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Mathematical Model for Optimum Temperature and Humidity Determination of Mashed Mushroom in Greenhouses by using Smart Farm Technology and Innovation

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ABSTRACT

Background: At the present time, various technologies have been used in the development of modern agriculture. The technology used to help in the development of agricultural farms is called a smart farm. Mashed Mushroom is a food due to their usefulness and high nutritional and good income, as this result, the researcher was interested in the use of technology and innovation of smart farms in the mashed mushroom cultivation house and find a mathematical model of the optimum temperature and humidity for growing mashed mushrooms. Furthermore, find a mathematical model of the yield amount of mashed mushrooms against temperature and humidity.

Methods: There are 5 methods in this research, to be composed of studying the problem, planning the operation process, using technology and innovation in smart farms, collecting data and finally finding a mathematical model of the optimum temperature and humidity for growing mashed mushrooms. In addition, a mathematical model of the yield of mashed mushrooms was obtained.

Result: The results showed that the mathematical model of the optimum temperature for mashed mushroom was $T= 0.3267t^3-2.83t^2+7.1433t+20$, the most appropriate temperature was 24.95±5.557°C at the average andthe mathematical model of the optimum humidity for mashed mushroom was $H= -0.8417t^3+4.82-0t^2.1883t+59.65$, the most appropriate humidity was 74.58±15.451% at the average. In addition, the mathematical model of product yield of mashed mushrooms was $\hat{y}$ = -1.479+0.055T+0.028H when temperature T and humidity H were determined.

Key words: Humidity, Mashed mushroom, Mathematical model, Smart farm, Temperature.

INTRODUCTION

At the present time, various technologies have been used in the development of modern agriculture (Janarth *et al.,* 2024; Minh *et al.,* 2024; Pashova and Mihaylova, 2024; Singh and Sahdeo, 2021). Furthermore, electronics technology, computer and information technology have been applied in the management of agricultural farms, for example, measurement and display systems *via* the internet to be a tool for managing water and fertilizer, which helps to reduce production costs. The pattern in which technology used to help in the development of agricultural farms is called a smart farm. This will allow farmers to access accurate environmental information. It can control the production of agricultural products more efficiently (Ruethaichanok, 2016) and lead to sustainable agriculture (Das, 2024; Meena *et al.,* 2024).

Mushrooms are considered a very popular food due to their usefulness and high nutritional or alimental value and good income, as this result, most farmers turn to grow more mushrooms. Some farmer groups were successful, but some groups failed, which is caused by many factors, namely weather conditions which are important for the growth of mushrooms. Different types of mushrooms have different temperature requirements, for example, hot weather is suitable for straw mushrooms, such that the optimum temperature for growth is 35-37°C, so it is popular to cultivate straw mushrooms in the periods of the summer and rainy season because of being the appropriate periods for the growth of straw mushroom, but if it's winter, straw mushrooms won't grow much. As for grey oyster mushroom and oyster mushroom, the optimum temperature for growth is in the range of 25-35°C (Banna, 1989). In addition, humidity is essential for mycelium or fiber growth, flower formation and mushroom growth. If humidity is too much, the fibers become very waterlogged andmushrooms can die. But if it is too dry, the mushroom will become hard or have hardness and the mushroom will not grow (Varitee, 2011).

In this research, the researcher was interested in the use of technology and innovation of smart farms in the

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mashed mushroom cultivation house and find a mathematical model of the optimum temperature and humidity for growing mashed mushrooms. Furthermore, find a mathematical model of the yield amount of mashed mushrooms against temperature and humidity.

MATERIALS AND METHODS

We have 5 methods in this research, to be composed of studying the problem, planning the operation process, use technology and innovation in smart farms, collect data and finally find a mathematical model of the optimum temperature and humidity for growing mashed mushrooms. The use of smart farm technology is divided into 2 parts: The method of designing and installing structure of the mashed mushroom house; and the method of designing the control system of mashed mushroom cultivation houses. Design and installation of mashed mushroom house structure are designed to have a width of 3.7 meters, a length of 9 meters and a height of 2.3 meters, which the structure of the house is made of wood. The private house is covered with black canvas in order to be able to control the temperature and humidity inside the house in which there are 3,500 spawning cells per house. The structure at the top of the house is equipped with a sprinkler system which connected to a water pump at the beams of the house for increasing humidity inside the house. The temperature and humidity sensor module are installed in the middle of the mushroom house to measure the temperature and humidity values and send the data to the controller for processing, as shown in Fig 1.



Fig 1: Design and installation of the house structure.

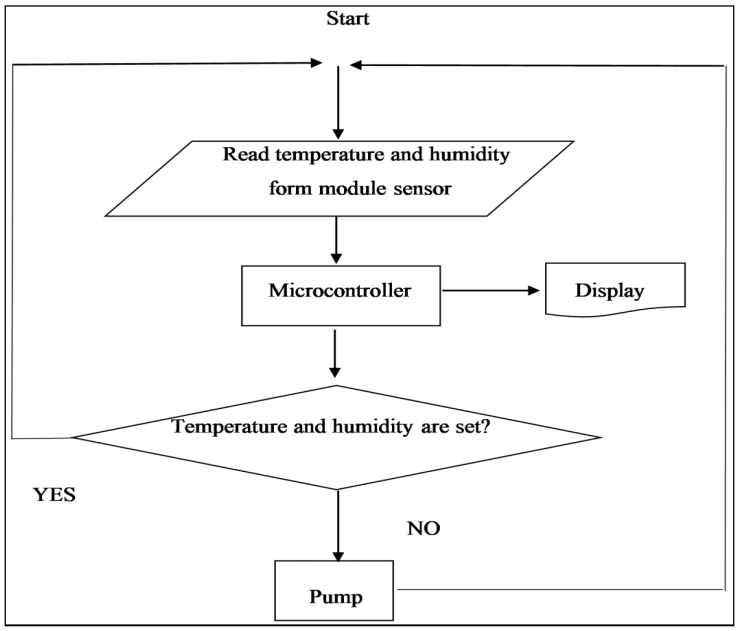

Fig 2: System operation.

