechanisms to regulate humidity levels, ensuring that they remain within the optimal range for the specific produce being stored.

## 2.3. Comparative study on storage of fruits and vegetables in evaporative cool chamber and in ambient

Kale et al. presented a comparative study conducted to assess the storage conditions of fruits and vegetables in an evaporative cool chamber versus ambient storage. The evaporative cool chamber is designed to maintain a controlled environment with lower temperatures and higher humidity, which are ideal for preserving the freshness of perishable items. In this study, fruits and vegetables were stored both in the evaporative cool chamber and in ambient conditions to evaluate their shelf life and quality. Results from the study showed that storing fruits and vegetables in the evaporative cool chamber significantly extended their shelf life compared to ambient storage. The controlled temperature and humidity levels in the cool chamber created an environment that slowed down the ripening process, reducing the risk of spoilage. Fruits and vegetables stored in the cool chamber retained their firmness, color, and nutritional value for a longer duration, making them more suitable for consumption. On the other hand, fruits and vegetables stored in ambient conditions exhibited signs of rapid deterioration, including wilting, loss of color, and decay. The fluctuating temperatures and lack of humidity control in the ambient environment accelerated the ripening process, leading to a shorter shelf life and increased food wastage.

# CHAPTER 3

## EXISTING SYSTEM

### 3.1. Direct cooling system

The process where water evaporates into the air to be cooled, simultaneously humidifying, it is direct evaporative cooling (DEC) and the thermal process is the adiabatic saturation. The main characteristics of this process is the fact that it is more efficient when the temperature is higher, that means, when more cooling is necessary for thermal comfort [1]. Direct evaporative cooling commonly used with residential systems, cools the air by evaporating water to increase the moisture content of the air. It involves the movement of air past or through a moist material where evaporation, and therefore cooling, occurs [2]. This cooled moist air is then allowed to move directly to where it is needed. In contrast to this process, indirect cooling uses some form of heat exchangers that use the cool moist air produced through evaporative cooling, to lower the temperature of the dry air. This cool dry air is then used to cool the environment, and the cool moist air is expelled . A direct evaporative cooling is a line of constant wet bulb temperatures. In the course of direct cooling operation, wet bulb temperature and enthalpy remains unchanged, dry bulb temperature reduces while relative humidity and specific humidity increases [3]. These systems have an effectiveness of 55 to 70%. Effectiveness is a measure of how closely the supply air temperature leaving the evaporative cooler approaches the outdoor wet-bulb temperature. Direct evaporative cooling systems are suitable for hot and dry climates where the design wet-bulb temperature is 68 °F or lower. In other climates, outdoor humidity levels are too high that allow sufficient cooling. However, there are some limitations of this system. The drop in temperature will generally be only a small fraction of the total evaporative reduction that is possible [4]. This is primarily due to the large volume of water that needs to be cooled by a relatively small evaporating surface area. Only a small number of items can be placed in large water containers. This system usually uses either a porous clay container or a water tight canvas bag in which water is stored. These containers are then either hung or placed so that the wind will blow past them. The water in the container slowly leaks through the clay or canvas material and evaporates from the surface as warm dry air flow past. This process of evaporation slowly cools the water.

