DESIGN AND MANUFACTURING OF A LOW-COST AUTOMATED MISTING SYSTEM FOR PRODUCE

A PROJECT REPORT
DE-41(DME)

Submitted by

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DECLARATION

We hereby declare that no portion of the work referred to in this Project Report has been submitted in support of an application for any other degree or qualification of this for any other university. All sources used in the preparation of this thesis have been acknowledged by means of citations and references. If any act of plagiarism is found, we are fully responsible for every disciplinary action taken against us depending upon the seriousness of the proven offence.

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First of all, Alhamdulillah, that our FYP is finally done and all Thanks to Allah for giving us the courage to stay motivated till the end.

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We would also like to thank all those people who, though, not mentioned here but have helped us in project directly or indirectly.

ABSTRACT

One-third of the food produced worldwide each year is lost or wasted, which results in both a financial loss and the waste of all the natural resources necessary for food production, processing, packaging, transportation, and marketing. We cannot afford to waste our natural resources if 28% of the world's agricultural land is used to grow crops that are wasted along with the water used to grow those crops. Fruit and vegetable waste output between harvest and consumer consumption is close to one-third, which is mostly attributable to long distribution routes and insufficient transport and storage methods. Our study aims to address this issue by creating a novel humidification system that delays fruit and vegetable decomposition, structural change, and moisture loss, so extending their shelf life. The mist makes the environment cold, damp, and non-toxic, which maintains quality and freshness. With the help of our technology, fresh produce is no longer stressed, its vitamins and polyphenols are better maintained, and its shelf life is extended, which reduces the number of fruits and vegetables that shops throw away. Misting systems keep food in the service case and in cold storage moist and help prevent deterioration. To keep your product appearing fresh and delectable, a specialized mist system is essential for preventing weight loss, shrinkage, and chemical composition degradation. You gain from greater sales in addition to the fact that customers can confidently buy high-quality, nutrient-dense fruit and vegetables that will keep fresher longer once they get them home by decreasing weight loss, extending, and retaining freshness. A properly constructed and fitted humidification mist system covers the entire room with moist air without producing excessive water droplets, keeping the floor surfaces dry. The fruits and vegetables will receive the appropriate amount of water at the appropriate times thanks to our completely automated system. Our misting system is simple to operate and maintain because it doesn't involve any additional labor.

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CHAPTER 1 – INTRODUCTION

1.1 Background

Water-mist technologies are a burgeoning trend in diverse fields such as fire safety and surface temperature control. Their popularity gained traction in the aftermath of the 1987 ban on halons, hydrogenated hydrocarbons notorious for their harmful impact on the ozone layer. Our interest lies in harnessing the potential of these systems in the agro-food sector, specifically for minimizing food wastage. According to the United Nations' Food and Agriculture Organization (FAO), roughly one-third of all food produced for human consumption worldwide, including fruits and vegetables, goes to waste each year. This is a result of factors ranging from microbial and chemical spoilage during production and post-harvest processes (defined as food loss), to waste generated from the habits of retailers and consumers.

Water Mist Systems present a viable solution for cutting down these food losses, particularly in the post-harvest stages of fruits and vegetables, thereby enhancing the environmental sustainability of food supply networks. The application of misting systems has been largely observed in retail cabinet displays. Yet, exploratory tests have also shown promise for the application of this technology in refrigeration rooms at various stages in the supply chain, such as distribution centers and wholesale markets. To harness the true potential of misting technology, it could be applied comprehensively across all stages of post-harvest processing for fruits and vegetables. This encompasses storage in refrigerated rooms at multiple points in the supply chain (like farms, processing centers, distribution hubs, and wholesale outlets), during transit, as well as at retail points of sale (in cabinet displays or refrigeration rooms). The practicality of adopting this method has been demonstrated in several case studies across Europe.

1.2 Motivation

A paramount challenge for food scientists globally revolves around prolonging the freshness of food and ensuring its safety concurrently. Particularly, fruits and vegetables are prone to rapid deterioration during the long journey from the point of harvest to consumption. Consequently, substantial postharvest food loss and wastage is an alarming worldwide issue. Our inspiration to undertake this research stems from our aim to develop Mist Pro, an Automated Water Misting System designed for supermarkets. This innovation aims to extend the food shelf-life, thus effectively mitigating food wastage.

1.3 Objective

To solve the problem of agro-food losses and to maintain the freshness of foods during the long process from harvest to point of consumption, we present the Mist Pro, Automated Water Misting System. The mist control system is opted to be automatic, i.e., the mist will be sprayed after the detection of any dryness in the food.

Our goal is to develop a **“Mist Pro, Automated Water Misting System”.** The main points of Mist Sprayer System include relevant calculations for pressure at different points. It also includes the proper specification of the valves and components used.

- Development of an automatic system for misting process
- Developing a Misting System to be used in the market for food (fruits, vegetables, meats etc.)
- To develop a fully functioning product (Misting System) that could be used according to our specified application.
- Development of a working model/ Final Product of the Automatic Mist Sprayer System

1.4 Sustainable Development Goals (SGD Goals)

The Sustainable Development Goals are the road map to a brighter and more sustainable future for everybody. They deal with issues like poverty, inequality, climate change, environmental degradation, peace, justice, and other worldwide problems we confront. The upcoming SGD Goals are fulfilled by our project

- **Goal 2 Zero Hunger:** Our project focuses on prevention of food wastage and provides a suitable way to store food and provides food security
- **Goal 3 Good Health and Well Being:** As explained earlier, misting process can be enhanced to improve the microbial quality of foods and can be used with chlorine for washing effect.
- **Goal 7 Affordable and Clean Energy:** Our main focus is to be reliable, affordable, and sustainable for general market.
- **Goal 12 Responsible Consumption and Production:** As we focus mainly on the use of food efficiently without any major losses and are focusing on the responsible consumption of water droplets in the form of Mist.
- **Goal 13 Climate Action:** More buildings will be exposed to milder winters and hotter summers as a result of climate change. Increased heat waves and heat stress are anticipated to lead to more illnesses and fatalities, as was the case in the scorching summers of 2003 and 2006. The urban heat island (UHI) effect exacerbates these issues. Urban regions that experience greater temperatures than rural ones are referred to as urban heat islands. Therefore, heat stress can be reduced in the outdoor and indoor urban environment by implementing adaptation measures like evaporative cooling/Mist Spraying Systems.

CHAPTER 2 - LITERATURE REVIEW

2.1 Introduction

A paramount challenge for food scientists globally revolves around prolonging the freshness of food, ensuring its safety concurrently. Particularly, fruits and vegetables are prone to rapid deterioration during the lengthy journey from the point of harvest to consumption. Consequently, substantial postharvest food loss and wastage is an alarming worldwide issue. The need to maintain the freshness and extend the shelf life of produce has led to several technological advancements in the agriculture industry. One such innovation is the automated misting system. The design and development of an automated misting system for produce is a distinctive solution that aims to enhance the post-harvest quality and shelf life of fresh produce. This literature review explores various studies conducted on the design and development of automated misting systems for produce.

2.2 Misting System and Its Importance

In the pursuit of methods to extend the life of fresh produce, researchers have identified appropriate humidity levels as a critical factor. Farid and El-Gindy (2017) explained how controlled humidity environments could delay ripening and senescence, thus reducing the loss of post-harvest fruits and vegetables. By maintaining an appropriate humidity level, automated misting systems are able to delay ripening and senescence in produce, thus significantly extending their shelf life. An automated misting system presents a reliable and efficient method to manage humidity levels, which directly impacts the quality and lifespan of produce (Sivakumar & Bautista-Baños, 2014).

Automated misting systems have been identified as a reliable and effective solution for such needs. They work by spraying a fine mist of water at regular intervals over the produce, creating a high humidity environment which reduces transpiration, the primary cause of water loss in fruits and vegetables. Aside from preserving freshness, these systems also enhance the visual appeal of the produce, making it more attractive to consumers (Elansari et al., 2018).

2.3 Traditional Misting Systems

The inception of misting systems can be traced back to the 1950s, primarily used for cooling outdoor environments (Hussein et al., 2008). Over the years, its application expanded into various sectors, including agriculture, for enhancing produce freshness. While the underlying principles have remained consistent - creating a high humidity environment to reduce produce water loss - the technology driving these systems has seen several advancements.

In the early stages, misting systems were manually operated, requiring regular human intervention to maintain optimal humidity levels (Farid & El-Gindy, 2017). These systems were not very efficient and often resulted in over-watering, causing potential waterlogging issues for the produce.

2.4 Introduction of timer based systems

A significant development in misting systems occurred with the introduction of timer-based misting systems. These systems revolutionized the field by incorporating mechanical or digital timers to schedule the intervals at which misting would occur. This innovation brought about a higher degree of automation and consistency in misting applications.

By utilizing timers, users could easily set specific time intervals for misting, ensuring a regular and predictable misting schedule. This automation greatly reduced the need for manual intervention and monitoring, making misting systems more convenient and user-friendly.

Moreover, the introduction of timer-based misting systems provided an efficient way to maintain optimal environmental conditions for various applications. These systems were particularly beneficial in horticulture, greenhouses, and livestock farming, where controlled humidity and temperature were crucial for plant growth or animal well-being.

However, despite their advantages, timer-based misting systems had some limitations. One significant drawback was their lack of flexibility in adapting to changes in environmental conditions. Since these systems relied solely on pre-programmed timers, they did not account for variations in temperature, humidity, or other factors that could affect the ideal misting frequency. In some cases, environmental conditions could change rapidly, such as sudden temperature spikes or drops, unexpected humidity levels, or shifts in airflow patterns. Timer-based misting systems were unable to dynamically adjust misting intervals based on these real-time variations. As a result, the misting cycles could become inadequate or excessive, leading to suboptimal misting efficiency or even potential damage to plants or animals.

To address these limitations, researchers and engineers began exploring more advanced misting systems that incorporated sensors and feedback mechanisms. These newer systems aimed to provide a higher level of automation and adaptability by monitoring and responding to real-time environmental conditions.

These sensor-based misting systems utilized a range of sensors, such as temperature sensors, humidity sensors, airflow sensors, and even plant or animal health monitoring sensors. The data collected by these sensors was then processed by sophisticated algorithms to determine the optimal misting frequency and duration in response to the current environmental conditions.

By dynamically adjusting misting intervals based on real-time data, sensor-based misting systems offered a more precise and efficient approach to maintaining ideal environmental conditions. They provided the flexibility to adapt to changing conditions, ensuring that misting was delivered when and where it was most needed.

Overall, while timer-based misting systems brought significant advancements in automation and consistency, their lack of flexibility limited their effectiveness in dynamically changing environments. The subsequent development of sensor-based misting systems marked a new era in misting technology, enabling more precise and adaptable misting applications in various fields, from agriculture to industrial cooling and beyond (Elansari et al., 2018).

2.5 Design elements

In addition to the development of timer-based misting systems, extensive research has focused on optimizing misting system performance through careful consideration of design elements, such as mist droplet size and frequency. These elements play a crucial role in achieving desired outcomes across various applications.

