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Characterising Thermal Behaviour of Smart Greenhouse Based on the Dehydration Performance

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Abstract

The importance of optimizing dehydration processes in agriculture, particularly in seafood and fruit production cannot be overstated. Conventional methods reliant on human observation and susceptible to weather conditions often lead to inefficiencies and inconsistent product quality. This paper addresses these challenges by introducing a novel approach, a smart greenhouse system powered by renewable energy sources to enhance drying processes and product quality. By integrating renewable energy sources, such as photovoltaic panels, the system efficiently powers heating mechanisms, ensuring optimal drying conditions irrespective of weather fluctuations. Temperature sensors enable real-time monitoring and regulation of greenhouse conditions, while a hygienic design safeguards product safety and quality. Methodologically, the study rigorously examines the greenhouse system's design, sizing and thermal behavior, particularly in relation to the utilization of solar energy. Through detailed calculations and experimentation, the research explores variables including the impact of wind angle on heater fan operation, optimal exhaust fan placement and the correlation between wind speed and greenhouse temperature. The findings underscore the profound influence of greenhouse design and management on dehydration efficiency. Notably, the research elucidates the significance of proper environmental control in achieving consistent and high-quality dehydration outcomes. Furthermore, the alignment of results with existing literature on smart greenhouse systems and dehydration performance substantiates the study's contributions and insights. The findings not only advance scientific understanding but also lay the groundwork for further research aimed at refining and scaling sustainable dehydration practices in agriculture.

Keywords: Smart Greenhouse, Dehydration, Conventional Greenhouse, Drying Technology, Greenhouse for Dehydration

Introduction

In recent years, the use of greenhouses has increased substantially, with the main objective being to raise the rate of plants producing fruits, and to be able to increase the rate of dried fruits and dried fish by utilizing the dehydration process (EL-Mesery et al., 2022). Greenhouses are a building or structures that use transparent or translucent materials which can allow sunlight to enter while creating a regulated environment for plant growth (Dhurve et al., 2017). Greenhouses perform several functions, including agriculture, research, and horticulture. The capacity to monitor and manage dryness, which is a measure of how effectively the greenhouse can maintain ideal moisture levels for the plants within, is an important feature of greenhouse design (Ihoume et al., 2022). Water stress can lead to decreased yield and plant performance, thus proper moisture management is critical for plant health and growth. Dehydration performance in a traditional greenhouse is frequently adjusted manually, which may be time-consuming and prone to human error.

A new style of greenhouse known as a smart greenhouse has been designed to solve these challenges. A smart greenhouse monitors and adjusts moisture levels as well as other key growing variables like temperature, humidity, and light intensity using modern technology such as sensors and automated control systems (Delfiya, 2019). While the traditional greenhouse only focuses on the hygiene and rate of production without knowing of waste that will be made and the quality of the end product. A smart greenhouse may produce a premium quality of dried fish by closely monitoring and controlling these parameters using modern technologies (Casas et al., 2022). Not only does this save time and work, but it also allows for more exact and consistent management of growing conditions, resulting in increased seafood and fruits development and production (Azam et al., 2020).

Traditionally, the sun drying technique is used since it is theoretically extremely simple, involving leaving the seafood goods in an open place. Naturally, there are benefits and drawbacks to this strategy, which mostly involves the temperature and weather (Yuwana et al., 2020). As a result, drying technology for greenhouses was developed, which may overcome most of the difficulties through a protected and regulated habitat. But there is still a lacks of drying technology for greenhouse, the first one is the use of heaters as the main source of energy for the dehydration process results in high energy consumption, high utility costs, lack of temperature control and damage to the quality of dried fish. Additionally, the process is dependent on sunny weather, leading to prolonged production time and low quality and quantity of the dried fish product (Purusothaman et al., 2019). Implementing alternative power sources, temperature control systems, and finding ways to dehydrate the fish during non-sunny days could help to address these issues.

The objective of this project is to design a greenhouse system that utilizes renewable energy sources, specifically a PV system with battery storage, to generate power for the heating system within the greenhouse. This design will include a temperature sensor that will control the heater to maintain the optimal temperature for drying fish. By using this renewable energy source, the greenhouse will be able to operate during the night time, decrease the dehydration time and produce premium quality products, which will increase the quantity of the product. Additionally, the greenhouse system will be designed to meet hygienic standards, ensuring the safety and quality of dried fish (Azaizia et al., 2020).

The scope of work for this project includes the design and implementation of a greenhouse system that utilizes renewable energy sources to generate power for the heating system within the greenhouse. The size of the greenhouse will be determined based on the specific location of the greenhouse in which this project will be implemented. The number of fans and temperature sensors that will be incorporated into the design will also be based on the specific needs of the project. These fans and temperature sensors will be used to control the temperature and circulation of air within the greenhouse, ensuring that optimal conditions are maintained for drying fish. The limitations of this project include product specific optimal drying conditions, wattage of PV system and battery storage, availability of materials and technologies, budget and resources, and unsuitability of the drying process during rainy season. The use of smart greenhouses in the process of dehydration to produce dried seafood will be focused on regarding the simulation to achieve the temperature separation equally inside the greenhouse during day and night. The technology consists of heat accumulated inside the greenhouse in visual and also recorded data temperature.

Overall System Process

The greenhouse is design based on existing greenhouse to accomplish the objectives of this project, a comprehensive system flowchart was developed to serve as a blueprint for the sequential progression of the project, which encompasses gaining insight through research, carrying out simulations, and evaluating data. Based on Figure 1, the flowchart starts with knowledge acquisition and data collection. This data is obtained from the literature review and research which is related to dehydration products by using a greenhouse system. Then, the clustering and classification of significant characteristics related to the greenhouse for dehydration are recorded to differentiate the difference between this greenhouse for dehydration project with the project from the literature review. Next, the size of the greenhouse needs to be chosen correctly in order to get enough accurate reading data that can be compared to past projects. Thus, the size of Company XYZ Solar Dehydrator Greenhouse located at Pahang, Malaysia has been chosen for the size design of this project.