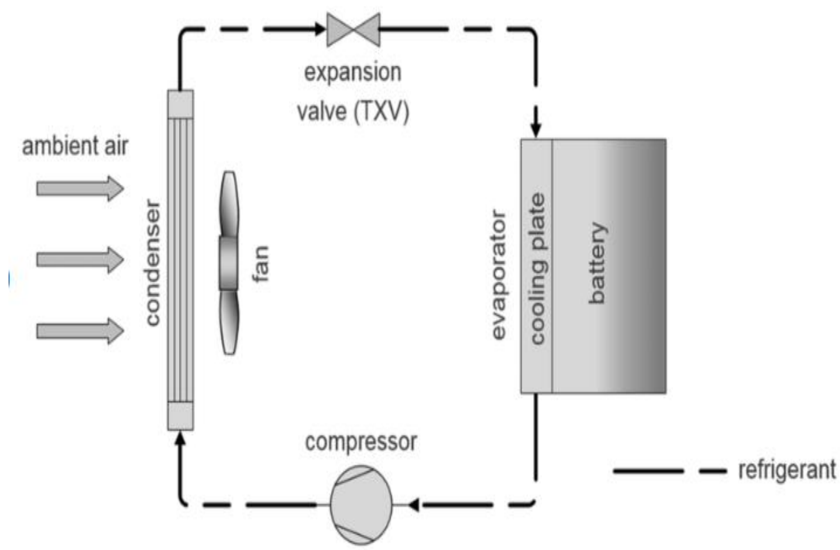


**Figure 3.1 :** Direct cooling system

## 3.2. Indirect evaporative cooling system

An indirect evaporative cooling system cools air without adding moisture to the indoor environment. It employs a heat exchanger to transfer heat from the incoming warm, dry air to a separate stream of water or a coolant. This process cools the air without increasing humidity, making it suitable for dry and arid climates where traditional evaporative coolers may be less effective. Indirect evaporative cooling uses an air to air heat exchanger to remove heat from the primary air stream without adding moisture [6]. In one configuration, hot dry outside air is passed through a series of horizontal tubes that are wetted on the outside. A secondary air stream blows over the outside of the coils and exhausts the warm, moist air to the outdoors. The outside air is cooled without adding moisture as it passes through the tubes. Indirect evaporative cooling typically has an effectiveness of 75%. The high level of humidity that is produced by direct evaporative cooling may be undesirable for some applications. Indirect evaporative cooling attempts to solve this problem by using the cool moist air produced through evaporation to cool drier air. The resulting cool air is then used to cool the desired environment. This transfer of coolness is accomplished with the help of a heat exchange .All methods of indirect evaporative cooling require power to run both water pump and fans. For this reason, indirect evaporative cooling have limited applications. It is primarily used to cool dwellings and rooms. In such situations these cooling system are generally less expensive to buy or build and operate than conventional air conditioning systems [7]. On the other hand, indirect evaporative cooling cannot be used in all environments and the reduction in temperature that can be achieved with this system is not as great as the reduction that can be achieved with conventional mechanical cooling systems.

