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Microclimate Control in Strawberry Production with Hydroponic System in Indoor Vertical Farming

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Abstract

The purpose of this paper is to analyze Microclimate Control in strawberry production using the hydroponic system in Indoor Vertical Farming. This research will discuss the Microclimate parameters that affect strawberry growth to be controlled in maintaining strawberry productivity. The parameters controlled include temperature, humidity, CO2 levels, light, and EC/pH of nutrients. The data collection technique of this research is taken using Priva Climate Computer technology whose settings are adjusted to the target parameters set and analyzed using the Priva Cloud Office Direct Client application which is part of the Priva Climate Computer technology. The results of the Microclimate control carried out, obtained temperature 17,8-20,9ºC, humidity 67,4-91,3%, Carbon Dioxide (CO2) levels 597-600 ppm, light with light intensity PPFD 29,9 µmol m-2s-1 and nutrient solution concentration with Electrical Conductivity (EC) 0,9-1,18 mS/cm and pH 5,8-6,1 in Indoor Vertical Farming. After going through a series of studies, the results of measuring environmental parameters are by the targets that have been set. It can be concluded that the results of the study are recommendations for environmental parameters for the growth of large and uniform strawberries. The results of this study can be used as a reference for readers to increase knowledge, practice commercials directly, and become a reference for further research.

Keywords: *Microclimate, Hydroponics, Indoor Vertical Farming, Priva Climate Computer*

Introduction

Agriculture is the most important sector in maintaining survival, where the world population continues to grow and has now reached 8.084 billion as of January 2024 (Wordmeter Info, 2024). Population growth requires food availability throughout the world to be met and demands world food productivity to increase. Then, the current challenge is the increasingly scarce land resources, especially due to the development of the industrial and service sectors, so that conventional agricultural business activities are increasingly uncompetitive. In addition, conventional agricultural systems are currently less desirable, especially for urban urbanites. Urban Horticulture (UH) is an important part of the future of sustainable agriculture, one way that can be done is by Vertical Farming (VF) (Kouloumprouka Zacharaki, Monaghan, Bromley, & Vickers, 2024).

Vertical Farming (VF) system agricultural cultivation technology can be collaborated with hydroponic systems as an alternative to renewable agriculture. According to Priono (2022) Hydroponics is a method of growing crops or cultivating

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plants without using soil but planting in water that contains a mixture of nutrients and cannot be separated from media other than soil, such as coconut husk, mineral fiber, sand, sawdust, and others as a substitute for soil media. Various types of vegetable and fruit plants can be cultivated with a Hydroponic system, one of which is strawberries.

Strawberries (Fragaria sp.) are a type of fruit that has high economic value and many benefits. Strawberries are loved by many for their attractive color and shape, fresh taste, as well as high nutritional composition (Lewers, Newell, Park, & Luo, 2020). In maintaining the growth and quality of this fruit, Microclimate Control is needed with environmental parameters including temperature, humidity, CO2, light, and nutrients that must be monitored every day using special sensors Madhavi (2023), because the Microclimate or environmental factors are very influential on the process of plant growth and regeneration (Nurjaman, Kusmoro, & Santoso, 2017).

UNS FARMS is an agricultural company in Dubai that relies on the production of vegetables and fruits with a Hydroponics system in Indoor Vertical Farming, in a closed room of 6000 m2, this indoor garden is one of the largest in Dubai. UNS FARMS relies on the use of Controlled Environment Agriculture (CEA) Techniques and LED Grow Lights as a substitute for sunlight, whose spectrum is made according to plant needs.

UNS FARMS produces Lettuce, Herbs, Microgreen, Cut Flowers, and Strawberries which are marketed to all supermarkets and HORECA throughout the United Arab Emirates. Therefore, in this engineering practice report, the author focuses on Microclimate Control which is closely related to the concept of renewable agriculture Hydroponic system at UNS FARMS Indoor Vertical Farming in Dubai, United Arab Emirates. This research uses the case study method because the results presented in the paper are the original results of projects that have been carried out by researchers, so this paper can be one of the documentation, as a reference and improvement in the next project.