The design of the greenhouse is drawn in Energy2d software. The design and embedding data by key in the value of the type of material for the structure, fan heater temperature with blow angle, and speed of the blower are being adjusted. Next, the operation of the greenhouse is analyzed based on the temperature that is desired which is about 50 °C. This temperature must be nearly distributed equally inside the greenhouse. Afterwards, the testing, evaluation, and results analysis are conducted to gain accurate data on this dehydration greenhouse system and whether the modification of the project from other research projects is needed which can decrease monthly cost, and produce premium quality end-product in minimum time consumption for dehydration (Karim et al., 2018). Lastly, the documentation and paper publication are done in this project which can be used for the next project to implement this research as a review and understanding to make the actual prototype.

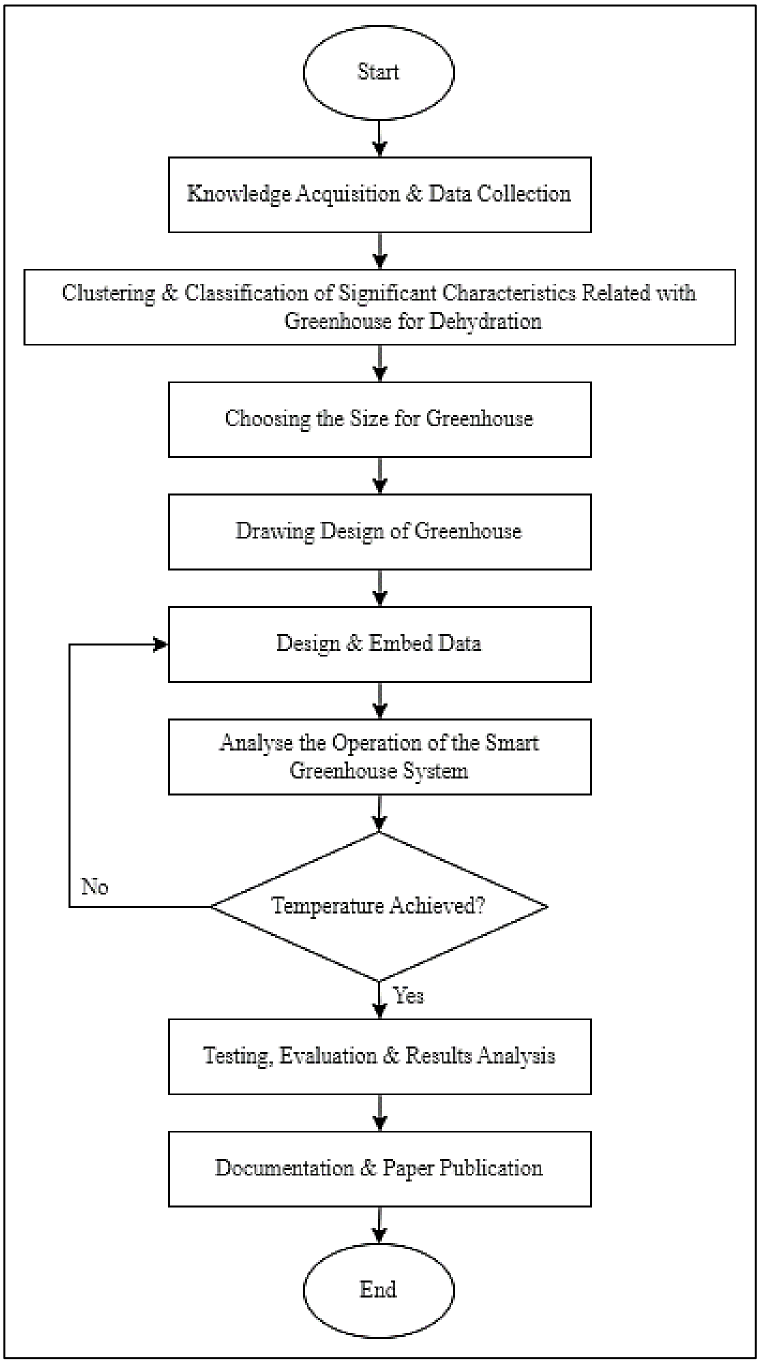

Figure 1: Flowchart of System Design

Greenhouse Design

The greenhouse is located in Tanjung Gemuk, Pahang, Malaysia with GPS addresses 2.65° North and 103.62° East as shown in Figure 2 which is marked with a purple 'X'. The yellow 'X' marked is the jetty for fisherman. Based on Figure 3, the design of the Company XYZ Solar Dehydrator Greenhouse is installed with a solar heat collector that can trap heat that can enhance heat temperature inside the greenhouse but the heat distribution is not equally distributed. Thus, this is the main reason for the proposed project on which adjusting the angle to the heat blower.