Liu et al. (2022) conducted a comprehensive study investigating the relationship between mist droplet size and absorption rates. Their findings highlighted the importance of droplet size in maximizing the efficiency of misting systems. The researchers concluded that finer mists with smaller droplet sizes tend to be more effective in maintaining optimal humidity levels. Smaller droplets have a larger surface area-to-volume ratio, allowing for faster evaporation and absorption by plants, surfaces, or the surrounding environment. This increased surface area enhances the overall effectiveness of the misting system in delivering moisture precisely where it is needed. Furthermore, research conducted by Di Gioia et al. (2021) examined the impact of misting frequency and duration on the freshness of produce. The study revealed that the timing and duration of misting events significantly influence the shelf life and quality of perishable goods. Properly timed and controlled misting can help reduce water loss and maintain the desired moisture levels in fruits, vegetables, and other fresh produce. This, in turn, slows down the wilting process, preserves texture, and extends the overall freshness and visual appeal of the products.

The research suggests that optimizing the frequency and duration of misting events can have a profound impact on the post-harvest preservation and quality of agricultural products. Fine-tuning these parameters allows for better control over moisture levels, reducing the risk of dehydration or excessive wetness, which can lead to spoilage or deterioration. To achieve optimal misting performance, modern misting systems often incorporate advanced technologies. These systems may utilize precision nozzles or atomizers designed to produce consistent droplet sizes within the desired range. Additionally, some misting systems employ variable frequency controls, allowing for customized misting schedules based on specific environmental conditions, plant requirements, or desired outcomes.

The integration of research findings into misting system design has led to enhanced precision and efficiency. Fine-tuned mist droplet size and controlled misting frequency contribute to improved water utilization, reduced waste, and enhanced effectiveness in achieving desired outcomes, whether it be maintaining optimal humidity levels, preserving freshness, or promoting growth in various applications. As misting technology continues to evolve, ongoing research and development efforts aim to uncover further insights into the relationship between design elements and system performance. This knowledge will inform the design and implementation of future misting systems, enabling even greater control, efficiency, and customization to meet the specific needs of diverse industries and applications.

2.6 Sensor Based Systems

In recent years, sensor-based control systems have emerged as a significant advancement in misting technology. These systems utilize a range of sensors to measure ambient conditions, including temperature and relative humidity, providing real-time data for precise control and adjustment of misting frequency (Tran et al., 2021). This technology has revolutionized the efficiency of misting systems, optimizing water usage while effectively maintaining optimal conditions for various applications, particularly in the preservation of produce.

By continuously monitoring environmental parameters, sensor-based control systems can dynamically adjust misting frequency and duration based on the specific needs of the produce or desired outcomes. For example, if the relative humidity drops below the desired threshold, the system can trigger misting events to elevate humidity levels and prevent dehydration. Conversely, if the humidity is already at an optimal level, the system can reduce or halt misting to conserve water and avoid excessive moisture accumulation. This level of automation and precision ensures that misting is provided exactly when and where it is most beneficial, optimizing both product quality and water efficiency.

One of the key advantages of sensor-based misting systems is their focus on environmental considerations. As highlighted in a comprehensive review by Williams and Martin (2019) on sustainable practices in produce preservation, automated misting systems contribute to eco-friendly practices. These systems prioritize efficient water usage, which is especially critical in regions facing water scarcity or where water resources need to be conserved. By employing sensors to monitor and adjust misting based on real-time conditions, these systems minimize water waste, reducing the overall environmental impact associated with misting operations. Moreover, sensor-based misting systems play a significant role in sustainability efforts by helping to reduce food waste. By maintaining optimal conditions for produce, such as fruits and vegetables, misting systems can extend the shelf life and freshness of these perishable items. This extension allows for better inventory management, reducing the likelihood of produce spoilage and minimizing the need for premature disposal. By decreasing food waste, misting systems contribute to overall sustainability goals, conserving resources and reducing greenhouse gas emissions associated with food production and waste management.

Efforts are being made to integrate sensor-based control systems with other technologies, such as machine learning algorithms and predictive analytics, to optimize misting operations based on historical data and predictive modeling. This integration allows misting systems to adapt and learn from patterns, further improving water efficiency and resource management. In conclusion, sensor-based control systems have transformed misting technology, offering precise control, increased efficiency, and reduced water usage in various applications. By incorporating sensors to monitor ambient conditions, these systems ensure optimal misting frequency while addressing environmental considerations. The eco-friendly nature of automated misting systems, as highlighted by research on sustainable practices, contributes to water conservation efforts and reduces food waste, making them an integral part of sustainable and efficient produce preservation practices.

CHAPTER 3 - COMPONENTS

The main components of our misting system are,

- Pump
- Solenoid valve
- Non-return valve
- Pressure switch
- Water storage tank
- Timer
- Humidity Sensor
- Mist nozzles
- Connecting Pipe
- Hard Water Filter

The specifications of these components are enlisted below.

3.1 High Pressure Switch

When the storage tank is filled according to the required pressure the high pressure switch cuts the connection of the booster pump

Figure 3.1 High Pressure Switch

Type	High Pressure Switch
Type	SPDT Micro Switch
Contact Rating	15 A at 230 VAC
Electrical Connection	Brass lugs
Differential	2.0
Range kg/cm^2	2.0 to 25
Hysteresis (Fixed)	2.0 kg/cm^2
Process Connection Size	1/4” BSPM
MOC of Body	Glass Field Nylon

Table 3.1 High Pressure Switch

3.2 Low Pressure Switch

Low pressure cuts the connection of booster pump when there is low pressure of water then required or no water in order to protect the booster pump.

Figure 3.2 Low Pressure Switch

Type	Low Pressure Switch
Type	SPDT Micro Switch
Contact Rating	15 A at 230 VAC
Electrical Connection	Brass lugs
Differential	0.5
Range kg/cm^2	0.5 to 5
Hysteresis (Fixed)	0.5 kg/cm^2
Process Connection Size	1/4” BSPM
MOC of Body	Glass Field Nylon
MOC of diaphragm	Viton
Spring	SS 316
Set Point adjustment	By M3 grub Screw
Size	90mm x 50mm x 65mm
Max. working Temperature	60°C

Table 3.2 Low Pressure Switch

3.3 Pump

The booster pump uses an impeller to increase the water flow rate and pressure.

Figure 3.3 Booster Pump

RO booster pump	
Rated current	1-4A
Voltage	24V
Material	Aluminum alloy
Valve body type	diaphragm
Working	90 psi
Water flow	800ml/min , 0.211 gal/min

Table 3.3 RO Booster Pump

3.4 Timer Switch

A timer relay appropriate for your incubator and other time-related projects is the Digital Incubator Timer Relay. The timer relay module is an LED digital display home automation delay timer control switch module timer controller. There are several industries and a variety of uses for the best incubator timer controller.

Figure 3.4 Timer Switch

Timer Switch	
Voltage	6-30V
Support micro USB	5.0V power supply
Output capability	Within DC 30V SA
Programmable Timing Circuit board	35238mp.

Table 3.4 Timer Switch

3.5 Hard Water Filter

The features of hard water filter include,

- Softens hard water which contain magnesium ions and calcium
- Reduces the process of scaling of RO membranes
- Composed of cationic particles

Figure 3.5 Hard Water Filter

Specifications	
Composition	Cationic Particles
Usage Time	6 months (10,000 L)
Max. Flow	100 L/H
Pressure	5 bars

Table 3.5 Hard Water Filter

3.6 Pressurized Tank

In pressurized air tank the diaphragm is expanded against tank shell. Air is compressed as expanding water pushes into the tank. This compressed air pushes contacting water back into the system.

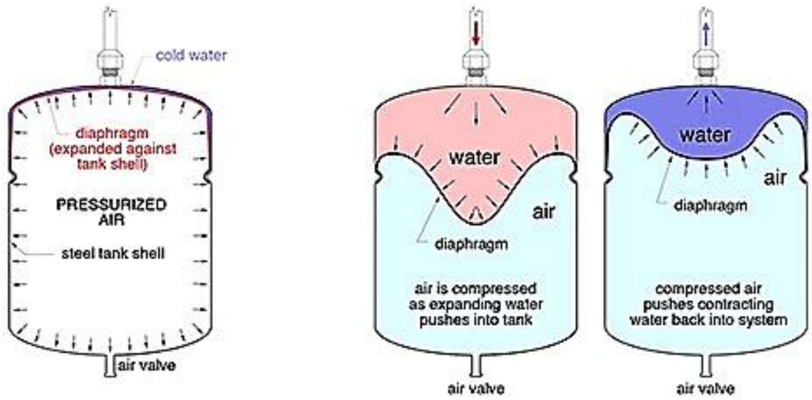

Figure 3.6 Pressurized Tank

Pressurized Air Tank	
Capacity	3.2 Gallons
Pre-charge Pressure	5-7 Psi
Max Working Pressure	50 Psi
Max Temperature	60°C

Table 3.6 Pressurized Air Tank

3.7 Humidity Sensor

A humidity sensor is an electronic device that measures and monitors relative humidity in the surrounding environment. It operates based on capacitive or resistive principles, utilizing materials that respond to moisture changes. These sensors provide vital data for a wide range of applications and are crucial for maintaining optimal conditions in numerous industries and systems.

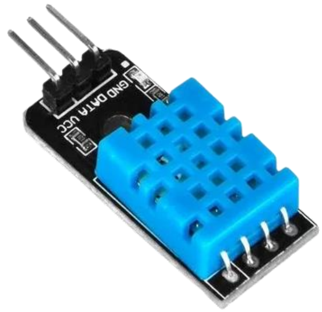

Figure 3.7 Humidity Sensor

3.8 Nozzles

The features of nozzles are as follows,

- Not easy clogged
- Wear resistance
- Spray evenly
- Can effectively improve the quality and production efficiency
- Can effectively regulate the humidification amount and the spray effect.
- Fully atomized
- Energy saving and low cost

Figure 3.8 Nozzle

Nozzles	
Type	Flat Fan Nozzles
Diameter	5mm
Mist spot	up to 3-7 microns

Table 3.7 Nozzles

3.9 Non Return Valve

Non Return Valve or NRV protects the booster pump from back flow of the storage tank when it is filled completely.

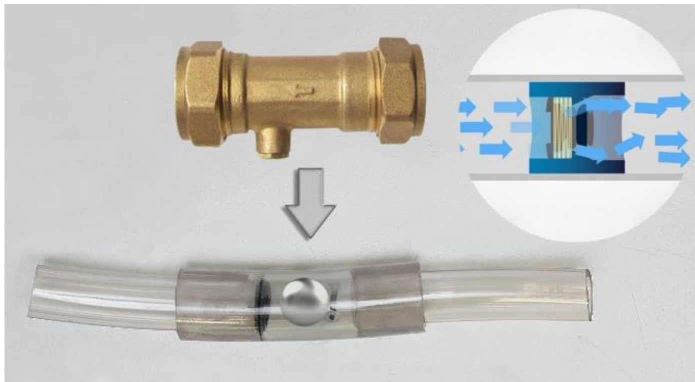

Figure 3.9 Working of NRV

3.10 Solenoid Valve

A solenoid valve is an electromechanical device that controls the flow of fluids or gases. It operates by using an electromagnetic field to move a plunger, allowing or blocking the flow through the valve. Solenoid valves offer precise and rapid control, making them indispensable in numerous industries such as manufacturing, process control, and automation.