Based on the explanation above, the research problems to be answered through this Engineering Practice Report are as follows: 1) What is the value of Microclimate Control of air temperature obtained in strawberry production using a hydroponic system in Indoor Vertical Farming, and is it by the growth phase target? 2) What is the value of Microclimate Control of air humidity obtained in strawberry production using a hydroponic system in Indoor Vertical Farming and is it by the growth phase target? 3) What is the value of Microclimate Control CO2 levels obtained in strawberry production using a hydroponic system in Indoor Vertical Farming and is it by the growth phase target? 4) What is the value of Microclimate Control of light intensity obtained in strawberry production using a hydroponic system in Indoor Vertical Farming and is it by the growth phase target? 5) What is the value of Microclimate Control nutrients (EC/pH) obtained in strawberry production using a hydroponic system in Indoor Vertical Farming and is it by the growth phase target?

The objectives of this study are as follows: 1) Analyzing the achievement of appropriate air temperature in Microclimate Control of strawberry production using a hydroponic system in Indoor Vertical Farming. 2) Analyze the achievement of

appropriate air humidity in Microclimate Control of strawberry production using a hydroponic system in Indoor Vertical Farming. 3) Analyze the achievement of appropriate CO2 levels in Microclimate Control of strawberry production using a hydroponic system in Indoor Vertical Farming.

Research Methods

This research was conducted using the case study method. A case study is a series of scientific activities carried out intensively, in detail, and in depth about a program, events, and activities, either at the level of individuals, groups of people, institutions, or organizations to obtain in-depth knowledge about the program (Rahardjo, 2010).

The data collection technique used to derive the value of each parameter of Microclimate Control is using Priva Climate Computer technology. Priva Climate Computer is one of the products of the PRIVA Company in the Netherlands, which develops environmental optimization technology and agricultural production control (www.priva.com). This technology works with the Internet of Things system, where sensors in Climate Control will automatically read data for each microclimate that has been set, and then automatically the data will enter the Priva Cloud Office Direct Client.

The data that has entered the cloud can be in the form of tables that can be converted into daily graphs, and then daily graph data by researchers is processed into average graphs according to the controlled Microclimate. Priva Climate Computer can set and control the parameters needed in Indoor Vertical Farming through sensors and control panels. The Priva Climate Computer also captures and records data on temperature, humidity, CO2, and light and controls plant nutrients through irrigation streams automatically.

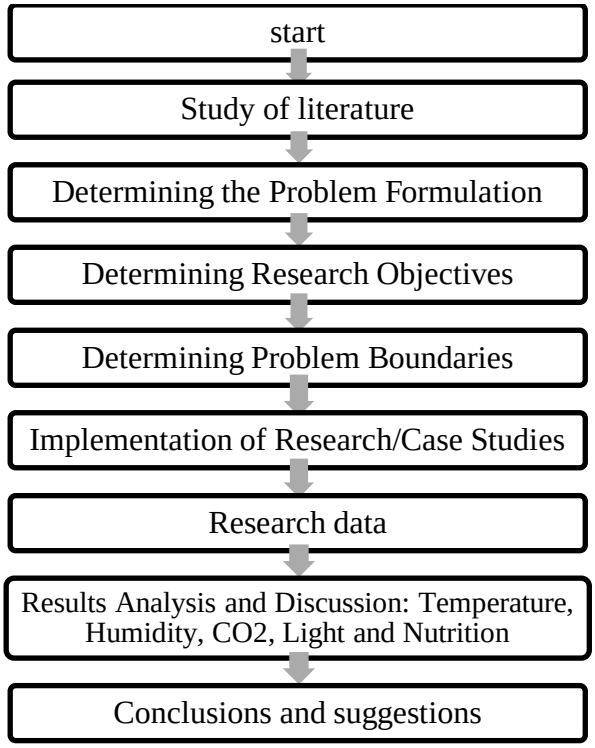

Figure 1. Research Flow

Results and Discussion

Environmental parameters have a noticeable effect on the productivity of strawberry crops. Facing increasingly erratic environmental weather is a new challenge for the continuity of strawberry cultivation. As explained above, strawberries are one of the fruits that are expected to be filled throughout the year. The results of research with the application of Environmental Control Hydroponic systems in Indoor Vertical Farming are presented in the discussion points below.