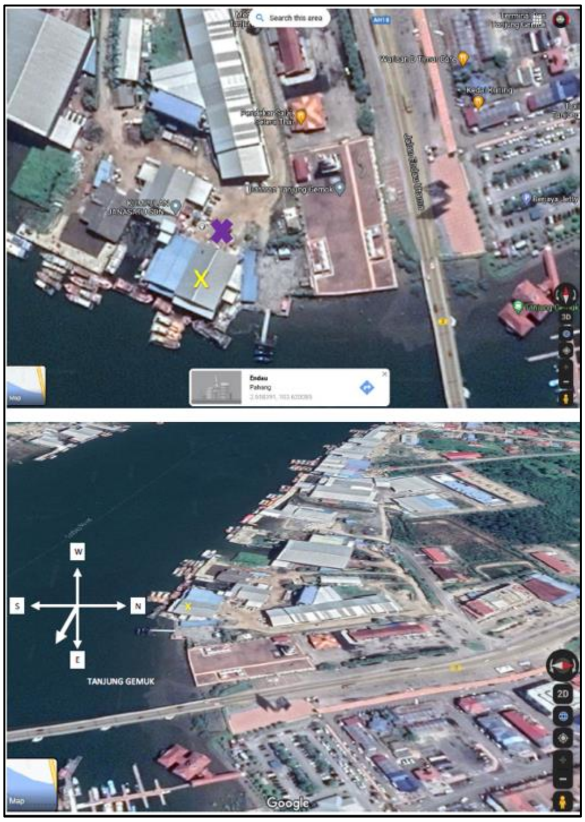

Figure 2: Google Map of Site Location

Figure 3: Greenhouse Company XYZ

The design measurement for the greenhouse with side and the top view is shown in Figure 4 and Figure 5 respectively. The length of the base of the greenhouse is 20ft while the height of the greenhouse is 8ft. The solar heat collector is installed with two units on each side with a fan heater at each solar heat collector and also four exhaust fans for ventilation inside the greenhouse. The key aspects of size design for a greenhouse used for fish dehydration include ensuring that there is enough airflow to dry the fish, the provision of a storage area for the fish that maintains optimal temperature and humidity and maximizing the use of the available space to yield the highest number of dried fish with minimal wasted space. This can be achieved by incorporating exhaust fan to control airflow and by designing the storage area to keep the fish at optimal conditions to preserve quality and prevent contamination.

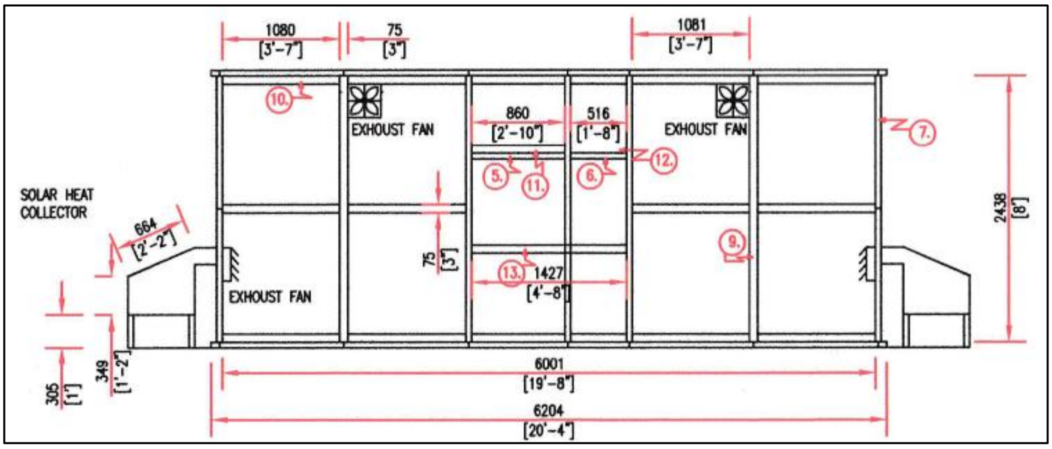

Figure 4: Side View Measurement Design of the Greenhouse

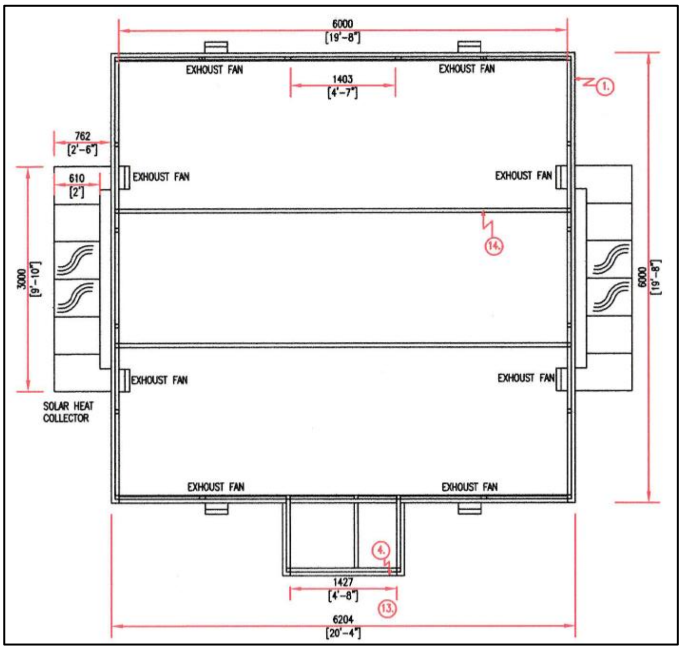

Figure 5: Top View Measurement Design of the Greenhouse

Design and Sizing

The Standalone Photovoltaic (SAPV) system is implemented in this greenhouse project which can provide a sustainable and cost-effective solution for maintain optimal temperature and humidity levels. This can significantly reduce the reliance on conventional energy sources as the Greenhouse Company XYZ now use direct utility supply and enhance the efficiency of the dehydration process. However, designing and implementing such system demands thoughtful examination of various factors such as weather conditions, energy storage, system efficiency, and economic feasibility. In this research, the feasibility of a standalone photovoltaic system for greenhouse dehydration will be examined, and methods to enhance its performance will be identified.

According Table 1, the main load in this greenhouse is lighting, exhaust fan and heater fan. The primary output of the system is two unit of heater fan that operate during night time when temperature inside the greenhouse drop to 45°C and the heater fan cut-off when the temperature inside the greenhouse achieve 60°C. The lighting is used also during night time to raise the temperature inside the greenhouse as well as given lighting for worker to observe the condition of the fish that will be dried. Two exhaust fan is used as blower for the solar heat collector to pull and distribute the heat inside the greenhouse while the other four exhaust fan is used to control airflow as well as control the humidity level. Table 2 shown the symbol name that is used in those equation after this based on Alternating Current (AC) load and Direct Current (DC) load. This includes the power load, number of units, converter and inverter efficiency, duration of operation, power factor and surge factor that the load of this greenhouse used.