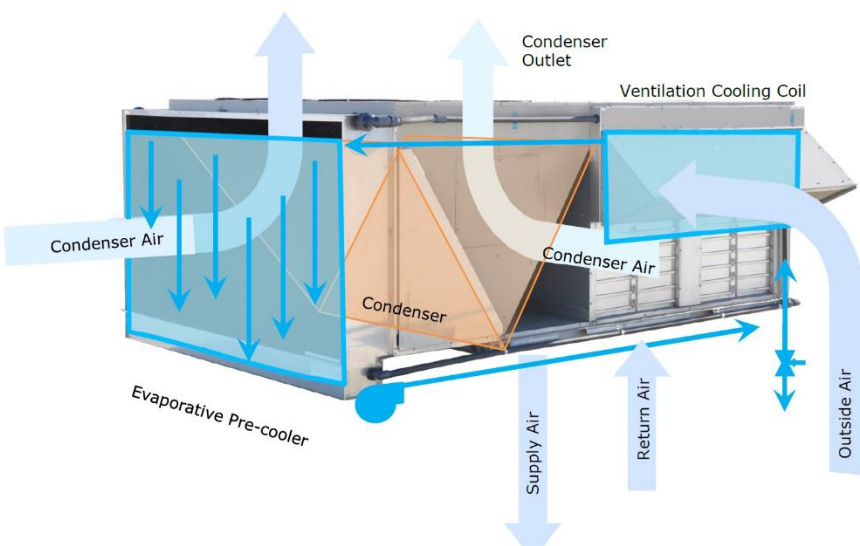


**Figure 3.2:** Indirect evaporative cooling system

# CHAPTER 4

## PROPOSED SYSTEM

Evaporative cooling is a physical phenomenon in which evaporation of a liquid, typically into surrounding air, cools an object or a liquid in contact with it. When considering water evaporating into air, the wet-bulb temperature, as compared to the air's dry-bulb temperature, is a measure of the potential for evaporative cooling. The greater the difference between the two temperatures, the greater the evaporative cooling effect. Evaporation of water produces a considerable cooling effect and the faster the evaporation the greater is the cooling. When the temperatures are the same, no net evaporation of water in air occurs, thus there is no cooling effect. The principle of working of this system is 'when a particular space is conditioned and maintained at a temperature lower than the ambient temperature surrounding the space, there should be release of some moisture from outside the body'. This maintains low temperature and elevated humidity in the space compared to the surrounding. This evaporative cool chamber fulfills all these requirements and is helpful to small farmers in rural areas .Evaporative coolers provide cool air by forcing hot dry air over a wetted pad. The water in the pad evaporates, removing heat from the air while adding moisture [8]. When water evaporates it draws energy from its surroundings which produces a considerable cooling effect. Evaporative cooling occurs when air, that is not too humid, passes over a wet surface; the faster the rate of evaporation the greater the cooling. The efficiency of an evaporative cooler depends on the humidity of the surrounding air. Very dry air can absorb a lot of moisture so greater cooling occurs. In the extreme case of air that is totally saturated with water, no evaporation can take place and no cooling occurs [9]. The evaporatively cooled storage structures work on the principle of adiabatic cooling caused by evaporation of water, made to drip over the bricks or cooler pads. Generally, an evaporative cooler is made of a porous material that is fed with water. Hot dry air is drawn over the material. The water evaporates into the air raising its humidity and at the same time reducing the temperature of the air. Cooling is provided by the evaporative heat exchange which takes advantage of the principles of the latent heat of evaporation where tremendous heat is exchanged when water evaporates. It makes use of the free latent energy in the atmosphere. The relationship between air and water is shown in the psychometric chart (Fig. 1). Air acts like a sponge to water. The key difference is that as the air increases in temperature it can hold more water. As air takes up water it moves along the line of constant energy D [10].

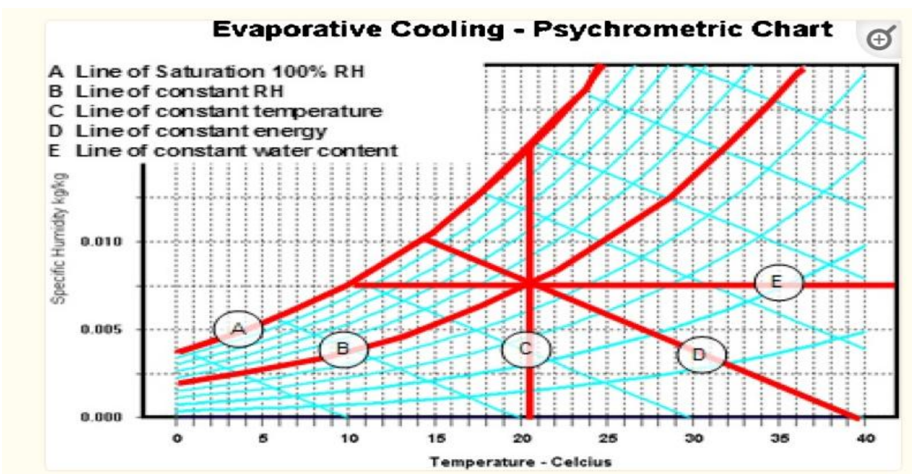


**Figure 4.1:** Psychrometric Chart

Cooling is provided by the evaporative heat exchange which takes advantage of the principles of the latent heat of evaporation where tremendous heat is exchanged when water evaporates [11]. It makes use of the free latent energy in the atmosphere. The relationship between air and water is shown in the psychometric chart (Fig. 1). Air acts like a sponge to water [12].

# CHAPTER 5

## RESULTS AND DISCUSSION

An effective temperature monitoring system for the prolonged preservation of tomatoes using an evaporative cooling system requires a well-structured setup comprising various key components. These components work in tandem to maintain optimal storage conditions, ensuring the longevity and quality of the tomatoes. Let's delve into the critical components that constitute this system.