A. Temperature

The results of temperature measurements taken from September 1, 2023, to November 30, 2023, using the Priva Climate Computer can be shown in Figure 2. up to Figure 3. below:

Figure 2. September 2023 Temperature Measurement Graph

From Figure 2. It can be seen that temperature control in Indoor Vertical Farming in September in the daytime period obtained an average temperature of 20.9ºC while in the night period, an average temperature of 19.8ºC was obtained.

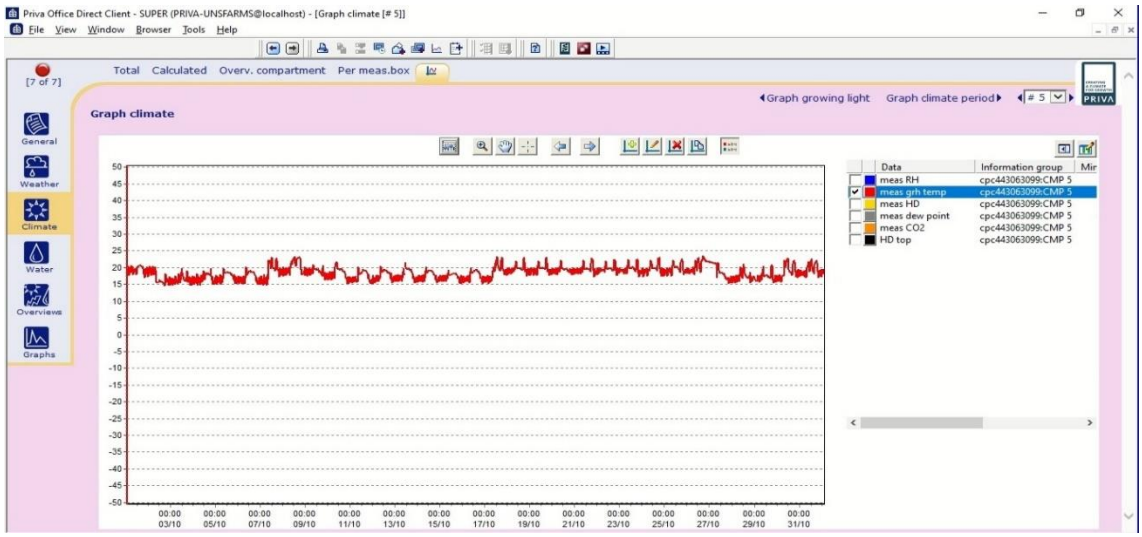

Figure 3. October 2023 Temperature Measurement Graph

From Figure 3. It can be seen that temperature control in Indoor Vertical Farming in October in the daytime period obtained an average temperature of 19.2ºC while in the night period, an average temperature of 17.8ºC was obtained. Based on data from November 2023 temperature measurements, it can be seen that temperature control in Indoor Vertical Farming in November in the daytime period obtained an

average temperature of 19.6ºC while in the night period, obtained an average temperature of 18ºC.

Meanwhile, from the Average Temperature data from September-November 2023, it can be seen that temperature control in Indoor Vertical Farming in the daytime period obtained an average temperature following the target setting of the Priva Climate Computer, where the average temperature target was a maximum of 23.0ºC, while in the night period, the average temperature in September was 0.80ºC higher and October was 1.0ºC higher than the target temperature of 17ºC. This is by the temperature control target in Indoor Vertical Farming.

B. Moisture

The results of humidity measurements were carried out from September 1, 2023, to November 30, 2023, using the Priva Climate Computer. Based on September 2023 Humidity measurement data, it can be seen that humidity control in Indoor Vertical Farming in September in the daytime period obtained an average humidity of 70.60% while in the night period, an average humidity of 82.70% was obtained.