Table 1
Load Profile

No.	Load	Power (W)	Unit	Duration (Hours)	Power Factor (p.u)	Surge Factor (p.u)
1	Lighting	13	2	12	1	1
2	Exhaust Fan	45	6	24	0.9	2
3	Heater Fan	2500	2	3	0.9	2

Table 2
Symbol Name

Name/Unit	Formula (Symbol)	
Load	AC Load	DC Load
Power/unit (W)	P_{ac1}	P_{dc1}
Number of units	n_{ac1}	n_{dc1}
Converter / Inverter efficiency	η_{ac1}	η_{dc1}
Duration of operation /day (h)	h_{ac1}	h_{dc1}
Power factor	$Pf1$	-
Surge factor (p.u)	$Sf1$	-

As shown in Eqn. (1), the total daily energy consumption, E_{req} is 25.451kWh which is important an important parameter to decide the sizing of battery storage system in this SAPV system and the PV input power needed. The total maximum demand, P_{max} is shown in Eqn. (2) with 6.191kW is needed to ensure power supply is sufficient to meet demand. The total maximum surge power demand, P_{smax} is 12.355kW as shown in Eqn. (3) to determine the power capacity required that the system can handle in short-term high-power usage scenarios. From the E_{req} obtained, the recommended system voltage, $V_{sys} = 96V$.

$$E_{req} = \left\{ \begin{matrix} \left[\frac{P_{dc1}\ x\ n_{dc1}\ x\ h_{dc1}}{Pf1\ x\ \eta_{ac1}}\right] + \left[\frac{P_{ac2}\ x\ n_{ac2}\ x\ h_{ac2}}{Pf2\ x\ \eta_{ac2}}\right] \\ + \left[\frac{P_{ac3}\ x\ n_{ac3}\ x\ h_{ac3}}{Pf3\ x\ \eta_{ac3}}\right] \end{matrix} \right\} = 25.451kWh \quad (1)$$

$$P_{max} = \left\{ \left[\frac{P_{dc1}\ x\ n_{dc1}}{Pf1\ x\ \eta_{dc1}}\right] + \left[\frac{P_{ac2}\ x\ n_{ac2}}{Pf2\ x\ \eta_{ac2}}\right] + \left[\frac{P_{ac3}\ x\ n_{ac3}}{Pf3\ x\ \eta_{ac3}}\right] \right\} = 6.191kW \quad (2)$$

$$P_{smax} = \left\{\left[\frac{P_{dc1}\ x\ n_{dc1}\ x\ s_{f1}}{Pf1\ x\ \eta_{dc1}}\right] + \left[\frac{P_{ac2}\ x\ n_{ac2}\ x\ s_{f2}}{Pf2\ x\ \eta_{ac2}}\right] + \left[\frac{P_{ac3}\ x\ n_{ac3}\ x\ s_{f3}}{Pf3\ x\ \eta_{ac3}}\right]\right\} = 12.355kW \quad (3)$$

After knowing the E_req value, the size of battery required for this system is 736.739Ah but the discharge rate of the battery which is 11.4242 also need to be known. This is because the discharge rate of the battery can affect performance and lifespan of the battery. The total surge current is 128.6979A to make sure the battery could support the surge current. Based on Eqn. (4), the battery available size, C_bat_available is 300Ah from Felicity Solar model, LPBF48300 give the number of batteries in parallel, N_p_bat is 3 units. While the number of batteries in series per string, N_s_bat is 2 units by using Eqn. (5) as the voltage of each battery is 48V. Thus, this system required 6units of battery as shown in Eqn. (6) to operate based on system demand.

$$N_{p\_bat} = round_{up}\left\{\frac{c_{bat_{req}}}{C_{bat_{available}}}\right\} = 3units \quad (4)$$

$$N_{s\_bat} = \left\{\frac{V_{sys}}{V_{bat_{unit}}}\right\} = 2units \quad (5)$$

$$N_{t\_bat} = N_{p\_bat}\ x\ N_{s\_bat} = 6units \quad (6)$$

This system used PV module of TSM-DEG20C.20 600W by Vertex in this calculation. The sunlight also partially can pass through the roof as the greenhouse roof is made transparent material and have 0.01m gap between the PV module. The output current from PV module, I_mp_out is 16.8198A. This value is needed to determine the number of parallel PV strings which is 5units as shown in Eqn. (7). From datasheet of the PV module, the standard voltage of the PV module is 24V. The number of PV module in series per string is 4 units as shown in Eqn. (8). Thus, the total PV array needed is 20 units by using equation in Eqn. (9). With the total PV array needed, this PV array exceed the size of the greenhouse roof thus the extra number of PV module will be put on the jetty.

$$N_{p\_pv} = round_{up}\left\{\frac{E_{req}\ x\ k_1}{V_{sys} \times I_{mp_{out}}\ x\ PSH \times \eta_{cou_{bat}}}\right\} = 5units \quad (7)$$

$$N_{s\_pv} = \frac{V_{sys}}{V_{pv\_}standard\_voltage} = 4units \quad (8)$$

$$N_{pv} = N_{p\_pv}\ x\ N_{s\_pv} = 20units \quad (9)$$

Determining the appropriate size and capabilities of the SAPV system for greenhouse dehydration is a complex process that involving various factors such as energy demand, size of battery storage and number of PV module needed. This affect the cost-effectiveness when install this system as the amount power of energy required to power heating system in the greenhouse is high. Thus, this SAPV system can save money on spending monthly for the utility bill of electricity.