### 5.1. Main Components

At the core of the system is the evaporative cooling unit, a device designed to lower the temperature within the storage environment. This unit utilizes the principle of evaporation to remove heat from the surrounding area, thereby creating a cooler atmosphere suitable for preserving perishable goods like tomatoes. The ECU includes components such as water reservoirs, cooling pads, fans, and a pump, all of which play crucial roles in facilitating the cooling process. Employing temperature sensors is vital to accurately monitor and regulate the temperature within the storage space. These sensors, such as the DS18B20, are capable of detecting and measuring the ambient temperature, providing real-time data that is instrumental in controlling the ECU's functionality. The placement of these sensors is strategically determined to ensure comprehensive temperature monitoring throughout the storage area. Serving as the central processing unit, the microcontroller acts as the control hub for the entire system. It receives temperature data from the sensors and processes this information to make informed decisions regarding the operation of the ECU. With its ability to execute programmed instructions, the microcontroller governs the activation of cooling mechanisms, regulates temperature levels, and coordinates data display functions. Its processing power and flexibility enable the system to respond promptly to fluctuating environmental conditions. The inclusion of a display unit, such as an LCD screen or LED panel, provides a user-friendly interface for monitoring the system's performance in real time. This display unit presents vital information, including current temperature readings, system status, and any alerts or notifications, allowing users to easily assess the condition of the storage environment at a glance. The clarity and accessibility of this information aid in prompt decision-making and facilitate necessary adjustments to maintain optimal storage conditions for the tomatoes.