Based on October 2023 Humidity measurement data, it can be seen that humidity control in Indoor Vertical Farming in October in the daytime period obtained an average humidity of 91.30% while in the night period, an average humidity of 82.90% was obtained. Meanwhile, in the November 2023 Humidity Measurement data, it can be seen that humidity control in the November Indoor Vertical Farming during the daytime period obtained an average humidity of 67.40% while in the night period, an average humidity of 85.80% was obtained. The results of measuring the average humidity of day and night can be shown in Figure 4 below:

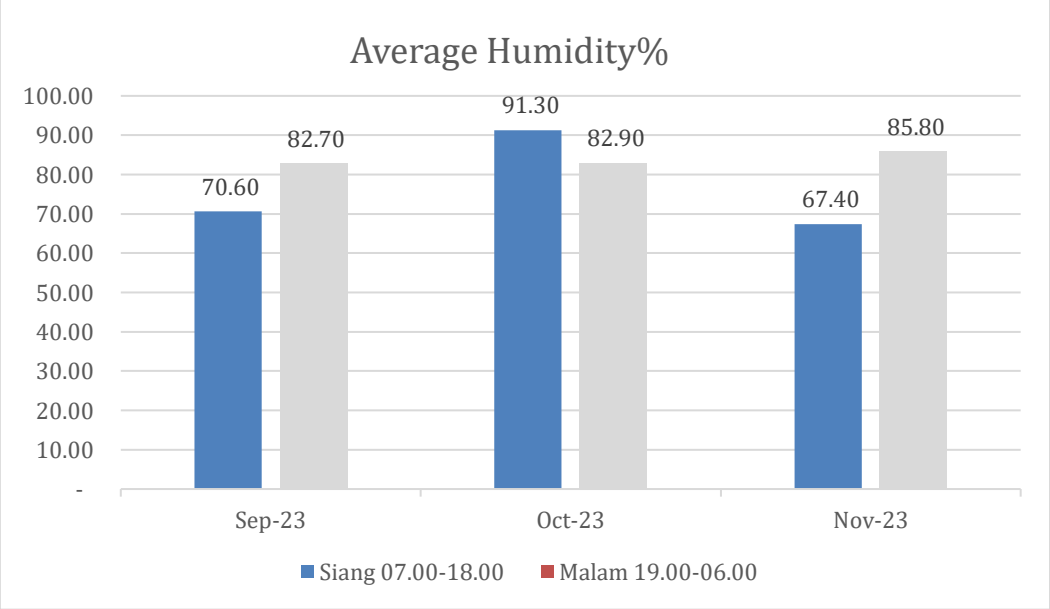

Figure 4. Average Humidity September-November 2023

From Figure 4. It can be seen that humidity control in Indoor Vertical Farming during the daytime period of September obtained an average humidity of 70.6%,

where the average humidity target was a maximum of 75%, while in the night period, 82.7% was obtained. Daytime humidity in October is 91.3% and nighttime humidity averages 82.9%, in November daytime humidity averages 67.4% and nighttime average humidity is 85.8%. This is by the target of controlling humidity in Indoor Vertical Farming.

C. Carbon dioxide (CO2)

The results of Carbon Dioxide (CO2) measurements carried out from September 1 to November 30, 2023, using the Priva Climate Computer. Based on September 2023 Carbon Dioxide (CO2) Measurement data, it can be seen that Carbon Dioxide (CO2) control in Indoor Vertical Farming in September was obtained at an average of 597 ppm. Also from the October 2023 Carbon Dioxide (CO2) Measurement data, it can be seen that the control of Carbon Dioxide (CO2) in Indoor Vertical Farming in October was obtained by an average of 600 ppm.

Meanwhile, from the November 2023 Carbon Dioxide (CO2) Measurement data, it can be seen that the control of Carbon Dioxide (CO2) in Indoor Vertical Farming in November was obtained at an average of 590 ppm. The results of the average Carbon Dioxide (CO2) measurement carried out from September 1 to November 30, 2023, can be shown in the figure below:

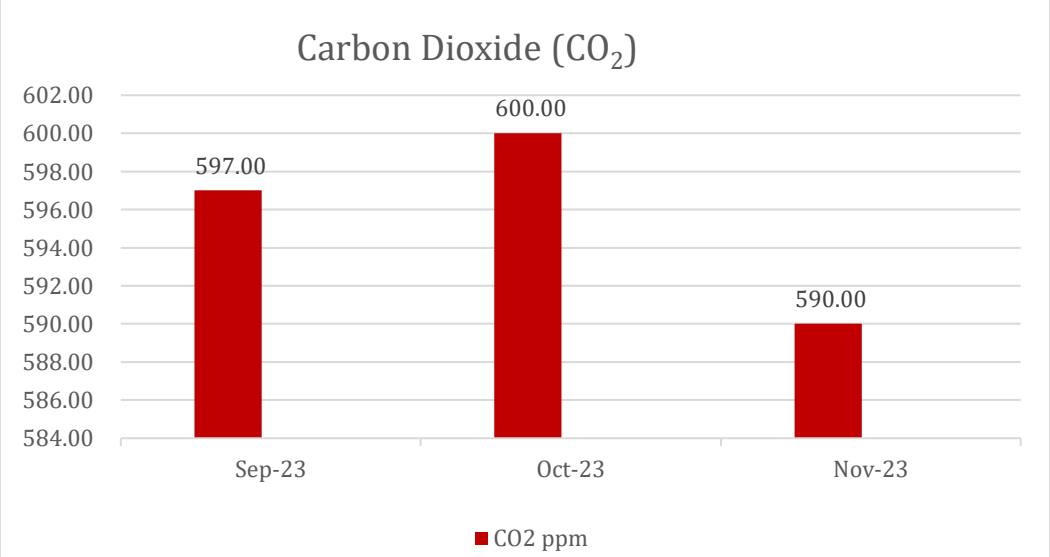

Figure 5. Carbon Dioxide (CO2) Average September-November 2023

From Figure 5, it can be seen that CO2 control in Indoor Vertical Farming in September obtained an average temperature of 597 ppm, in October an average of 600 ppm, and in November 2023 an average of 590 ppm. The target setting of Priva Climate Computer CO2 is 500-700 ppm.

D. Light

LED Grow Lights Light Measurement for Indoor Vertical Farming lighting using the Spectrometer tool, the measurement results obtained light intensity data,

PPFD 291.9 µmol m-2 s-1. The Daily Light Integral (DLI) Level target, September 2023 is 15 mol m-2 d-1 and from October to November is 17 mol m-2 d-1, from the calculation of the Daily Light Integral (DLI) Level, obtained Photoperiod September LED grow lights light up for 15 hours and Photoperiod October to November, LED grow lights light up for 17 hours.

E. Electrical Conductivity (EC) dan pH Larutan Nutrisi

The results of EC and nutrient pH measurements for strawberry plants carried out from September 1, 2023, to November 30, 2023, using EC sensors and pH taken on average can be shown in Figure 6 below:

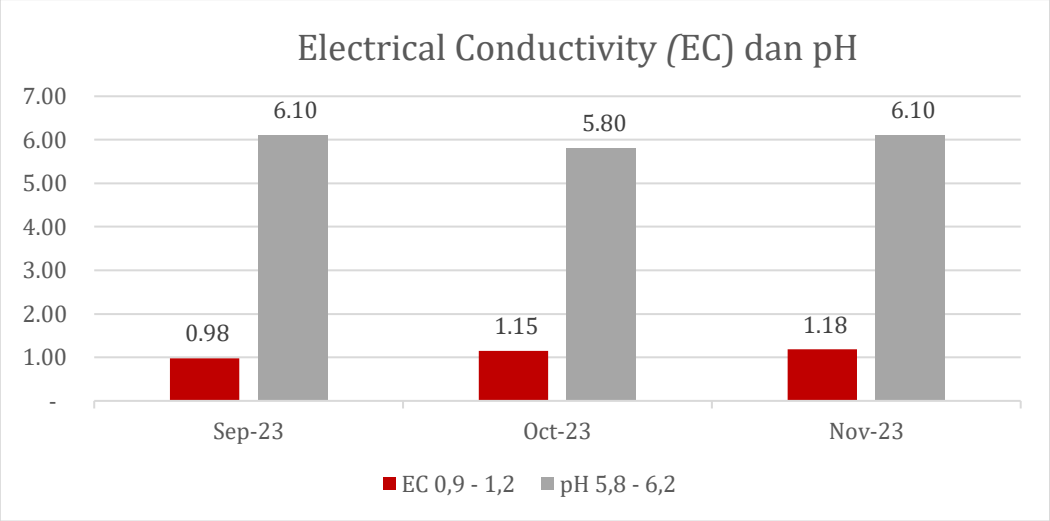

Figure 6. Results Average measurement of EC and nutrient pH of strawberries

From Figure 6, it can be seen that EC and pH control in Indoor Vertical Farming for the September 2023 period obtained an average EC of 0.98 mS/cm and pH of 6.1 where the EC target is 0.9-1.0 mS/cm and pH 5.8-6.2. In October 2023, EC averaged 1.15 mS/cm and pH 5.8, where the EC target was 1.1- 1.2 mS/cm and pH 5.8 – 6.2, and in November 2023 EC averaged 1.18 mS/cm and pH 6.1 where the EC target was 1.1- 1.2 mS/cm, and pH 5.8 – 6.2.