Result and Discussion

This research aims to thoroughly examine the thermal performance of a smart greenhouse and its impact on dehydrating fish. Data gathered from the greenhouse will be analyzed to determine the efficiency of the smart greenhouse system in maintaining ideal temperature. The findings will be discussed in relation to the objectives of this research, with emphasis on any noteworthy discoveries or observations. The results will also be compared to previous research on greenhouses and dehydration to provide context and confirm the validity of the study's conclusions. Five main observation is discussed in this research which are wind angle, location of exhaust fan, number of heater fan, variation of wind speed to achieve desired temperature and electricity bill based on power consumption that will be used in this greenhouse. This proposed is based on simulation from Energy2D software as shown in Figure 6, the greenhouse with complete loads, temperature sensor and same sizing as Greenhouse Company XYZ.

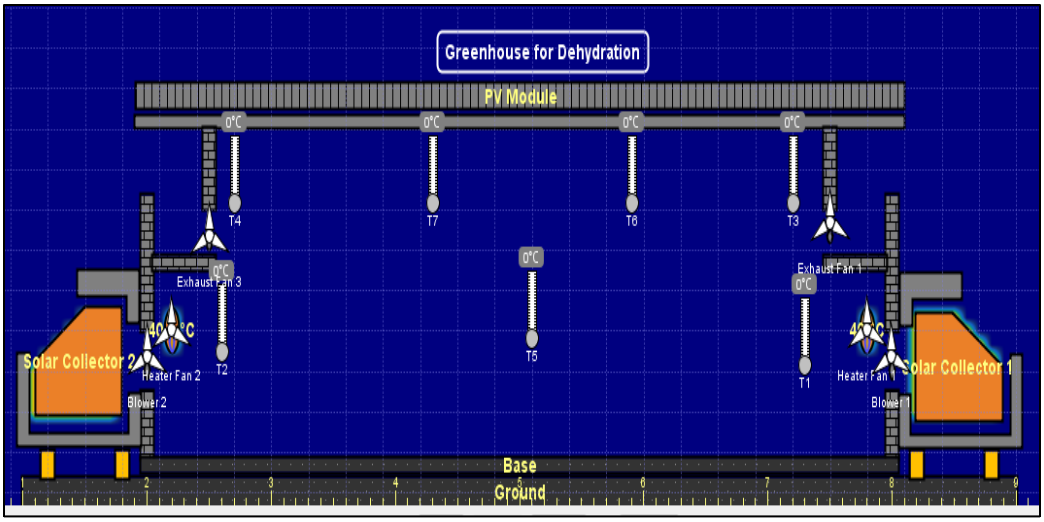

Figure 6: Greenhouse for Dehydration

Wind Angle

The angle of the heater fan in relation to the greenhouse plays an important role in the dehydration process. The angle of the fan can affect the distribution of heat within the greenhouse, which in turn can influence the temperature. A proper angle can ensure that the heat is distributed evenly throughout the greenhouse, resulting in optimal conditions for dehydration as shown in Figure 7. On the other hand, an incorrect angle can lead to uneven heating, resulting in hot and cold spots within the greenhouse, which can negatively impact the dehydration process. Therefore, the angle of the heater fan is a crucial factor that must be considered when designing a smart greenhouse for dehydration. The visualization of different colour is defined to different the temperature level based on Figure 8.

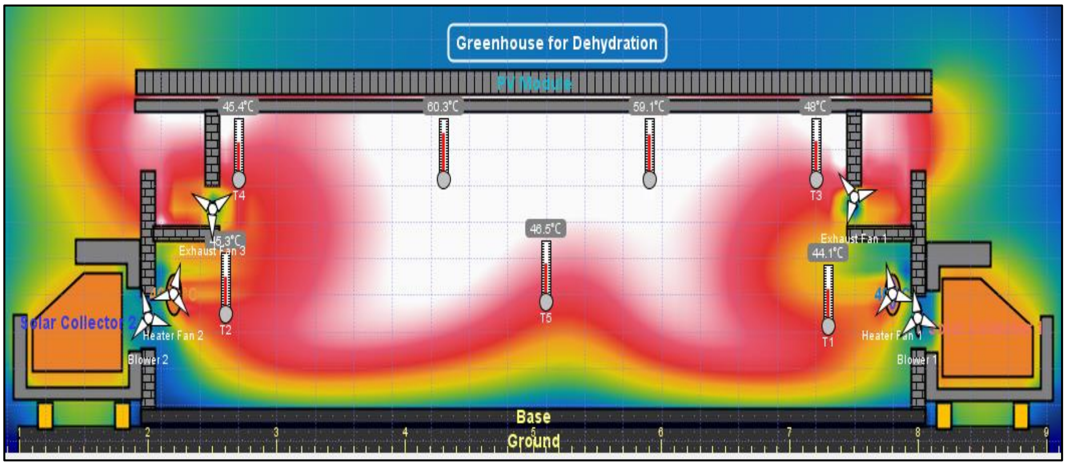

Figure 7: Simulation Regarding Wind Angle

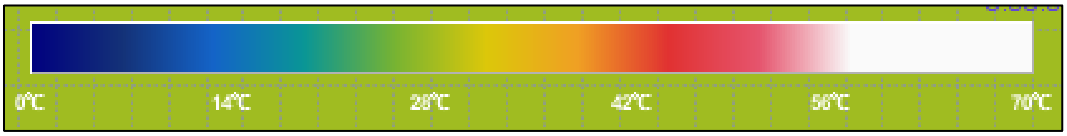

Figure 8: Simulation Regarding Wind Angle

Figure 9 shown the example of right heater fan that will blow heat in the direction of the arrow and left heater fan will blow in vice versa direction. According to Table 3, the wind angle is measured in degrees and represents the direction that the wind is blowing in relation to the greenhouse. The desired temperature region is the area of the greenhouse that is achieving the desired temperature for the crop, and it is represented by a color scale that ranges from red (indicating a low achievement of the desired temperature) to white (indicating high achievement of the desired temperature). The percentage is the ratio of the desired temperature region to the total region of the greenhouse. The value of wind angle starts with 10° and have increment of 40° for each test. This value is decided to compare the wind angle when it is blow to the bottom side, middle side and top side of the greenhouse. During 50° wind angle for both side of heater fan, the percentage shows the highest among others for this size of greenhouse. The relationship between wind angle and the desired temperature region in a greenhouse is linked to the principles of heat transfer. The movement of thermal energy from the solar heat collector and heater fan into the fish that will be dried through the greenhouse structure is not always evenly distributed, resulting in areas that are too hot or too cold for the fish.