Figure 3.10 Solenoid Valve

CHAPTER 4 – NOZZLE SELECTION

Selecting the right nozzle for a misting system is a crucial factor that determines its effectiveness, particularly when designed for the preservation of vegetables. In our project, we have chosen flat fan nozzles for their distinct characteristics that suit our requirements. However, understanding the diversity in nozzles and their respective flow patterns is integral to making an informed choice. Figure 4.01 shows some types of nozzles and the difference between them. Further detail about the nozzles is provided below.

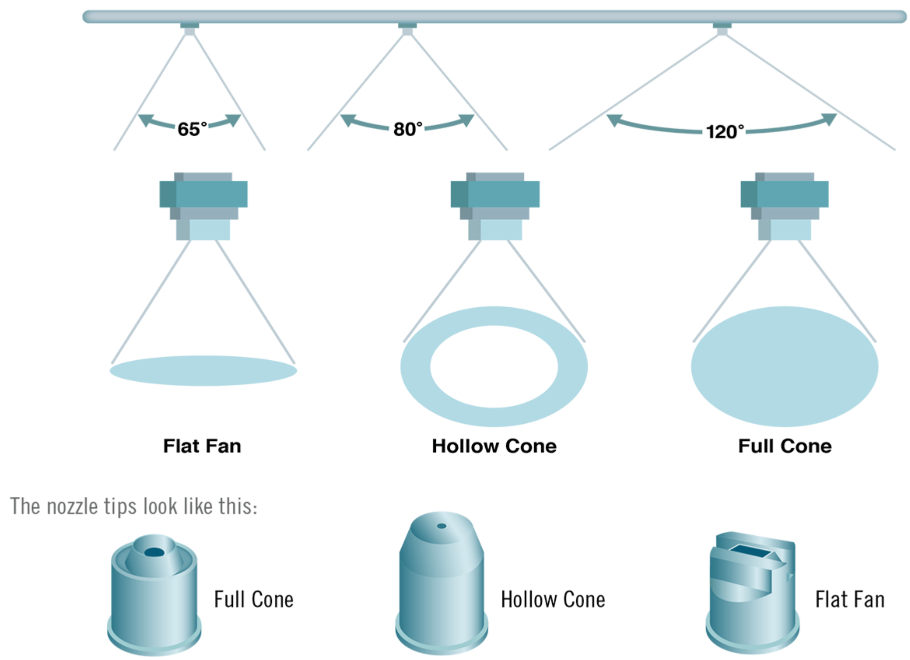

Figure 4.01 Types of nozzles

4.1 Full Cone Nozzles

These nozzles produce a round spray pattern in the shape of a full cone, distributing droplets evenly across a circular area. Their applications range from cooling and washing to dust suppression. However, their circular spray pattern may not provide as uniform a coverage over larger, flat areas as the flat fan nozzle.

4.2 Hollow Cone Nozzles

Hollow cone nozzles, like full cone nozzles, are a type of nozzle used in various applications that require a fine spray and high atomization. While both full cone and hollow cone nozzles produce a conical spray pattern, the distribution of the spray differs between the two. In the case of hollow cone nozzles, the spray is concentrated on the periphery of the cone, leaving the interior relatively dry. This unique spray pattern makes hollow cone nozzles well-suited for specific applications where targeted coverage is desired. The concentrated spray at the periphery ensures that the desired area is effectively coated with the atomized liquid, while the drier interior minimizes overspray and waste.

In summary, hollow cone nozzles are designed to produce a conical spray pattern with concentrated spray at the periphery and a relatively dry interior. This unique spray distribution makes them ideal for applications that require fine spraying, high atomization, and targeted coverage. From gas cooling and fire suppression to various industrial processes, hollow cone nozzles play a vital role in achieving efficient and precise liquid distribution while minimizing waste and optimizing performance.

4.3 Straight Jet Nozzles

Straight jet nozzles, also known as solid stream nozzles, are a type of nozzle that produces a straight and focused jet of liquid. Unlike full cone or hollow cone nozzles, which disperse liquid in a conical spray pattern, straight jet nozzles maintain a concentrated and powerful stream. This nozzle design is commonly used in applications where precision and distance are key factors, such as high-pressure cleaning, fire protection, or water jet cutting. Straight jet nozzles are known for their ability to deliver a strong and targeted flow, allowing for effective cleaning or fire suppression at a distance. The focused stream produced by these nozzles enables operators to direct the liquid precisely where it is needed, maximizing the efficiency and effectiveness of the application.

4.4 Spiral Nozzles

Spiral nozzles, also referred to as swirl nozzles or helix nozzles, are specialized nozzles that produce a unique spiral spray pattern. These nozzles utilize a spiral chamber design, which imparts a swirling motion to the liquid as it exits the nozzle. This swirling action creates a spiral spray pattern characterized by a combination of fine droplets and larger droplets moving in a rotating pattern. Spiral nozzles are commonly used in various applications, including gas cooling, dust suppression, and chemical processing. The spiral spray pattern provides enhanced coverage and distribution compared to traditional spray patterns, making spiral nozzles particularly effective in applications where uniform and thorough liquid dispersion is required. The unique design of spiral nozzles allows for efficient atomization and a controlled spray angle, providing versatility and adaptability to meet specific application requirements.

4.5 Flat Fan Nozzles

Our decision to utilize flat fan nozzles in our vegetable misting system was made after meticulous consideration of various factors. This nozzle type is known for its distinct operational characteristics and the specific advantages it brings to the field of vegetable preservation.

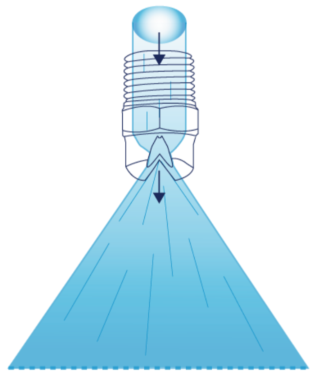

Figure 4.5a Flat Fan Nozzle

4.5.1 Spray Pattern

The primary attribute of flat fan nozzles is their unique spray pattern. These nozzles produce a flat, thin, fan-shaped spray that is perfect for applications requiring a linear spread of mist over a broad area. This design allows the droplets to be distributed evenly across a wide expanse, ensuring uniform coverage of the vegetables and thus maximizing their exposure to mist. Moreover, the flat fan patterns thin, even spray ensures that water is distributed efficiently, without over-saturating any particular area. This is critical for our application because excessive moisture could lead to spoilage, whereas insufficient moisture might not provide the necessary cooling effect. The flat fan nozzle, with its balanced and uniform spray pattern, thus offers a solution that optimizes moisture distribution.

Additionally, the shape of the spray pattern can often be adjusted on flat fan nozzles by altering the pressure or the nozzle design. This versatility allows us to customize the spray pattern to suit the specific needs of different vegetables, contributing further to the efficient operation of our misting system.

4.5.2 Cooling Efficiency

Another significant advantage of flat fan nozzles is their cooling efficiency. By generating a wide, thin spray, these nozzles increase the surface area of the water, which in turn promotes rapid evaporation and efficient cooling. This is an essential feature for our vegetable misting system, as maintaining a cool environment can significantly enhance the freshness and extend the shelf-life of the produce.

4.5.3 Droplet Size

Flat fan nozzles are known for their ability to produce small, uniform droplets. This fine mist is less likely to cause physical damage to delicate fruits and vegetables than larger water droplets. Moreover, smaller droplets ensure better adherence to the surface of the produce, providing consistent moisture without making the produce excessively wet.

4.5.4 Operational Flexibility

Flat fan nozzles are available in a wide range of sizes and capacities, offering operational flexibility to cater to the specific needs of different types of produce and varying storage environments. Flat fan nozzles can be selected or adjusted to provide the ideal conditions.

4.5.5 Durability and Maintenance

Flat fan nozzles are generally constructed from materials such as stainless steel or plastic that offer robustness and longevity. Additionally, they are relatively easy to clean and maintain, minimizing the risk of clogging and ensuring consistent performance.

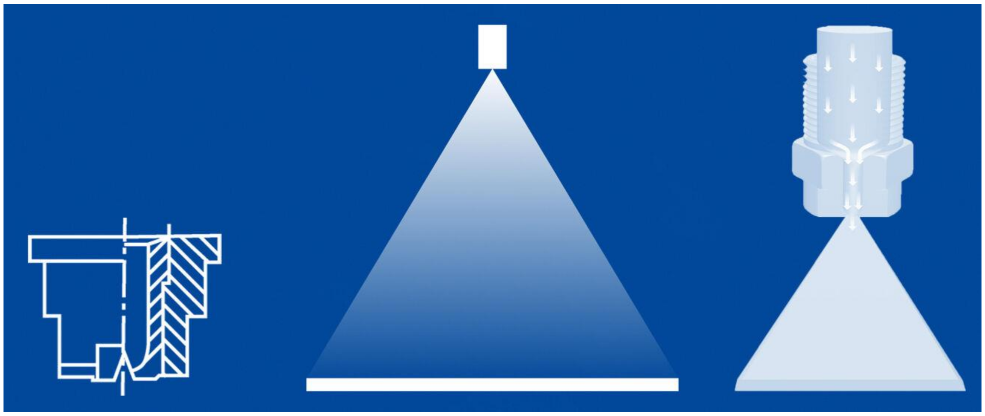

Figure 4.5b Flat Fan Nozzles

CHAPTER 5 – METHODOLOGY

5.1 Project Flow Chart

In this project, the input of the system is connected with the water tap from which the water is taken and after that the incoming water is filtered by using the hard water filter then the filtered water will passed from the solenoid valve the water goes through the pump where the pressure is generated and then after the pump there will be a non-return valve which protects the pump from backward pressure that will comes from the water tank when it becomes filled. This water tank is basically the storage of water if the water will stop coming from the incoming tap. Then from the water tank, the water will move towards the mist nozzles through the solenoid valves and timer that will open and close the valve according to the need. The mist nozzles then produce the mist at the product end. The flow chart of the project is:

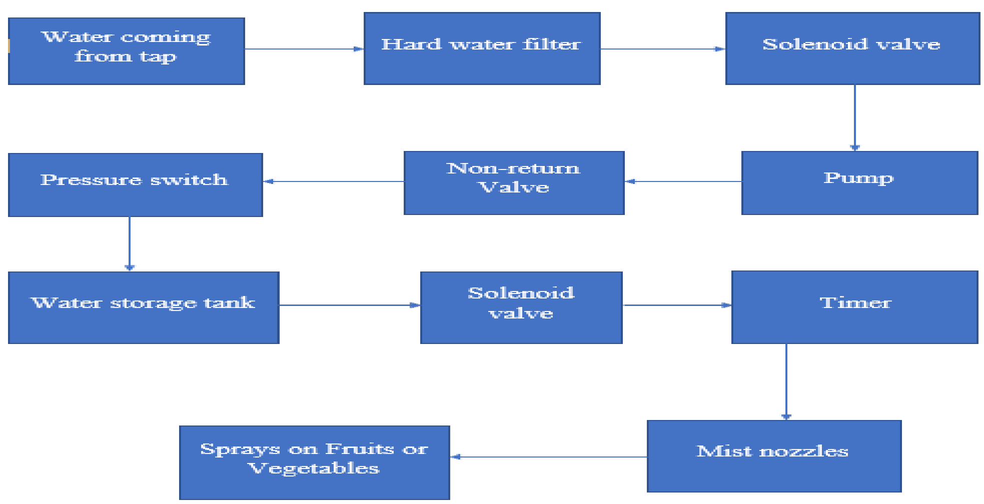

Figure 5.1 Project Flow Plan

5.2 CAD Models

Computer-Aided Design (CAD) models are an integral tool in numerous industries, playing a pivotal role in the design and development of various products. CAD models provide a realistic 3D representation of the product, allowing us to visualize the final product before it's physically built. CAD software automatically creates detailed documentation of the design, including specifications, materials, dimensions, and assembly instructions.