Based on data on EC and pH settings of strawberries nutrients on the Priva Climat Control Dashboard, an overview of the work process of nutrient control in regulating EC and pH levels. The EC and pH range are nutrient levels by Environmental Control for strawberry cultivation from vegetative to generative phases (Kusuma & Bima, 2022).

F. Overview of Engineering Aspects

Engineers are people who work in engineering, in other words, engineers are people who use scientific knowledge to solve practical problems using technology (Hasbullah et al., 2021). Engineer is a professional title designation for people who already have an academic degree in Engineering studies. This profession is a very urgent need in today's increasingly technologically literate times. However, to become

a professional engineer, several principles are needed that must be mastered and applied by the person, including:

1. Aspects of the Engineering Code of Ethics

The professional code of ethics is a guideline for behavior, attitudes, and actions in the implementation of activities in everyday life, including the engineering profession. The engineering code of ethics in question is an engineering action controlled by an engineering professional organization and if there is a violation, the organization has the right to determine the appropriate action first (Susilawati & Si, 2019).

The Indonesian Engineers Association (PII) as an engineering professional organization has compiled and formulated the Indonesian Engineer Code of Ethics under the name Catur Karsa Sapta Darma Engineer Indonesia (PII Ethics Honor Council, 2021) with the following details:

a) Basic Principles &; Rules of Practice &; Conduct of Engineers; 1) Prioritizing the nobility of mind, security, safety, health, and benefit of the community and the environment. 2) Practice only in the field of competence. 3) Express opinions to the public only objectively and based on the overarching truth.

b) Catur Karsa: 1) Prioritizing nobleness. 2) Use his knowledge and abilities for the benefit of the welfare of mankind. 3) Work conscientiously for the benefit of society, by its duties and responsibilities. 4) Improve their competence and dignity as professional engineers based on the expertise of the engineering profession.

c) Sapta Darma: 1) Indonesian engineers always prioritize the safety, health, and welfare of the community. 2) Indonesian engineers always work according to their competence. 3) Indonesian engineers only express opinions that can be justified. 4) Indonesian engineers always avoid conflicts of interest in their duty responsibilities.

Aspects of the Engineering Code of Ethics in Indoor Vertical Farming operations at UNS FARMS, in its management, use its knowledge and abilities for the benefit of human welfare, especially in meeting the needs of vegetables and fruits in the United Arab Emirates. Prioritizing the safety, health, and welfare of the community, engineering ethics, ethics will run from company owners, directors, management, and employees.

2. Aspects of Professionalism

Professionalism is the characteristics (ability, skill, way of doing something, and others) as reasonably done and exists in a professional that is manifested to fulfill what has been said so that actions can be accepted by related elements. An engineer must have a spirit of professionalism in realizing professional work with quality Waisapi (2022) supported by the following characteristics: a) Have high skill in a field as well as skills in using certain equipment required in the performance of tasks related to the field of liman. b) Have knowledge experience and intelligence in analyzing a problem and be sensitive in reading situations quickly accurately and

carefully in making the best decisions based on sensitivity. c) Have a forward-oriented attitude so that they can anticipate the development of the environment that lies in front of them. d) Have an independent attitude based on confidence in personal abilities and be open to listening and respecting the opinions of others, but careful in choosing the best for themselves and their personal development.

The implementation of Professionalism Aspects in Indoor Vertical Farming Microclimate Control Operations is: a) The manager has competencies by their fields, competencies obtained from education or training. b) In addition, in carrying out their duties, the manager follows the applicable regulations and guidelines by processing the HACCP certificate (Hazard Analysis and Critical Control Point) and Food Safety Management System HACCP-ISO 22000: 2018, is a food safety management method that is systematic and based on familiar principles, aimed at identifying hazards that are likely to occur at each stage in the supply chain vegetables and fruit.