Wind plays a crucial role by increasing the rate of convection, the transfer of heat through the movement gas, by moving the air around the greenhouse. This helps to distribute heat more evenly throughout the greenhouse, maintaining the desired temperature for the fish to dry. Data from the experiment in the table shows that as wind angle increases from 10° to 130°, the desired temperature region also increases, which indicates that the wind is distributing heat evenly and maintaining the desired temperature for the fish to dry. This is due to the increase in wind speed and direction which boosts the rate of convection and heat transfer, thereby maintaining the optimal temperature for the fish to dry as well as give good quality of dried fish as the final product (Villagran et al., 2021).

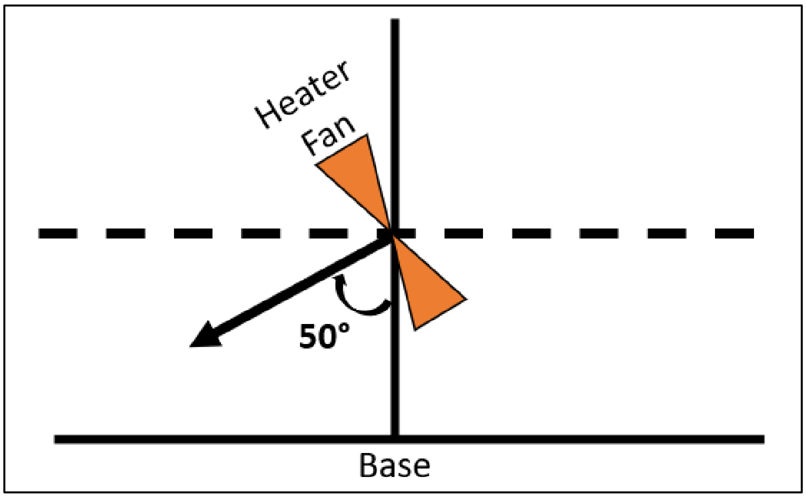

Figure 9: Right Heater Fan

Table 3
Percentage of Desired Temperature Region Based on Wind Angle

Wind Angle	**Desired Temperature Region with Red to White Colour**		**Percentage**
	Total Region	128	
10°	26		20.31%
50°	109		85.16%
90°	96		75.00%
130°	8		6.25%

Number of Heater Fan
The simulation shown in Figure 10 during the number of heater fan is one which gave about half of the smart greenhouse to achieve desired temperature region. The number of heater fans used will depend on the size of the greenhouse. Based on Table 4, during the number of heater fan that operate is one, 62.5% of the greenhouse achieved the desired temperature region with red to white colour scale. While, two heater fans maintain the desired temperature with 85.16% of the greenhouse region. Thus, this shown that two exhaust fans gave better impact for the heat distribution.
This number of heaters can be use during rainy season which fisherman will not go to find fish, thus number of fresh fish that need to be dried decrease. To save the energy for running the heater fan, only one heater fan will be used. The number of heater fans in a greenhouse is important in determining the ideal temperature range for dehydrating fish products. More heater fans can increase the heat in the greenhouse, facilitating faster dehydration, but an excessive number can also raise the temperature too high, potentially causing harm to the fish products (Arifianti et al., 2018). It is important to carefully monitor and adjust the number of heater fans to achieve optimal dehydration conditions.

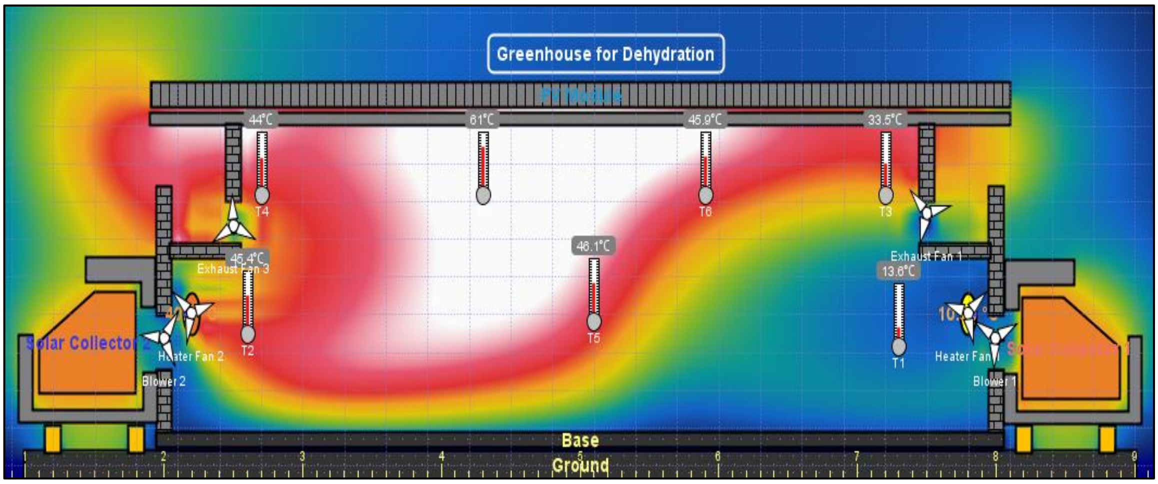

Figure 10: Simulation When Number of Heater Fan is One

Table 4
Percentage of Desired Temperature Region Based on Number of Heater Fan

Number of Heater Fan	Desired Temperature Region with Red to White Colour		Percentage
	Total Region	128	
1	80		62.5%
2	109		85.16%

Location of Exhaust Fan

The simulation shown in Figure 11 during the location of exhaust fan is on top that gave the high temperature in center of the greenhouse. The location of exhaust used will depend on the size of the greenhouse. Based on Table 5, top location of exhaust fan gave 54.69% of desired temperature region while the middle location of exhaust fan gave 85.16% of desired temperature region. Thus, this shown that the middle location of exhaust fan gave better impact for the heat distribution.