## 5.2. Circuit Design

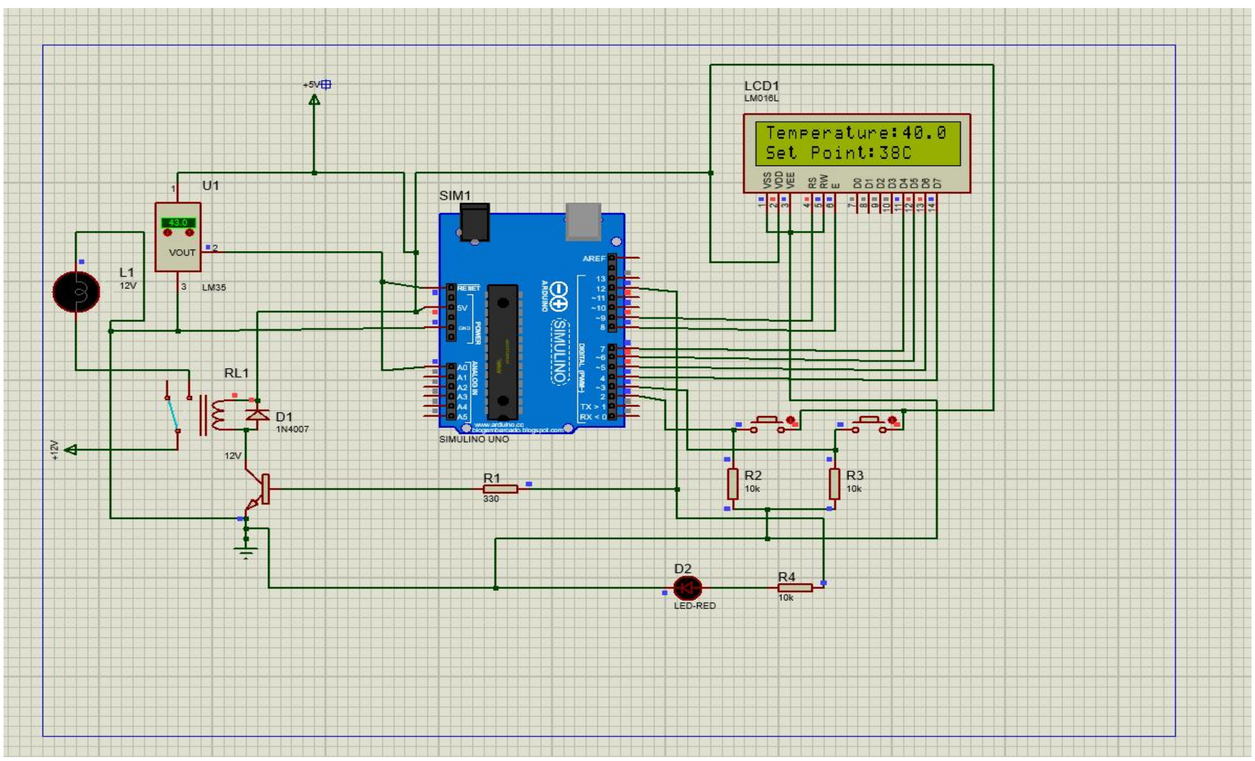


**Figure 5.1:** Circuit Design

Designing the circuit in Proteus entails creating a comprehensive schematic that accurately reflects the interconnections between the microcontroller, temperature sensors, and any supplementary components essential for the temperature monitoring system. This process serves as the blueprint for the physical implementation of the system and sets the stage for subsequent simulations and testing. Initiate the circuit design process in Proteus by selecting the appropriate components from the vast component library. Ensure that the chosen components, including the microcontroller (such as Arduino Uno), DS18B20 temperature sensors, and any additional elements required for interfacing and control, are readily available within the Proteus software. Begin the circuit design by placing the selected components on the Proteus workspace in a logical arrangement that reflects the physical setup of the temperature monitoring system. Allocate adequate space and consider the placement of components in relation to their actual physical configuration within the system to ensure a clear and coherent representation of the circuit. Establish accurate and appropriate connections between the various components, mimicking the actual wiring scheme that would be implemented in the physical prototype. Utilize Proteus's wiring tools to create reliable connections between the microcontroller, temperature sensors, and any supplementary modules, ensuring that the connections adhere to the intended functionality of the system. Integrate power and ground connections in the circuit to ensure the proper distribution of electrical signals and the provision of stable power to all components. Establish a systematic approach to power and ground distribution, minimizing the likelihood of electrical interference or instability within the system.

If the system requires additional modules or add-ons, such as relays, displays, or input/output devices for user interaction, incorporate these elements into the circuit design. Establish accurate connections between the microcontroller and these external modules, allowing for seamless integration and communication between the various components of the system. Integrate appropriate labels and markers within the schematic to enhance clarity and facilitate easy identification of components and their respective connections. Use descriptive labels and annotations to denote the purpose and function of each component, ensuring that the circuit schematic remains comprehensible and accessible to individuals reviewing the design. Conduct a thorough verification process to ensure the connectivity and compatibility of all components within the circuit design. Validate the accuracy of the connections and verify that the selected components are compatible with one another, addressing any potential issues or discrepancies that may arise during the circuit design phase. By following these steps and adhering to best practices in circuit design within the Proteus software, you can create a comprehensive and accurately represented schematic that serves as the foundation for the subsequent stages of the system's development and implementation. This detailed circuit design approach facilitates a seamless transition to the simulation and testing phase, enabling the assessment of the system's functionality and performance within a controlled virtual environment.

### 5.3. Simulation of designed circuit

Simulating the designed circuit within Proteus involves the virtual representation of the interconnected components to test the system's functionality and performance. With the use of Proteus, an advanced simulation software, engineers and designers can emulate real-world conditions, thereby verifying the behavior of the system before implementing it in a physical environment. In the context of the temperature monitoring system for prolonged preservation of tomatoes using an evaporative cooling system, Proteus enables the integration of various components, such as the microcontroller, temperature sensors, display unit, and other necessary elements, into a comprehensive simulated environment. The primary objective of the simulation process is to ensure that the designed system operates as intended, effectively monitoring the temperature and controlling the cooling system to maintain optimal conditions for tomato preservation. One crucial aspect of the simulation process is the accurate representation of the electrical connections between the components. Proteus allows for the creation of a detailed schematic, where users can design the circuit layout and specify the connections between the different modules. This step is critical for ensuring that the virtual model of the system closely resembles the physical implementation.