The CAD Models of our project include the model of Nozzle and the model of the whole project. Both of these are provided below.

5.2.1 CAD Model of Nozzle

Within our project, we have incorporated two essential CAD models: the Nozzle model and the complete project model. Both of these models are presented below, providing a comprehensive and detailed representation of the corresponding components. These models offer an in-depth understanding of the design, enabling precise visualization and analysis of the entire project. The Nozzle model encompasses intricate details and precise measurements, ensuring accurate integration within the larger assembly. The CAD Model of nozzle is shown in Figure 5.2.1.

Figure 5.2.1 CAD Model of Nozzle

5.2.2 CAD Model of Whole Assembly

The complete project model showcases the assembly of all components, offering a holistic view of the final product and its inter-connections. CAD Model is more efficient than flow diagrams as it provides a 3D view and provides a clear picture of the whole assembly. It provides better understanding of the components and their positioning. Cad model of all the components assembled together is given below.

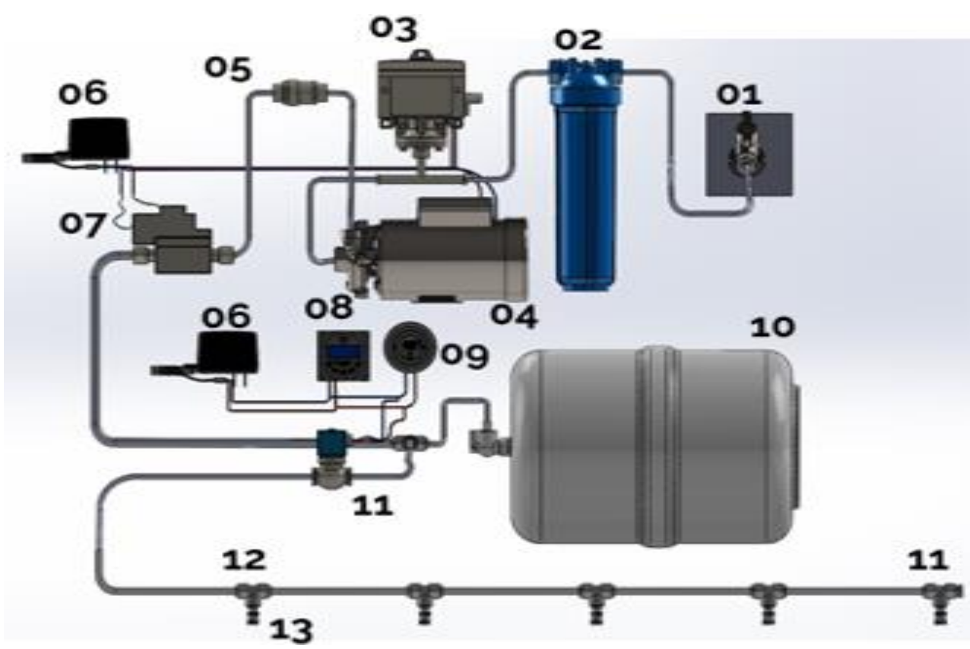

Figure 5.2.2 CAD Model of the whole assembly

The Table of contents includes the list of all the components that were used for the model. These components are mentioned in a proper order and are according to the flow diagram and the CAD Model. The serial number of components tell their position/ point in the model.

Serial Number	Components
1	Water Source
2	Hard water filter
3	Low press switch
4	water pump
5	Non return valve
6	Adapter
7	High pressure switch
8	Timer switch
9	Humidity sensor
10	Pres tank
11	Solenoid Valve
12	T joint
13	Nozzle

Table 5.2.2 Contents of CAD Model

5.3 Layout Design of the Misting System

To elucidate the operational sequence of our meticulously engineered vegetable and fruit misting system, it's essential to comprehend each component's role and their interaction in sequence. The entire process is initiated from a water source, which forms the fundamental input for our misting system. This source water, which could contain hardness-causing minerals, is led through a hard water filter. This filter is a vital element, as it purifies the water, preventing potential issues that hard water could introduce, such as clogging or inefficiency in the misting nozzles. Before the hard water filter, we have installed a low-pressure switch. The inclusion of this switch in our design is to ensure the continuous availability of source water to the pump. It operates on a simple yet effective principle: when there's an absence of water from the source, the low-pressure switch deactivates the system, preventing the pump from running dry and subsequently averting potential damage to the pump. With the assurance of water availability, the system engages the pump, setting in motion the process of filling an air pressurized tank. This tank has been engineered to withstand pressure of up to 120 psi. The pump's role is not only to transfer the water but also to pressurize the air within the tank, which is crucial for the subsequent misting process. To safeguard our system from any potential issues arising from back pressure, we have integrated a non-return valve adjacent to the pump. This valve ensures that water flow is unidirectional, moving from the source towards the pump and into the tank, effectively eliminating the risk of backflow. Beyond the pump and non-return valve, our design includes a high-pressure switch. This switch serves as a safety mechanism by deactivating the system once the tank's pressure reaches its operational limit. This automatic shutdown feature is an essential safeguard that prevents any complications or damages resulting from over-pressurization. Once the tank has been filled and pressurized adequately, the system flow progresses towards a solenoid valve, whose operations are regulated by a timer module. This component introduces an element of automation to our design, allowing the misting process to be scheduled and managed efficiently. When the pre-set time arrives, the timer module signals the solenoid valve to open. Upon receiving this signal, the solenoid valve opens, releasing the pressurized water from the tank to flow through the flat fan nozzles. It is at this stage that the actual misting takes place, with the nozzles producing a fine, even mist that ensures optimal cooling and preservation of fruits and vegetables.

In essence, each component of our misting system is a cog in a well-oiled machine, working in synergy to carry out the effective misting process, thereby facilitating the preservation of vegetables and fruits in an efficient and automated manner.

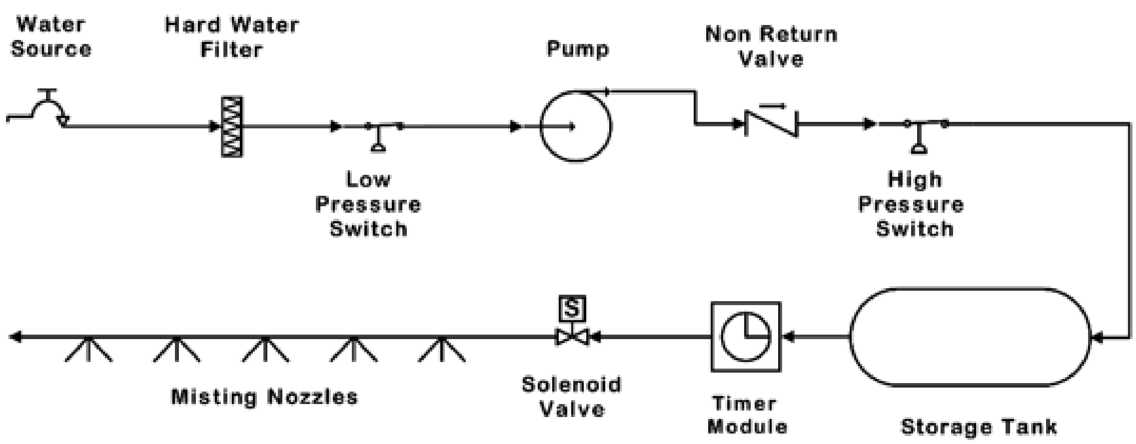

Figure 5.3a PID Layout Design

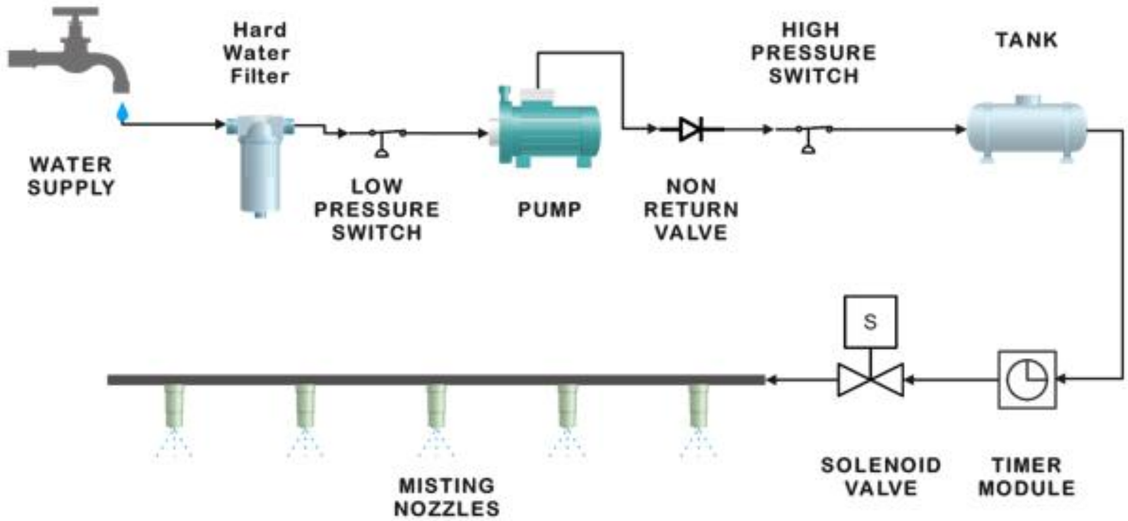

Figure 5.3b Symbolic Layout Design

CHAPTER 6 – FABRICATION

6.1 Material Acquired

The list of the material utilized for the completion of the project is as follows,

- 1x Hard Water Filter
- 2x Solenoid Valves
- 1x RO-988 Pump
- 1x Non-Return Valve
- 1x High-Pressure Switch
- 1x Air Charged Tank
- 8x 0.5 mm Nozzles
- 7x Head Tee Joints
- 1x Humidity Sensor
- 1x Alarm Buzzer
- 1x Timer Switch
- RO Pipe
- Control System
- Adaptor
- Wires

Figure 6.1 Material Purchased

6.2 Final Prototype

We assembled the required parts and components together and developed our prototype model of automated misting system. This final prototype had all the components explained beforehand. To give these components proper space and misting nozzles proper support, we manufactured a cart type structure. This structure contains a compartment for storing the pressurized tank, pump and pipes etc. and a stand like upper structure for holding nozzles. We also included a shelf or a level to put produce for misting purposes. The figure 6.2 shows the final prototype of our model.