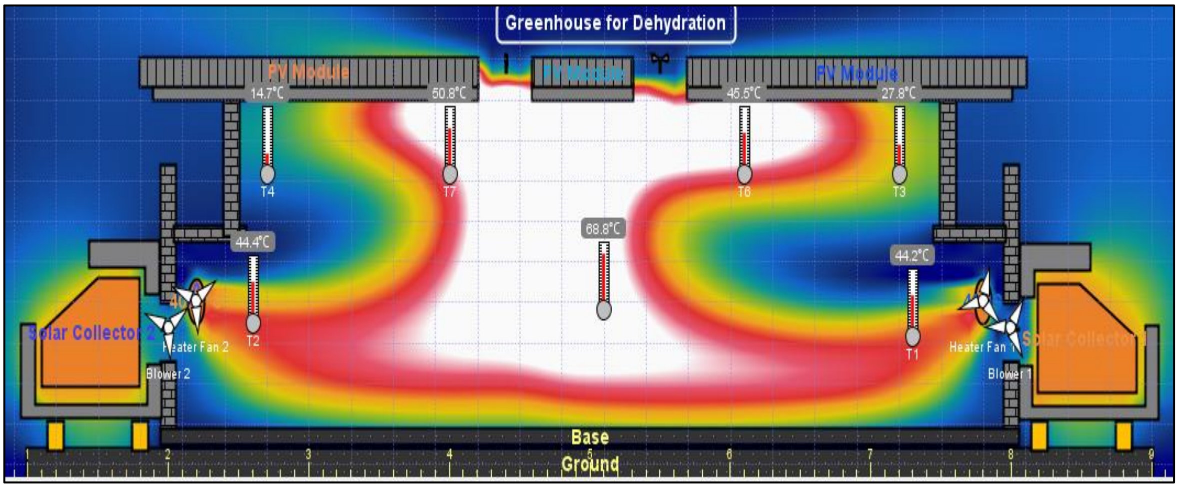

Figure 11: Simulation When Number of Heater Fan is One

Table 5
Percentage of Desired Temperature Region Based on Location of Exhaust Fan

Location of Exhaust Fan	Desired Temperature Region with Red to White Colour		Percentage
	Total Region	128	
Top	70		54.69%
Middle	109		85.16%

Based on temperature reading in Figure 12, the highest temperature is 70°C while the lowest is 18°C. This too high temperature can damage the quality of dried fish and too low temperature can make the fish does not dry completely. Thus, will make the worker job even harder as need to keep exchange and move the fish inside the greenhouse. This not support the goals of this research. For the location of exhaust fan on middle of the greenhouse, the highest temperature is 60°C and lowest temperature is 45°C as shown in Figure 13. This is the optimal and appropriate temperature do the dehydration of fish (Mehta et al., 2018).

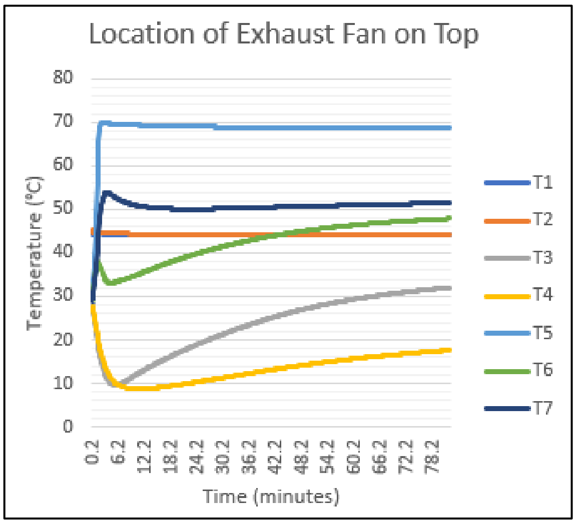

Figure 12: Location of Exhaust Fan on Top

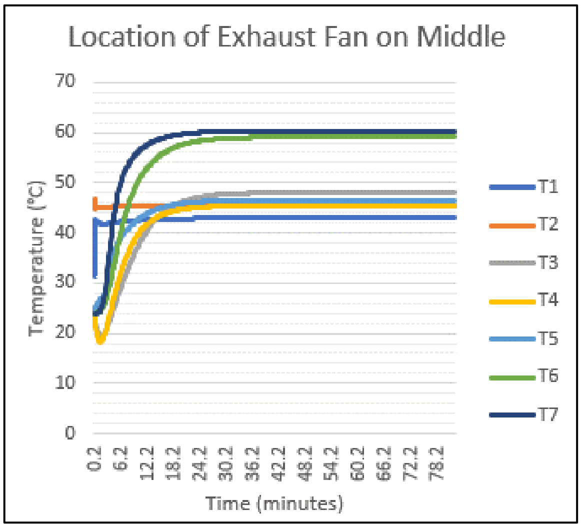

Figure 13: Location of Exhaust Fan on Middle

The location of exhaust fans in greenhouse can greatly impact the temperature for dehydrating seafood. These fans aid in removing excess heat and humidity to maintain optimal conditions for drying. Placing exhaust fans near the top of the greenhouse will aid in removing hot air and cooling the greenhouse while placing them near the bottom will aid in reducing humidity. The size, number and power of the fans also play a role in regulating temperature and humidity. Optimal placement and appropriate size and power of exhaust fans can maintain ideal drying conditions and enhance the quality and yield of produce (Ananno et al., 2020).