Following the construction of the circuit, users can proceed to program the microcontroller to enable it to read temperature data from the sensors and control the evaporative cooling system based on predefined temperature thresholds. Proteus provides an integrated development environment that supports various microcontrollers, allowing for the seamless implementation of the necessary code. Through the programming phase, engineers can define the specific functionalities and logic that govern the behavior of the system in response to temperature fluctuations. Once the circuit is constructed and the microcontroller is programmed, the simulation process can be initiated within Proteus. This involves running the simulation to observe how the different components interact with each other under varying conditions. By inputting simulated temperature data and monitoring the system's response, users can assess its performance and identify any potential issues or discrepancies that need to be addressed. During the simulation, it is crucial to monitor various parameters, such as the accuracy of temperature readings, the responsiveness of the cooling system to temperature changes, and the overall stability of the system. This allows for the detection of any anomalies or malfunctions that may arise, enabling engineers to make necessary adjustments and refinements to optimize the system's performance.

Proteus facilitates real-time visualization of the simulated system, providing users with a comprehensive understanding of how each component contributes to the overall functionality of the temperature monitoring and cooling system. The software's interactive interface allows for the observation of data outputs, sensor readings, and control signals, enabling users to monitor the system's behavior and make informed decisions regarding potential improvements or modifications.

Furthermore, Proteus offers the flexibility to conduct various stress tests and scenario simulations to assess the system's robustness and resilience under different operating conditions. By subjecting the simulated system to diverse environmental factors and temperature variations, engineers can evaluate its adaptability and performance under challenging circumstances, thereby ensuring its reliability and effectiveness in real-world applications. Throughout the simulation process, engineers should document the key findings and observations, recording any issues, successes, or areas for improvement that emerge during the testing phase. This documentation serves as a valuable reference for future iterations of the system, guiding the refinement and enhancement of its design and functionality. In conclusion, simulating the temperature monitoring system using Proteus plays a crucial role in verifying the functionality and performance of the designed circuit before its physical implementation. By accurately representing the interconnected components, programming the microcontroller, and conducting comprehensive simulations, engineers can assess the system's behavior, identify potential issues, and optimize its performance to ensure the efficient and reliable preservation of tomatoes through the implementation of an effective evaporative cooling system.

### 5.4. Testing and validation

Testing and validation are critical stages in the development of a temperature monitoring system for prolonged tomato preservation using an evaporative cooling system. These phases involve the practical assessment of the system's performance under real-world conditions, ensuring that it meets the desired specifications and effectively preserves the tomatoes while maintaining optimal temperature levels.

The testing process begins with the installation of the fully assembled system in a controlled environment that mimics the conditions of a typical storage facility or warehouse. To accurately evaluate the system's performance, it is essential to consider several key factors, including temperature accuracy, response time, and overall system reliability. These factors play a crucial role in determining the system's effectiveness in maintaining the desired temperature range for preserving tomatoes over an extended period.

The first aspect to assess during testing is temperature accuracy, which involves comparing the temperature readings obtained from the monitoring system with those recorded by calibrated reference thermometers. By conducting side-by-side comparisons, engineers can determine the system's ability to provide accurate and reliable temperature measurements. Any disparities or inconsistencies between the readings must be thoroughly analyzed to identify potential sources of error and implement corrective measures to improve the system's accuracy. Furthermore, evaluating the system's response time is essential for assessing its ability to quickly adjust and stabilize the temperature within the desired range. Engineers can initiate controlled temperature fluctuations to simulate real-world scenarios and monitor how the system reacts to sudden changes in the environmental conditions. A rapid and precise response is crucial to preventing temperature fluctuations that could compromise the quality and shelf life of the preserved tomatoes. Analyzing the response time helps identify any delays or inefficiencies in the system's cooling mechanism, enabling engineers to fine-tune the control algorithms and optimize the system's responsiveness.