Figure 6.2 Final Prototype

6.3 Cost Analysis

6.3.1 Cost of Materials

The cost analysis includes the cost of all the components used. This does not include the transport, maintenance and services charges. The cost analysis table of our project according to scheme components is as follows;

Sr no	Material	Quantity	Price (Rs)
1	Solenoid Valve	1	900
2	Elbow joint	Variable	50
3	Softening System	1	2600
4	Nozzle	Variable	2500
5	Pipe	Variable	700
6	Pump	1	5500
7	Tank	1	5500
8	Humidity Controller	1	1350
9	Low Pressure Switch	1	450
10	Adaptor	1	2500
11	Tee Joints	Variable	2500
12	Timer Module	1	600
Grand Total			**30,000**

Table 6.3.1 Cost of Materials

The quantity of some components is variable. This is because the quantity of components like nozzles, elbow joints and pipe length etc. depends on the surface areas we need to cover for misting, and is variable according to our order. This can increase or decrease the cost of the project/ model.

6.3.2 Proposed Cost

The proposed cost is higher than the total cost of project. This includes all the transport, maintenance and services charges and the cost of labour as well. The proposed cost of the project ranges between Rs 70,000 – Rs 80,000. Where Rs 70,000 is the lowest cost and will include the minimum number of nozzles, tee joints and elbow joints and a smaller tank. This system will be basic with further additions and improvements according to the increase in cost and working area.

Chapter 7 – VARIABLES AFFECTING THE MISTING QUANTITY

The amount of water required to mist fruits and vegetables in shops may vary depending on several factors, including the type of produce, humidity levels, and temperature. In general, it is recommended to mist the produce with a fine mist to prevent excess water from accumulating on the surface. Here are some general guidelines for misting different types of produce:

1 Leafy Greens: Leafy greens such as lettuce, spinach, and kale require regular misting to prevent wilting. A light misting once or twice a day should be sufficient.

2 Berries: Berries such as strawberries, raspberries, and blueberries are delicate and can be easily damaged by excess moisture. A light misting once a day is recommended.

3 Citrus Fruits: Citrus fruits such as oranges, lemons, and grapefruits benefit from regular misting to prevent dehydration. A light misting once or twice a day should be sufficient.

4 Tomatoes: Tomatoes should be misted lightly to prevent them from drying out. However, excessive moisture can cause them to spoil quickly, so it is important to monitor the humidity levels and adjust the misting accordingly.

5 Root Vegetables: Root vegetables such as carrots and potatoes do not require misting as they can rot when exposed to excess moisture.

It is important to note that these are general guidelines, and the amount of water required to mist produce may vary depending on the specific conditions in the shop. It is always a good idea to monitor the produce regularly and adjust the misting as needed to prevent spoilage and maintain freshness.

The shelf-life of produce depends mainly on two things relative humidity, respiration rates and Chilling and Freezing injuries.

7.1 Relative Humidity

The driving force for evaporation is decreased by humidification by lowering the differential in vapor pressure between the water on the surface of the crop and the air. Unwrapped meats' aesthetic deterioration has been linked to the level of dehydration, which renders the product unappealing to customers. The research also demonstrated that variations in RH had a significant impact, with a drop from 95 to 40 percent enhancing weight loss over a 6 hour display period by a factor of 14 to 18. RH (Relative Humidity) was also found to be the primary factor regulating weight loss and the display life of delicatessen goods, according to commercial tests conducted at FRPERC (Evans and Russell, personal communication). After around 100 minutes, the effect of surface drying at a RH of 40% became noticeable. The products may be on display for 4 to 6 hours at 85% RH before surface drying became apparent. At 40% RH, the overall weight loss was around three times more than it was at 85% RH. The use of humidification technology is becoming more widespread in meat cabinets as a result of work like this, but it has not been widely used in produce cabinets. Fruits and vegetables suffer when humidity levels are too low. Produce that shrinks, wrinkles, or spoils quickly was probably stored in an environment with an inappropriate humidity level.

Vegetables

Carrots, cauliflower, celery, beans, peas, radishes, corn, turnips, asparagus, beets, broccoli, and cabbage, as well as high relative humidity between 85% and 95% are among the vegetables that must be grown in this environment. High humidity is also necessary for lettuce, scallions, and greens, but they should be kept apart. For pumpkins, squash, onions, and garlic, keep things dry, with a humidity level below 85%.

Fruits

Apples, sour cherries, peaches, pears, plums, apricots, avocados, and berries prefer high humidity, while grapes, sweet cherries, melons, and citrus fruits prefer medium levels.
The ideal moisture level for various common fruits and vegetables is shown in the table below.

PRODUCT	Optimal Humidity %
Apples	90-95
Apricots	90-95
Artichokes	90-95
Asparagus	95-100
Avocados ripe	85-95
Avocados unripe	85-95
Bananas green	85-95
Bananas unripe	85-95
Basil	90-95
Beans dry	90-95
Beans green	95
Blackberries	90-95
Blueberries	90-95
Broccoli	90-95
	Optimal

PRODUCT	Humidity %
Cabbage	98-100
Cantaloupe	90-95
Carrots	90-95
Cauliflower	95-98
Celery	98-100
Chard	97-99
Cherries	90-95
Chicory	90-95
Coconuts	80-85
Collards	95-100
Corn	95-98
Cucumbers	95
Currants	95
Eggplant	90-95
Endive	95-100
Escarole	90-95
	Optimal

PRODUCT	Humidity %
Figs	90-95
Garlic	65-70
Grapefruit	90-95
Grapes	85
Kiwi	90-95
Green peas	90-95
Lemons	90-95
Lettuce	95-100
Spinach	95-100
Strawberries	90-95

PRODUCT	Optimal Humidity %
Onions	65-75
Oranges	90-95
Papayas	90-95
Parsley	98-100
Potatoes	90-95
Precut Fruit	90-95
Precut Vegetables	90-95
Prunes	90-95

Table 7.1a Optimal Humidity of Produce

The following table shows the relation between Relative Humidity with the Storage life of fruits and vegetables.

Commodity	Temperature (°F)	Rel. humidity (percent)	Approximate storage life
Fruits			
Apples	30–40	90–95	1–12 months
Apricots	31–32	90–95	1–3 weeks
Berries			
Blackberries	31–32	90–95	2–3 days
Currants	31–32	90–95	1–4 weeks
Elderberries	31–32	90–95	1–2 weeks
Gooseberries	31–32	90–95	3–4 weeks
Raspberries	31–32	90–95	2–3 days
Strawberries	32	90–95	3–7 days
Cherries, sour	32	90–95	3–7 days
Cherries, sweet	30–31	90–95	2–3 weeks
Grapes, American	31–32	85	2–8 weeks
Nectarines	31–32	90–95	2–4 weeks
Peaches	31–32	90–95	2–4 weeks
Pears	29–31	90–95	2–7 months
Plums and prunes	31–32	90–95	2–5 weeks
Quinces	31–32	90	2–3 months

Vegetables			
Artichokes, Jerusalem	31–32	90–95	4–5 months
Asparagus	32–35	95–100	2–3 weeks
Beans, dry	40–50	40–50	6–10 months
Beans green or snap	40–45	95	7–10 days
Beans, lima	37–41	95	5–7 days
Beans, sprouts	32	95–100	7–9 days
Beets, topped	32	98–100	4–6 months
Broccoli	32	95–100	10–14 days
Brussels, sprouts	32	95–100	3–5 weeks
Cabbage, early	32	98–100	3–6 weeks
Cabbage, late	32	98–100	5–6 months
Cabbage, Chinese	32	95–100	2–3 months
Carrots, bunched	32	95–100	2 weeks
Carrots, mature	32	98–100	7–9 months
Cauliflower	32	95–98	3–4 weeks
Celeriac	32	97–99	6–8 months
Celery	32	98–100	2–3 months
Chard	32	95–100	10–14 days
Chicory, witloof	32	95–100	2–4 weeks
Collards	32	95–100	10–14 days
Corn, sweet	32	95–98	5–8 days
Cucumbers	50–55	95	10–14 days
Eggplant	46–54	90–95	1 week
Endive and escarole	32	95–100	2–3 weeks
Garlic	32	65–70	6–7 months
Greens, leafy	32	95–100	10–14 days
Horseradish	30–32	98–100	10–12 months
Jicama	55–65	65–70	1–2 months
Kale	32	95–100	2–3 weeks
Kohlrabi	32	98–100	2–3 months
Leeks	32	95–100	2–3 months
Lettuce	32	98–100	2–3 weeks
Melons			
Cantaloupe (3/4 slip)	36–41	95	15 days
Cantaloupe (full slip)	32–36	95	5–14 days
Casaba	50	90–95	3 weeks
Crenshaw	45	90–95	2 weeks
Honey Dew	45	90–95	3 weeks

Persian	45	90–95	2 weeks
Watermelon	50–60	90	2–3 weeks
Mushrooms	32	95	3–4 days
Okra	45–50	90–95	7–10 days
Onions, green	32	95–100	3–4 weeks
Onion, dry	32	65–70	1–8 months
Onion sets	32	65–70	6–8 months
Parsley	32	95–100	2–2.5 months
Parsnips	32	98–100	4–6 months
Peas, green	32	95–98	1–2 weeks
Peas, southern	40–41	95	6–8 days
Peppers, chili (dry)	32–50	60–70	6 months
Peppers, sweet	45–55	90–95	2–3 weeks
Potatoes, early crop	40	90–95	4–5 months
Potatoes, late crop	38–40	90–95	5–10 months
Pumpkins	50–55	50–70	2–3 months
Radishes, spring	32	95–100	3–4 weeks
Radishes, winter	32	95–100	2–4 months
Rhubarb	32	95–100	2–4 weeks
Rutabagas	32	98–100	4–6 months
Salsify	32	95–98	2–4 months
Spinach	32	95–100	10–14 days
Squashes, summer	41–50	95	1–2 weeks
Squashes, winter	50	50–70	1–6 months
Sweet potatoes	55–60	85–90	4–7 months
Tomatoes mature, green	55–70	90–95	1–3 weeks
Tomatoes firm, ripe	55–70	90–95	4–7 days
Turnips	32	95	4–5 months
Turnip greens	32	95–100	10–14 days
Watercress	32	95–100	2–3 weeks

Table 7.1b commonly grown fruits and vegetables with recommended storage conditions

7.3 Chilling Injury

Low temperatures can harm a lot of tropical or subtropical fruits, vegetables, and ornamentals. After being exposed to cold temperatures below 10 to 15 °C (50 to 59 °F), but above their freezing points, these crops become harmed (Lyons 1973; Wang 1990). A few temperate-adapted horticulture crops are also prone to chilling damage. The threshold temperatures for such temperate crops are often lower, at 5 °C (41 °F). The tissues become weaker as a result of being unable to carry out regular metabolic functions at these freezing temperatures. The onset of chilling injury depends on both the exposure time and temperature. A product may be able to endure temperatures a few degrees into the critical zone for a longer period of time before damage becomes irreversible, while damage may happen quickly if temperatures are far below the threshold level.