Variation of Wind Speed to Achieve Desired Temperature

The variation of wind speed can have a significant impact on the ability to achieve the desired temperature in a greenhouse for dehydration. Wind speed can affect the temperature inside a greenhouse by influencing the rate of heat loss through convection, conduction, and radiation. This heater fan wind speed is range from 0.1m/s to 0.3m/s. Based on Figure 14, when the wind speed of heater fan increase, the temperature inside increases. But, some temperature region inside the greenhouse will drop when the wind speed is high. The optimum wind speed for dehydration take place is 0.15m/s. This is because the temperature inside the greenhouse achieves the desired temperature which is range from 45°C to 60°C while the others wind speed is out of range.

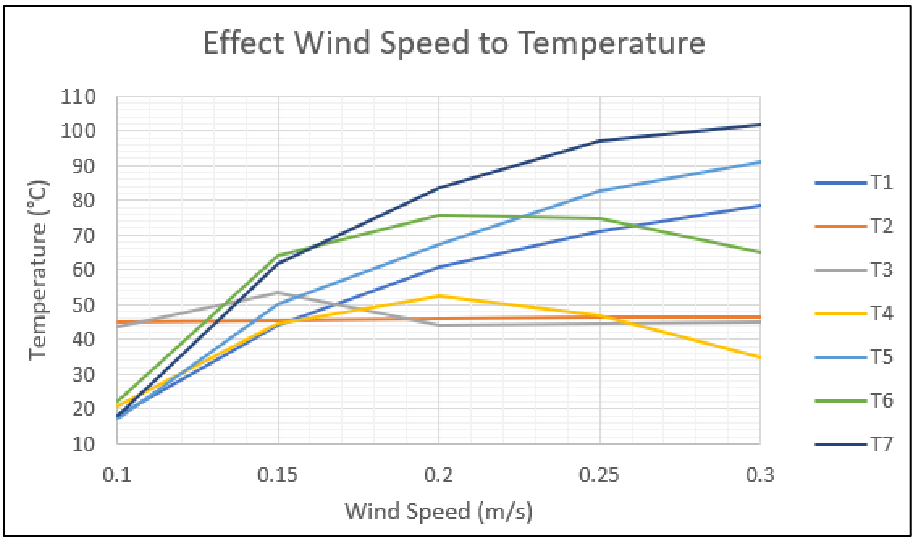

Figure 14: Effect Wind Speed to Temperature

When wind speed is low, the rate of heat loss is reduced, which can cause the temperature inside the greenhouse to increase. This can make it more difficult to achieve the desired temperature for dehydration, as the higher temperature can lead to increased humidity and slower drying times. On the other hand, when wind speed is high, the rate of heat loss is increased, which can cause the temperature inside the greenhouse to decrease. This can make it easier to achieve the desired temperature for dehydration, as the lower temperature can lead to lower humidity and faster drying times. However, the high wind speed can also cause damage to the greenhouse structure and the fish products, and if it is too high, the temperature inside the greenhouse can drop too low and cause damage to the fish products (Bouraoui et al., 2020). It is important to find the right balance of wind speed that can maintain the optimal temperature for dehydration while also protecting the greenhouse and the fish products that needs to be dry.

Electricity Bill Based on Power Consumption

Table 6 shown the power consumption in kilowatt-hours (kWh) based on the number of heater fan used over the course of one day and one month with the electricity bill in Malaysian Ringgit (RM) per month. The green house is assumed to be operated 24 hours per day, 7 day per week in the calculation. The energy block rates for electricity bill are based on power consumption for Tariff B – Low Voltage Commercial Tariff by Tenaga Nasional Berhad (TNB), Malaysia. According to this table also, the power consumption for one heater fan in one day is 16.679kWh, and the electricity bill for one month is RM239.89. For two heater fans, the power consumption in one day is 25.451kWh, and the electricity bill for one month is RM373.84. This implies that, having more heater fans will increase the power consumption and resulting a higher electricity bill. This number of heater fan used can be implemented during rainy season which the greenhouse can use one heater fan as the fisherman cannot catch fish that will be made as dried fish. Thus, production rate of dried fish will be low and the electricity cost will be low which resulting on no waste of electricity (Gospodinova et al., 2020). A SAPV system is used in this smart greenhouse to produce free energy and store it in batteries, eliminating the need for grid electricity and optimizing food production both day and night. If the customer spends around RM500.00 each month for the utility bill and change the electricity supply to 6kW of SAPV system, the total spend for the SAPV system is around RM30000.00 will leads to a return of investment within 5 years or sooner depends on the market price of installation of SAPV system.

Table 6
Percentage of Desired Temperature Region Based on Location of Exhaust Fan

Number of Heater Fan	**Power Consumption (kWh)**		**Electricity Bill per Month (RM)**
	1-day	**1-month**	
1	16.679	500.370	239.89
2	25.451	763.530	373.84

Conclusion

Overall, the thermal behaviour of a smart greenhouse based on the dehydration performance is a complex and multi-faceted issue. The results of this research show that the proper design and management of the greenhouse environment, including factors such as the angle of the heater fan, exhaust fan location and number of heater fan on or off, can significantly impact the efficiency and effectiveness of the dehydration process. The renewable energy source used with battery storage that can be use during night based on the calculation can gave time efficient which resulting in increasing of production rate of dried fish each day. Additionally, it has been found that the results of this research are in line with existing literature on smart greenhouse systems and dehydration performance, which provides validation for the findings. After the payback period, the energy produced by the smart greenhouse's PV system is nearly cost-free. This research has provided a deeper understanding of the thermal behaviour of a smart greenhouse and its impact on the dehydration performance. It is recommended that further research be conducted and implemented prototype based on this research to continue to improve the design and management of smart greenhouses for optimal dehydration performance. Finally, it is important to keep in mind that the thermal behaviour of a smart greenhouse is not only limited to the dehydration performance, but also its potential impact on the other seafood and fruits.

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