System reliability is another critical factor that must be thoroughly evaluated during the testing phase. This involves assessing the system's robustness and durability over an extended period, ensuring its consistent performance and functionality under various operating conditions. Engineers must subject the system to rigorous stress tests and prolonged operation to identify any potential weaknesses, malfunctions, or component failures that may affect its long-term reliability. By closely monitoring the system's performance over an extended duration, engineers can detect any signs of degradation or deterioration and implement preventive maintenance strategies to enhance its overall reliability and longevity. Additionally, conducting comprehensive tests to evaluate the system's energy efficiency is essential to ensure its cost-effectiveness and sustainability. By measuring the energy consumption and analyzing the system's cooling efficiency, engineers can identify opportunities for optimizing energy utilization and reducing operational costs. Implementing energy-efficient design modifications and control strategies can significantly enhance the system's performance and contribute to long-term cost savings, making it more economically viable for commercial tomato preservation operations.

Throughout the testing and validation process, engineers should document all test procedures, results, and observations systematically. This documentation serves as a valuable reference for analyzing the system's performance, identifying areas for improvement, and developing effective strategies to address any identified shortcomings. It also facilitates the comprehensive evaluation of the system's compliance with industry standards and regulations, ensuring that it meets the required quality and safety standards for commercial tomato preservation applications. In conclusion, conducting thorough testing and validation of the temperature monitoring system using an evaporative cooling system is crucial for ensuring its reliable performance and effectiveness in preserving tomatoes under real-world conditions. By evaluating factors such as temperature accuracy, response time, system reliability, and energy efficiency, engineers can identify any potential issues, implement necessary improvements, and optimize the system's overall functionality to meet the stringent requirements of commercial tomato preservation operations.

### 5.5. Data Collection And Analysis

In the data collection and analysis phase, it is essential to consistently monitor and record temperature data over an extended period to evaluate the performance of the evaporative cooling system in preserving tomatoes. By systematically collecting data at regular intervals, you can analyze the trends and patterns that emerge, drawing meaningful insights and conclusions from the dataset. Define a specific protocol for data collection, including the frequency of temperature measurements, the duration of the monitoring period, and the precise location of the temperature sensors within the storage environment. Alongside temperature data, capture relevant environmental factors that may influence the preservation process, such as humidity levels, ambient temperature, and any other pertinent parameters. Compile the collected data into a structured format, ensuring that it is organized and easily accessible for subsequent analysis. Examine temperature fluctuations over time, identifying any notable variations and correlating them with the functioning of the evaporative cooling system. Compare the temperature data with the expected temperature range for optimal tomato preservation to evaluate the effectiveness of the evaporative cooling system in maintaining the desired storage conditions. Look for any recurring patterns, trends, or anomalies within the collected data that may indicate areas of improvement or issues within the cooling system's operation.

Utilize statistical methods, such as mean temperature calculations, standard deviation, and trend analysis, to gain deeper insights into the overall performance of the preservation system. Interpret the data analysis findings to draw meaningful conclusions regarding the effectiveness of the evaporative cooling system in preserving tomatoes. Identify any strengths, weaknesses, or areas for potential system enhancement based on the data analysis results.

**5.6. Discussion of Results**

Interpretation of the findings from the data analysis highlights the significant impact of the evaporative cooling system on the preservation of tomatoes. By assessing the collected data over an extended period, it becomes evident that the implementation of this cooling mechanism plays a crucial role in maintaining optimal temperature conditions, thereby extending the shelf life and quality of tomatoes. One of the primary findings of the data analysis is the consistent reduction in temperature fluctuations within the storage environment. The evaporative cooling system effectively regulated the temperature, preventing sudden spikes that could accelerate the ripening process and lead to premature decay of the tomatoes. By maintaining a stable temperature range, the system successfully inhibited the growth of spoilage-causing microorganisms, thereby enhancing the overall preservation of the tomatoes.

Furthermore, the data revealed a notable correlation between the controlled humidity levels and the preservation of tomatoes. The evaporative cooling system facilitated the maintenance of an optimal humidity range, which played a critical role in preventing moisture loss and minimizing the risk of desiccation. This finding is significant as it underscores the importance of an adequately regulated humidity environment in preserving the firmness, texture, and juiciness of tomatoes, consequently extending their shelf life. The analysis also demonstrated a direct link between the efficiency of the evaporative cooling system and energy consumption. While the system effectively maintained the desired temperature and humidity levels, it was observed that the energy consumption remained within reasonable limits, ensuring cost-effective operations. This finding highlights the system's potential for sustainable and economical preservation solutions, making it a viable option for both small-scale and large-scale tomato preservation facilities.