7.4 Freezing Injury

Commodities that are resistant to chilling harm should be stored at temperatures that are as low as possible but just above freezing. When ice crystals accumulate in the tissues, freezing damage happens. The freezing point may be impacted by cultivars, geographical factors, and growth circumstances. The greatest temperature at which freezing of a particular product may take place should be considered as a guide when determining the ideal storage temperature in order to be safe. Different fresh fruits and vegetables have varying degrees of resistance to freezing damage. While some commodities can be repeatedly frozen and thawed with little to no damage, others are irreparably harmed by even a small freezing. According to how sensitive they are to freezing, all fruits and vegetables can be divided into three groups: **the most susceptible**, which are likely to suffer serious harm from even a single light freezing, **the moderately susceptible**, which will recover from one or two light freezing periods, and **the least susceptible**, which can withstand multiple light freezing without suffering serious harm.

The table below lists the symptoms that affect fruits and vegetables that are prone to chilling harm when exposed to temperatures over 32°F and below their optimal range.

Commodity	Approx. lowest safe temperature (°F)	Symptoms of injury from below-optimum temperatures
Apples-certain cultivars	36–38	Internal browning, brown core, soggy breakdown, soft scald
Asparagus	32–36	Dull, gray-green, limp tips
Beans (lima)	34–40	Rusty brown specks, spots, or areas
Beans (snap)	45	Pitting and russeting
Cucumbers	45	Pitting, water-soaked spots, decay
Eggplants	45	Surface scald, alternaria rot, blackening of seeds

Commodity	Approx. lowest safe temperature (°F)	Symptoms of injury from below-optimum temperatures
Melons		
Cantaloupe	36–41	Pitting, surface decay
Honey Dew	45–50	Reddish-tan discoloration, pitting, surface decay, failure to ripen
Casaba	45–50	Same as above, but no discoloration
Crenshaw and Persian	45–50	Same as above, but no discoloration
Watermelons	40	Pitting, objectionable flavor
Okra	45	Discoloration, water-soaked areas, pitting, decay
Peppers, sweet	45	Sheet pitting, alternaria rot on pods and calyxes, darkening of seed
Potatoes	38	Sweetening
Pumpkins and hardshell squashes	50	Decay, especially alternaria rot
Sweet Potatoes	55	Decay, pitting, internal discoloration; hard core when cooked
Tomatoes		
Ripe	45–50	Water soaking and softening decay
Mature-green	55	Poor color when ripe, alternaria rot

Table 7.3 Symptoms of injury from below-optimum temperatures

CHAPTER 8 – PRESSURE LOSSES

8.1 Calculations

In the course of designing our vegetable and fruit misting system, we have undertaken an analysis of pressure losses within the system using the **Darcy-Weisbach equation**. The Darcy-Weisbach formula, a well-established and widely accepted method, is integral in the hydraulic analysis of fluid systems, and was thus deemed the most appropriate choice for our investigation. This equation provides a practical and robust means to estimate frictional pressure losses in pipes, which is essential to ensure the efficient operation of our misting system. It considers important parameters such as pipe length, diameter, fluid velocity, and the pipe material's roughness factor, enabling a comprehensive evaluation of the system's hydraulic behavior. Consequently, its application in our project offers valuable insights into the design optimization, improving system performance by ensuring adequate pressure at each misting nozzle, and facilitating the best possible preservation conditions for fruits and vegetables.

As part of our analysis, we calculated the pressure losses within our misting system under two distinct arrangements - series and parallel. These configurations represent two different ways in which the components of the misting system - primarily the nozzles and the associated piping - can be set up, each with its own implications for the overall system pressure and flow rate.

8.2 Series Arrangement Analysis

The series arrangement implies that the components are connected end-to-end in a single path. In this configuration, the same water flow passes through all the components, but the total pressure loss is the sum of the pressure losses across each individual component. By understanding the pressure loss in a series configuration, we can gain valuable insights into the pressure requirements of our pump and the performance of the system when all components operate in unison.

$\boldsymbol{Darcy-WeisbachEquation}$

$$\boldsymbol{\Delta P = f\frac{Lv^2 f}{\partial D}} \text{ where } f \text{ is Darcy friction factor}$$

$\boldsymbol{PipeLosses}$

$$R_e = \frac{\rho_{VD}}{\mu} = \frac{1000 \times 0.3807 \times 0.004}{0.001}$$

$$\boldsymbol{R_e = 1522.8 < 2000} \textbf{ laminar}$$

$$A = \frac{\pi d^2}{4} = \pi \times \frac{(0.3 \times 10^{-3})^2}{4} = \boldsymbol{7.068 \times 10^{-8}} \textbf{ m}^{\mathbf{2}}$$

$$\mathbf{Q} \quad = \mathbf{0.0758GPM} = \mathbf{4.782 \times 10^{-6}\ m^3/s}$$

$$v_{1=}Q/A = \frac{4.782 \times 10^{-6}}{1.256 \times 10^{-5}} = 0.3807 \text{ m/s}$$

$$A_1V_1 = A_2V_2$$

$$1.256 \times 10^{-5} \times 0.3807 = 7.068 \times 10^{-8} \times V_2$$

$$\boldsymbol{V_2 = 67 \cdot 65\ \ m/s}$$

For laminar flow f will be

$$\boldsymbol{f = 64/\mathrm{Re} = \frac{6t}{1522.8} = 0.420}$$

$$\mathit{All\ the\ unknowns\ are\ known\ now\ we\ can\ putt\ the\ value\ in\ the\ Darcy - Weishbach\ relation.}$$

$$\Delta P = \frac{0.0420 \times 0.3084 \times (0.3807)^2}{2 \times 0.004} \times 1000$$

$$\Delta P = 234.66 \text{ Pa} = 0.034 \text{ Psi}$$

$UsingBernoulli'sEquation$

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$
$$P_2 - P_1 = \frac{1}{2}\rho(v_1^2 - v_2^2)$$

$$P_2 - P_1 \quad = \frac{1}{2} \times 1000(8.83^2 - 8.20^2)$$
$$P_2 - P_1 \quad = 5364.45P_2 = 0.7780P_{si}$$
$$P_3 - P_2 \quad = \frac{1}{2} \times 1000(8.20^2 - 7.853^2)$$
$$= 2785.19P_a = 0.4039$$
$$P_4 - P_3 \quad = \frac{1}{2} \times 1000(7.88^2 - 7.586^2)$$
$$= 2061.1065P_a = 0.2989$$
$$P_5 - P_4 \quad = \frac{1}{2} \times 000(7.586^2 - 7.497^2)$$
$$= 671.1939 = 0.097P_{si}$$
$$P_6 - P_5 \quad = \frac{1}{2} \times 1000(7.497^2 - 7.318^2)$$
$$= 1325 = 0.0.1921P_{si}$$
$$P_7 - P_6 \quad = \frac{1}{2} \times 1000(7.318^2 - 7.051^2)$$
$$= 1918.26 = 0.2782P_{si}$$
$$P_8 - P_7 \quad = \frac{1}{2} \times 1000(7.051^2 - 6.693^2)$$
$$= 2460.176 = 0.3568P_{si}$$
$$P_9 - P_8 \quad = \frac{1}{2} \times 1000(6.693^2 - 6.604^2)$$
$$= 391.71 = 0.0858P_{si}$$

8.2.1 Graphical Representation

In the subsequent section of our study, we present graphical data analysis derived from our calculated pressure losses, focusing specifically on the impact of varying nozzle quantities on the misting system's operational parameters. The representation of this data in the form of graphs allows for a more intuitive understanding of the system dynamics, as well as a visual demonstration of the trends and relationships between the variables.

8.2.1.1 Velocity vs Number of Nozzles

The first graph we present depicts the relationship between the velocity of the fluid and the number of nozzles. This graph serves to illustrate how changes in the number of nozzles in the system affect the fluid's velocity. Understanding this relationship is fundamental, as the velocity at which the fluid exits the nozzles directly influences the quality of the mist produced, and thereby the effectiveness of the cooling and preservation

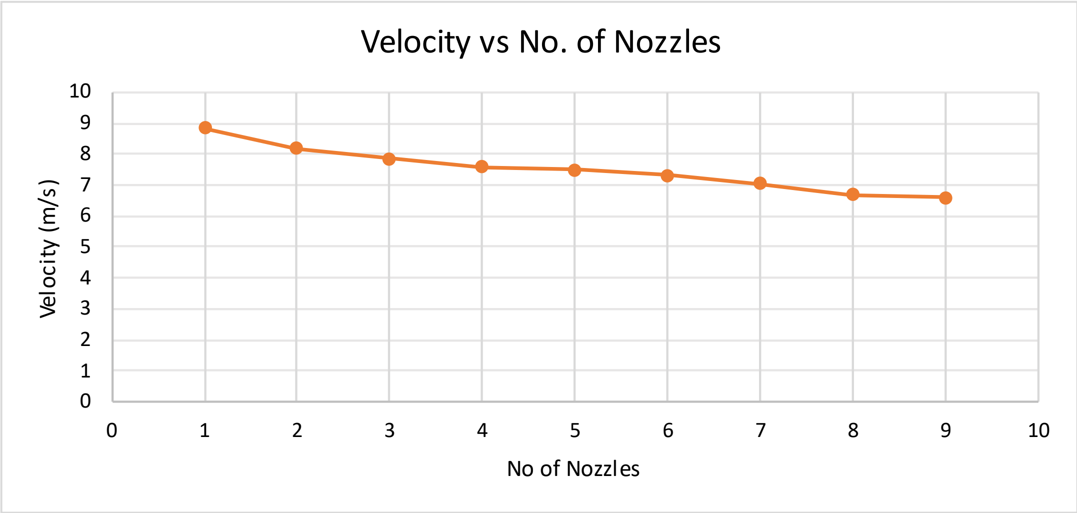

Figure 8.2.1.1 Velocity vs No of nozzles

8.2.1.2 Flow Rate vs Number of Nozzles

The second graph represents the relationship between the flow rate and the number of nozzles. The flow rate, which is the volume of fluid passing through the nozzles per unit of time, is another crucial parameter that impacts the system's performance. This graph demonstrates how changes in the quantity of nozzles alter the system's flow rate, providing key insights into how best to balance the number of nozzles with the required flow rate for optimal misting.

Flow Rate (GPM) VS No. of Nozzles

The graph shows the relation between flow rate (in GPM) and nozzle number. This relation is according to the values calculated above. This is for series arrangement of nozzles.