3. K3L Aspect

Occupational Safety and Health The environment called K3L is an element in the labor system that has an important role in the sustainability of the economic wheels in the work unit (Darmayani et al., 2023);(Chowdhury et al., 2020). Some things that must be applied in the implementation of K3L are obeying to use of Personal Protective Equipment (PPE), Work Safety Equipment (APK), and First Aid in P3K Accidents. The following is the analysis of the K3L case study at UNS FARMS United Arab Emirates.

Environmental Control Operation and Maintenance activities in Indoor Vertical Farming involve many engineering practices and need to pay attention to occupational health and safety and the environment (K3L). Occupational health and safety and environmental (K3L) practices are only limited to carrying out Standard Operating Procedures applied by HACCP (Hazard Analysis and Critical Control Point), including SOP for Strawberry Production, Occupational Health Certificate for workers, selection of raw materials, pest control, environmental hygiene, tools and uniforms of workers and periodic maintenance of instrument tools, calibration of measuring instruments and test laboratories Analysis of water and plants.

Although in carrying out operations and maintenance activities have implemented K3L, they have not fully implemented K3 risk management which includes hazard identification, risk assessment, and risk control in activities that support Operation and Maintenance activities. This needs to be done to provide effective occupational safety and health protection in a planned, measurable, structured, and integrated manner to prevent and reduce work accidents and occupational diseases and increase productivity by creating a safe, comfortable, and efficient workplace.

G. System Analysis and Improvement Suggestions

Microclimate Control is very influential on the abundance and distribution of plant species in an environment or ecosystem (Maisyaroh, 2010). The main

environmental factors that greatly affect plant growth and need to be controlled are light intensity and humidity (Martono, 2012). Photosynthesis is an important process in plant growth that converts CO2 and H2O into glucose and oxygen, this process involves light energy so that the resulting product is chemical energy in the form of food substances (Zannah, Evie, Sudarti, & Trapsilo, 2023). Both Microclimates have an important role in the process of growth and development of strawberry plants and determine the quality of the fruit produced.

Hydroponic systems in Indoor Vertical Farming do not get Microclimates naturally from nature, so arrangements are needed by Microclimate recommendations in subchapter 2.3. From the results of this study, 2 environmental factors still need improvement, namely temperature and CO2 levels. Temperature improvement is carried out by adding its own Mechanical Cooling in Indoor Vertical Farming strawberries, to achieve a temperature target lower than 17 ºC.

Mechanical Cooling is a cooling system in greenhouses that utilizes fans, heat pumps, and heat exchangers so that it can maintain temperatures at low levels, especially in hot areas with high ambient temperatures and radiation levels (Ghoulem, El Moueddeb, Nehdi, Boukhanouf, & Calautit, 2019). Then, improve CO2 levels by adding the number of Carbon Dioxide (CO2) distribution nozzles to increase CO2 levels up to 700 ppm. A nozzle is a tool for watering plants that are run using a high-pressure water pump, where nutrients flow through PVC pipes and the volume is adjusted to the needs of plants (Fadhil, Argo, & Hendrawan, 2015).

Conclusion

Microclimate control in September 2023 showed results in line with the vegetative phase target, with daytime temperatures of 20.9ºC and nighttime temperatures of 19.8ºC, however, in October-November 2023, daytime temperatures reached the generative phase target, while nighttime temperatures exceeded the target for the generative phase. Humidity in September is in line with vegetative targets, but in October, daytime humidity exceeds generative phase targets, and in November, nighttime humidity is in line with generative targets.

CO2 levels during the period are by the set regulatory targets. The intensity of light in September corresponds to the vegetative target, but in October-November it reaches values corresponding to the generative phase. The EC and pH values in September are in line with the vegetative target, while in October-November, the EC and pH values reach the target for the generative phase. With proper microclimate control, environmental parameters such as temperature, humidity, CO2 levels, light intensity, EC, and pH affect strawberry production in the Hydroponics system at Indoor Vertical Farming, resulting in large and uniform strawberries.

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