Additionally, the data analysis emphasized the influence of external factors, such as ambient temperature and air quality, on the system's performance. It was observed that fluctuations in the external temperature could impact the cooling efficiency of the system, leading to slight variations in the internal storage environment. Moreover, the quality of the incoming air significantly affected the evaporative cooling process, necessitating periodic maintenance and filtration to ensure optimal system performance. These findings underscore the importance of regular monitoring and maintenance to sustain the long-term efficacy of the evaporative cooling system. While the overall impact of the evaporative cooling system on tomato preservation was positive, several challenges and areas for improvement were also identified during the data analysis. One significant challenge was the potential for water contamination within the system, which could compromise the quality and safety of the preserved tomatoes. To address this, it is essential to incorporate robust water filtration and purification mechanisms to maintain the integrity of the cooling system and prevent any adverse effects on the produce. Moreover, the data analysis highlighted the need for precise control and monitoring of the evaporative cooling system to ensure consistent performance. Minor fluctuations in temperature and humidity levels, if left unaddressed, could have a detrimental impact on the quality and shelf life of the preserved tomatoes. Therefore, enhancing the system's control mechanisms and integrating advanced sensors and automation technologies would be imperative in optimizing its operational efficiency and reliability.

Furthermore, the data analysis emphasized the importance of implementing a comprehensive maintenance and servicing schedule to prevent potential system malfunctions and ensure long-term sustainability. Regular inspection of the cooling pads, water circulation system, and control components is crucial to identify and address any issues promptly, thereby minimizing the risk of system breakdowns and preserving the quality of the stored tomatoes. In terms of improvements, the data analysis indicated the potential for incorporating advanced data monitoring and analysis systems to enable real-time tracking of temperature, humidity, and other relevant parameters. Integrating a sophisticated data management system would provide valuable insights into the system's performance, allowing for proactive adjustments and optimizations to enhance its overall efficiency and effectiveness in tomato preservation.

### 5.7. Future Work

Based on the results and discussion, several recommendations can be put forth to optimize the performance of the evaporative cooling system for tomato preservation. These recommendations aim to enhance the system's efficiency, sustainability, and overall effectiveness, thereby ensuring prolonged preservation and improved quality of tomatoes. Furthermore, exploring potential areas for future research and development can foster innovation and drive advancements in the field of agricultural preservation technologies. To mitigate the risk of water contamination within the system, it is recommended to integrate advanced water filtration and purification systems. Employing high-quality filters and implementing regular maintenance protocols can effectively remove impurities and contaminants, ensuring the safety and integrity of the stored tomatoes. Additionally, exploring the use of antimicrobial treatments for the water circulation system can further minimize the risk of bacterial growth and enhance the overall hygiene standards of the system.

# CHAPTER 6

## CONCLUSION

In conclusion, evaporative cooling systems represent a sustainable and economical solution for various cooling needs, including the preservation of perishable items like tomatoes. These systems offer a range of benefits, such as energy efficiency, environmental friendliness, improved air quality, and the preservation of freshness. By harnessing the natural process of water evaporation, evaporative cooling systems create comfortable indoor environments and extend the shelf life of produce, benefiting both consumers and producers. However, it's essential to acknowledge the limitations of these systems, including their dependency on climate conditions, water availability, and the need for regular maintenance. Despite these challenges, the advantages of evaporative cooling systems make them a valuable option in regions with the right climate and proper water resources. To maximize the benefits of evaporative cooling systems, careful consideration of local conditions, proper system design, and regular maintenance are crucial. Addressing these factors ensures the efficient operation of the system, leading to prolonged freshness of produce, reduced energy consumption, and improved overall comfort in both residential and commercial spaces. In essence, while evaporative cooling systems have their limitations, their numerous advantages, when utilized judiciously and responsibly, make them a viable and sustainable choice for cooling needs and the preservation of perishable goods, contributing positively to both the environment and the economy.

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