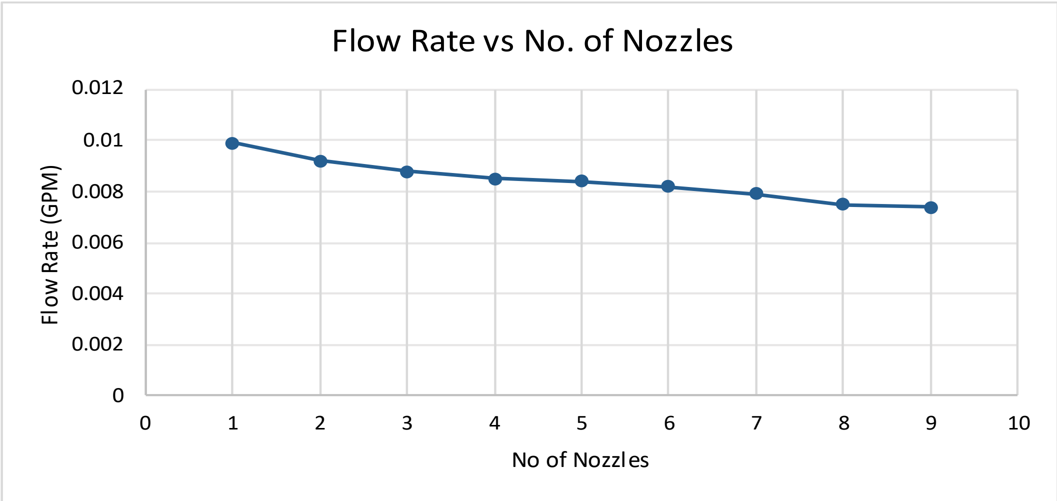

Figure 8.2.1.2a Flow Rate vs No of nozzles

Flow Rate (m^3/s) VS No. of Nozzles

This graph shows the relationship between flow rate (in meter cube per second) and the nozzle number. This is for the series arrangement of nozzles.

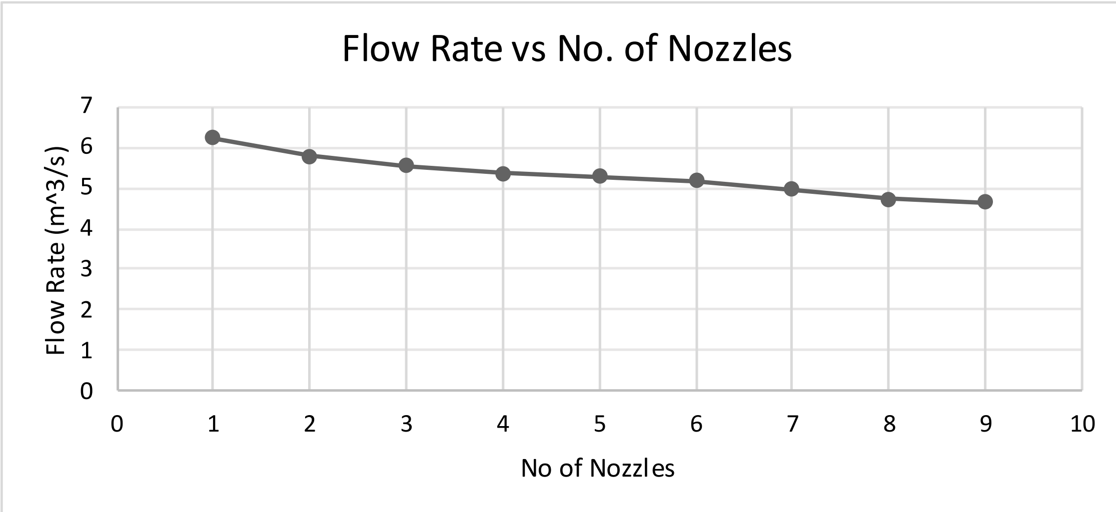

Figure 8.2.1.2b Flow Rate vs No of nozzles

8.3 Parallel Arrangement Analysis

Parallel arrangement involves components that are connected alongside each other, creating multiple paths for the water flow. Here, the total flow rate is the sum of the flow rates through each path, while the pressure loss across each path remains the same. This arrangement is particularly relevant to our misting system as the nozzles are often set up in parallel to ensure uniform coverage. Calculating pressure losses in a parallel configuration helps us understand how the system will perform under these conditions and how to balance the flow rate and pressure across multiple paths.

$$A_1 = \frac{\pi d^2}{4} = \pi \times \frac{\left(4\times10^{-3}\right)^2}{4} = 1.256 \times 10^{-8}\ \mathrm{m}^2$$

$$where\ \ A1\ is\ the\ area\ of\ the\ pipe$$

$$A_2 = \frac{\pi d^2}{4} = \pi \times \frac{(0.3 \times 10^{-3})^2}{4} = 7.068 \times 10^{-8}\ \mathrm{m}^2$$

$$where\ A2\ is\ the\ area\ of\ the\ orifice/\ nozzle$$

$$Q\ \text{total}\ 1 = 3.0099 \times \frac{10^{-6}\ \text{m}^3}{\text{s}}$$

$$v_{1=}\frac{Q_1}{A_1} = \frac{3.0099 \times 10^{-6}}{1.256 \times 10^{-5}} = 0.239\ \text{m/s}$$

$$Q\ \text{total}\ 2 = 2.98115 \times 10^{-6}\ \text{m}^3/\text{s}$$

$$v_{2=}\frac{Q_2}{A_2} = \frac{2.98115 \times 10^{-6}}{1.256 \times 10^{-5}} = 0.237\ \text{m/s}$$

$$1ft = 0.3081\ \text{m}$$

Pipe Losses

Flow Path 1

$$R_e = \frac{\rho_{VD}}{\mu} = \frac{1000 \times 0.239 \times 0.004}{0.001}$$

$$R_e = 956 < 2000\ \text{laminar}$$

The flow in the pipe is Laminar

$$f = 64/\text{Re} = \frac{64}{956} = 0.0669$$

$$\text{Darcy} - \text{ Weisbach Equation}$$

$$\Delta P_1 = \frac{fLV_1^2\rho}{2D}$$

$$\Delta P_1 = \frac{0.0669 \times 0.3084 \times 0.239^2 \times 1000}{2 \times 0.004}$$

$$= 147.3147\ \text{Pa} = 0.0213Psi$$

$$\text{Using Bernoulli's Equation}$$

$$\boldsymbol{P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2}$$

$$
\begin{aligned}
P_2 - P_1 &= \frac{1}{2} \times 1000(9.069^2 - 8.855^2) \\
P_2 - P_1 &= 1917.868 P_a = 0.278 Psi \\
P_3 - P_2 &= \frac{1}{2} \times 1000(8.855^2 - 8.447^2) \\
&= 3529.608 P_a = 0.512 Psi \\
P_4 - P_3 &= \frac{1}{2} \times 1000(8.447^2 - 8.177^2) \\
&= 2244.24 P_a = 0.3255 Psi \\
P_5 - P_4 &= \frac{1}{2} \times 1000(8.177^2 - 8.036^2) \\
&= 1143.015 P_a = 0.16578 Psi
\end{aligned}
$$

$$
\text{For Path 1, by adding them all we get}
$$

$$
\Delta P_1 = 1.28128 Psi
$$

Flow Path 2

$$
R_e = \frac{\rho_{VD}}{\mu} = \frac{1000 \times 0.237 \times 0.004}{0.001}
$$

$$
R_e = 948 < 2000 \text{ laminar}
$$

The flow in the pipe is Laminar

$$
f = 64/\text{Re} = \frac{64}{948} = 0.0675
$$

$$
\begin{aligned}
&\text{Darcy} - \text{Weisbach Equation} \\
\Delta P_2 &= \frac{f L V_2^2 \rho}{2D} \\
\Delta P_2 &= \frac{0.0675 \times 0.3084 \times 0.237^2 \times 1000}{2 \times 0.004} \\
&= 146.1578 \text{ Pa} = 0.0212 Psi
\end{aligned}
$$

$$
\text{Using Bernoulli's Equation}
$$

$$
P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2
$$

$$P_2 - P_1 = \frac{1}{2} \times 1000(8.966^2 - 8.733^2)$$
$$P_2 - P_1 = 2061.9335P_a = 0.3Psi$$
$$P_3 - P_2 = \frac{1}{2} \times 1000(8.733^2 - 8.347^2)$$
$$= 3296.44P_a = 0.478Psi$$
$$P_4 - P_3 = \frac{1}{2} \times 1000(8.347^2 - 8.121^2)$$
$$= 1860.884P_a = 0.27Psi$$
$$P_5 - P_4 = \frac{1}{2} \times 1000(8.121^2 - 8.011^2)$$
$$= 887.26P_a = 0.1287Psi$$

For Path 2, by adding them all we get

$$\Delta P_2 = 1.1767Psi$$

The total pressure loss across both paths 1 and 2 comes out to be

$$\Delta P = 2.45798Psi$$

8.3.1 Velocity vs Number of Nozzles

As the number of nozzles operating in parallel rises, the total available flow is divided amongst them, leading to a lower velocity of fluid per nozzle. This is because the overall system flow rate remains constant, yet the fluid is distributed over an increasing number of pathways. As a result, the velocity through each nozzle decreases with the addition of more nozzles.

Velocity (m/s) VS No. of Nozzles

This graph shows the relationship between velocity and the nozzle number. This is for the parallel arrangement of nozzles. Unit of velocity taken is meter per second.

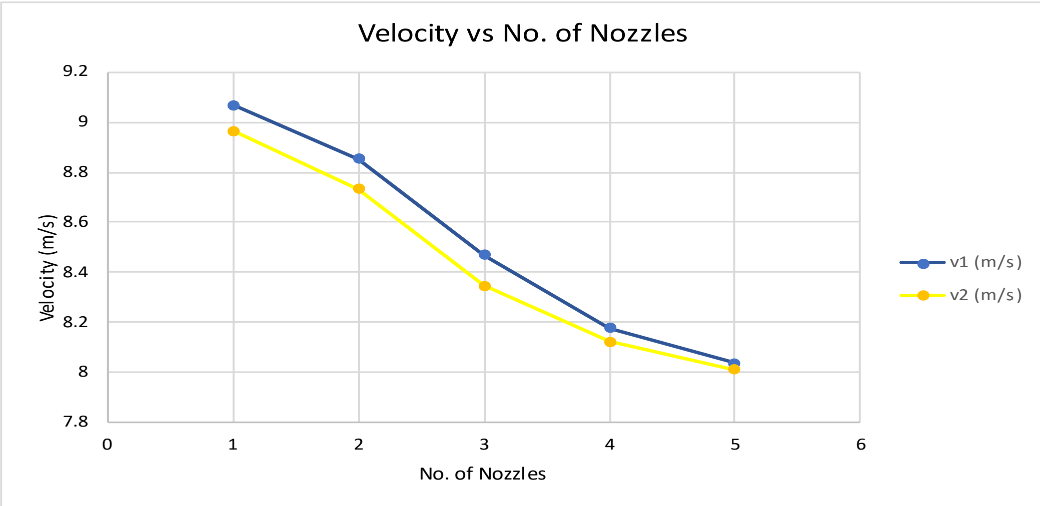

Figure 8.3.1 Velocity vs No of nozzles

8.3.2 Flow Rate vs Number of Nozzles

We note a corresponding decrease in the individual flow rate through each nozzle. As the quantity of nozzles augments, the total flow rate is apportioned across a larger number of output points, which naturally reduces the volume of fluid exiting through each nozzle per unit time.

<u>Flow Rate (m^3/s) VS No. of Nozzles</u>

This graph shows the relationship between flow rate (in meter cube per second) and the nozzle number. This is for the parallel arrangement of nozzles.

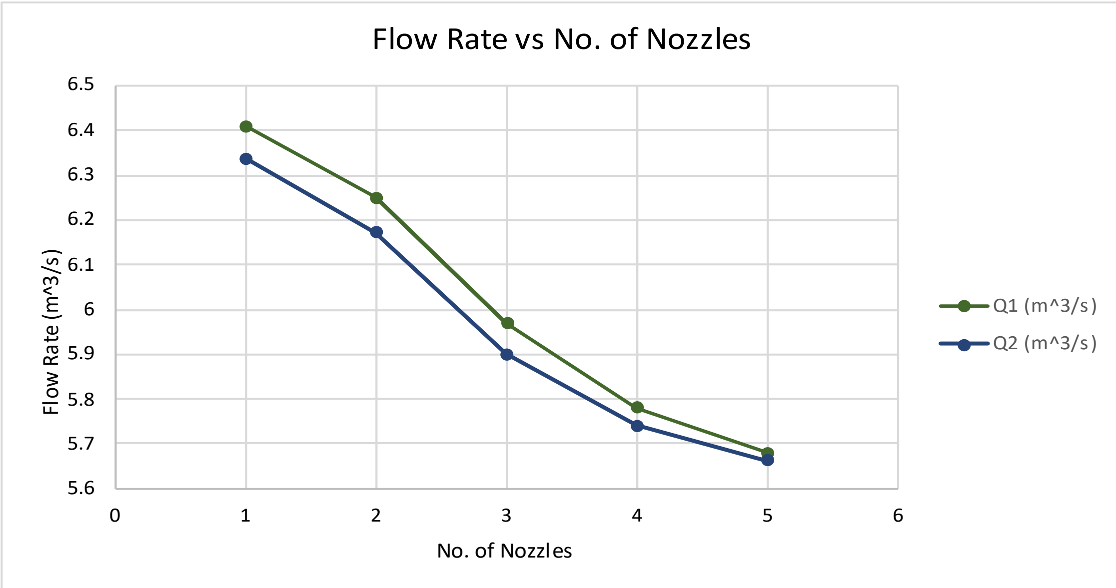

Figure 8.3.2 Flow Rate vs No of nozzles

CHAPTER 9 – EXPERIMENTAL ANALYSIS

9.1 Overview

In our journey to ascertain the effectiveness and efficiency of our misting system, we instituted an experimental analysis aimed at directly observing its impact on the shelf-life of various fruits and vegetables. This empirical approach aids in reinforcing the theoretical assertions and provides a pragmatic view of the system's performance in real-world conditions.

The subjects of this experiment included a diverse selection of produce - Carrot, Aubergine, Capsicum, Cucumber, and Coriander. These were carefully selected to represent a broad spectrum of perishable goods that our system is designed to preserve. We categorized these items into two distinct groups to enable a comparative study.

One group of produce was placed under the controlled environment of our misting system, where they received regular, scheduled misting. The second group, serving as the control, was placed in an open environment without the advantage of our misting system. This comparative method allowed for a fair and direct analysis of the effect of our system on extending shelf-life.

The experimental analysis was conducted over a period of three days. During this time, we closely monitored and documented the condition of the produce in both groups. The aim was to draw accurate, evidence-based conclusions on the system's impact on the freshness and longevity of fruits and vegetables. This empirical methodology forms an essential part of our research, offering an objective perspective on the system's efficacy and its potential contribution to reducing food waste. The following sections will delve into the detailed observations and results derived from this experiment.

9.2 Optimum Environment

The table below indicates the optimum relative humidity required to extend the shelf life of each type of produce. It's crucial to consider these levels in the design of the misting system to ensure it provides the appropriate conditions for preserving each type of produce.

Produce	Optimal Relative Humidity for Maximum Shelf Life (%)
Carrot	98-100
Aubergine	90-95
Capsicum	90-95
Cucumber	95-98
Coriander	95-100

Table 9.2 Optimum relative humidity

9.3 Observations

To execute our experimental analysis meticulously, we set a schedule for observation spanning three days, with intervals of 12 hours. The rationale behind this time frame was to capture the transition and evolution of the condition of the produce under both sets of circumstances – under the influence of the misting system and in an open environment.

Every twelve hours, the fruits and vegetables in both groups were inspected in detail, with key changes in appearance and texture documented. We supplemented these observations with photographic evidence, capturing the physical state of the produce at each inspection interval. These photographs serve as a vital record, documenting the visible differences and trends over time.

This structured approach of periodic observation every twelve hours allowed for an accurate tracking of changes. It not only facilitated the objective comparison of the two sets of produce but also enabled a time-lapse study of the decay process under both conditions. This meticulous and rigorous monitoring process allowed us to determine the genuine effectiveness of our misting system in extending the shelf life of fruits and vegetables.

DAY 1: Morning

Under Misting System

Without Misting System

DAY 1: Evening

Under Misting System

Without Misting System

DAY 2: Morning

Under Misting System

Without Misting System

DAY 2: Evening

Under Misting System

Without Misting System

DAY 3: Morning

Under Misting System

Without Misting System

DAY 3: Evening

Under Misting System

Without Misting System

Figure 9.3 Misting Observation

9.4 Results:

In concluding our experimental findings, we begin with the analysis of cucumbers. The results were strikingly clear, underscoring the efficacy of our misting system.

9.4.1 Cucumber

For the cucumbers placed under the misting system, we observed minimal, almost negligible changes over the three-day period. These cucumbers retained their freshness and robust appearance from the first day through to the third day. This level of freshness retention is a testament to the effectiveness of the misting system in maintaining optimal humidity and temperature conditions, crucial to preserving the cucumber's quality and extending its shelf life.

In stark contrast, the cucumbers not placed under the misting system presented a different narrative. Although they maintained reasonable freshness and quality for the first day, subtle changes were evident by the second day. By the third day, these cucumbers exhibited a substantial decline in quality, with noticeable signs of deterioration. This rapid decay contrasts sharply with the near-constant freshness observed in the cucumbers under the misting system.

9.4.2 Carrot

The carrots placed under the misting system demonstrated consistent quality over the three-day observational period. They retained a glossy, vibrant appearance, indicating sustained freshness

and vitality. Although there was a minuscule deviation in their state from day one to day three, the change was barely noticeable. The shiny, bright complexion typically associated with freshly harvested carrots was largely retained, further demonstrating the effectiveness of our misting system in preserving quality.
On the other hand, the carrots not protected by the misting system presented a different outcome. Despite holding up well for the first day, there were observable changes by day two. By the third day, their condition had deteriorated markedly. The radiant color and shine had faded, and signs of wilting were evident, suggesting a loss of freshness and quality.

9.4.3 Aubergine

The aubergines kept under the misting system displayed impressive resistance to deterioration over the three-day period. They retained a vibrant, glossy appearance, indicating their sustained freshness. The changes observed from the first day to the third were so minor that they were nearly imperceptible. They managed to maintain their shine and fresh-looking surface, embodying the ideal state of freshly harvested aubergines.
In contrast, the aubergines not protected by the misting system displayed a vastly different story. Although they managed to retain their freshness for the first day, minor changes began to surface by the second day. By the third day, their deterioration was rapid and marked. Not only had they lost their vibrant color and shine, but visible scars also began to form on their surface, signaling a significant loss of freshness and quality.

9.4.4 Capsicum

The capsicums subjected to the misting system over the three-day period showcased a minor change, remaining mostly fresh and retaining their glossy appearance. Their skin maintained its original shine and color, further reflecting the desirable state of freshly picked capsicums. This preservation of freshness testifies to the capabilities of our misting system in maintaining optimal conditions for prolonged shelf life.
On the contrary, the capsicums left outside the misting system unfolded a contrasting narrative. Their initial freshness remained for the first day, but there were noticeable changes by the second day. On the third day, their condition deteriorated significantly. The once vibrant and shiny skin had lost its color and sheen, scars started to appear, and their firmness gave way to a softer texture. This swift decay clearly emphasized the importance of optimal storage conditions in preserving the quality and extending the shelf life of capsicums.

9.4.5 Coriander

The coriander kept under the misting system showed positive results over the three-day period. While there was a noticeable change from day one to day three, the overall condition remained good. The observable changes were within acceptable bounds, indicating that the coriander had retained a degree of freshness and was still suitable for use.

Contrastingly, the coriander left in the open environment without the misting system showed significant deterioration. After maintaining a fair state on the first day, the coriander started to deteriorate by the second day. On the third day, the decay became quite rapid, and the coriander turned brown by the end of the day, indicating a severe loss of freshness and quality. The once vibrant coriander had lost its color, shine, and appeal, and was in such a degraded state that it was no longer usable and could be considered waste.

CHAPTER 10 - CONCLUSION AND FUTURE WORK

10.1 Conclusion

In sum, our experimental findings across all five types of produce -- cucumber, carrot, Aubergine, capsicum, and coriander -- distinctly demonstrate the effectiveness and efficiency of our misting system in maintaining freshness and extending shelf life. In all cases, the produce subjected to the misting system exhibited superior freshness, shine, and overall quality over the three-day period, with only minor changes in appearance. Conversely, produce not protected by the misting system exhibited clear signs of rapid deterioration, losing their color, shine, and firmness, and developing visible signs of spoilage such as surface scars and a softening texture. The impact was most striking in the case of coriander, which turned brown and unusable by day three. The experimental results validate our misting system as a powerful tool in the fight against food waste, highlighting its potential for significant application in the preservation and longevity of a broad range of perishable goods in the agro-food industry. The research undertaken in this thesis affirms the critical role of the automated misting system for preserving produce quality. It is unequivocal that this technological advancement not only extends the shelf life of produce but also maintains its nutritional integrity and aesthetic appeal, vital elements in promoting consumer purchase. Automation and control systems emerged as key components in optimizing misting operations. This intelligent automation not only enhances the quality and shelf life of produce but also reduces energy consumption and operational costs. Economic feasibility, maintenance requirements, and scalability should be considered to facilitate widespread adoption of misting technology. This thesis underscore the transformative potential of automated misting systems in the realm of food retail.

10.2 Future Work

The automated misting system for produce holds great promise for revolutionizing post-harvest management and enhancing the overall quality and market value of fresh produce. Through further advancements and interdisciplinary collaborations, this technology can contribute significantly to addressing food security challenges, reducing post-harvest losses, and promoting sustainable agricultural practices. Future work could also look into integrating advanced Internet of Things (IoT) technologies and machine learning algorithms into these systems to achieve real-time monitoring and dynamic adaptation to varying conditions. By leveraging these technologies, misting systems can be optimized and personalized to specific produce types, environmental conditions, and growth stages. Furthermore, investigating alternative misting solutions, such as organic compounds or plant-based extracts, may lead to sustainable and eco-friendly approaches.

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