In the part of the control system design for the mashed mushroom cultivation house, the humidity and temperature sensor modules are used to read the temperature and humidity values inside the house before sending data to the control system for processing by using a microcontroller. If the temperature and humidity inside the house are not as desired, the control system will order to turn on the water pump for the sprinkler system working.

According to a study of Department of Agriculture (Department of Agriculture, 2020), it was found that the optimum temperature of mashed mushroom cultivation was 33-36°C and the optimum humidity of mashed mushroom cultivation was 70-80 per cent. Therefore, we choose the temperature at 35°C and the humidity at 75 per cent for the system condition design, which is the working principle of the system (Boonyung and Santi, 2017) shown in Fig 2.

In the part of analyzing a mathematical model to determine the optimum temperature and humidity of mashed mushroom cultivation, we divided this study method into 2 parts: A mathematical model to determine the optimum temperature and humidity of mashed mushroom cultivation anda mathematical model of yields of mashed mushrooms on temperature and humidity (Saranya and Sophana, 2021). By the first step, we use Pearson's correlation analysis to study the relationship between temperature and humidity content on yields of mashed mushrooms. In the second step, we use factor analysis method to classify the variables by using principal component analysis method for solving linear correlation

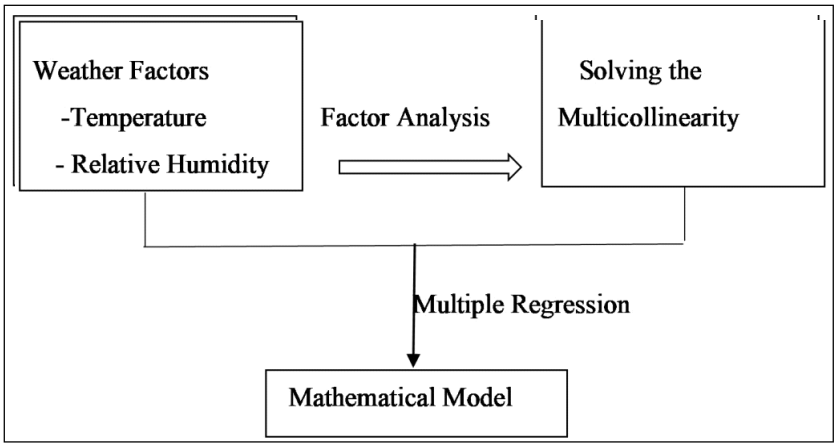

Fig 3: Conceptual framework.

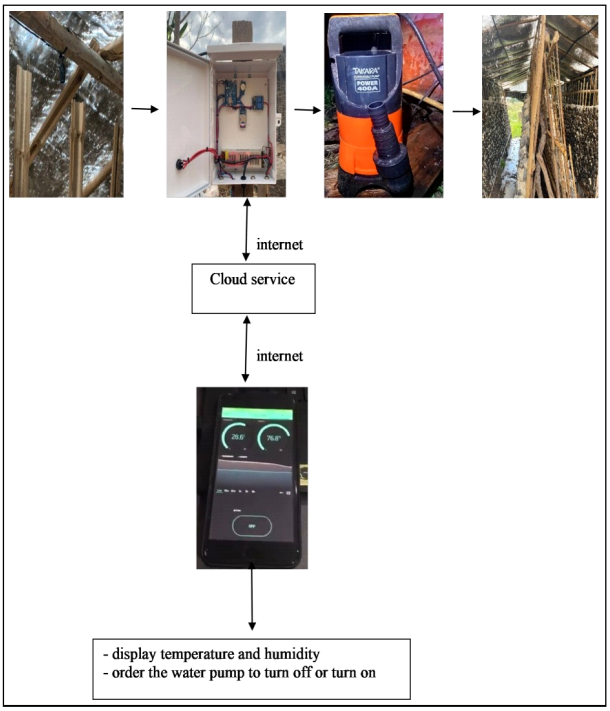

Fig 4: The use of technology and innovation of smart farms in the mashed mushroom cultivation houses.

problems (multicollinearity) to get the most accurate and suitable climate factors for mathematical modeling. And multiple regression analysis was used to create a mathematical model in the final step, as shown in Fig 3.

RESULTS AND DISCUSSION

The researcher has used technology and innovation of smart farms in the mashed mushroom cultivation house as shown in Fig 4.

The system operates according to the conditions in Table 1, temperature and humidity data were collected in the mashed mushroom cultivation houses every 3 hours for a period of 4 months from March 17, 2022 to July 17, 2022. The experiment results are as shown in Table 2 (The results of testing).

Temperature and humidity data of mashed mushroom cultivation houses from March 17, 2022 to July 17, 2022 are as shown in Fig 5.

From Table 3 and Table 4, throughout the cultivation period it was found that the highest temperature was 43.2°C, the lowest temperature was 12.6°C and the average temperature was 24.95±5.557°C which was suitable for mushroom flowering. The highest humidity was 98.8%, the lowest humidity was 30.17% and the average humidity was 74.58±15.45% which was suitable for mushroom flowering. We recorded the yield amount of mashed mushroom in the control house and compared to the yield amount of the mashed mushroom in the general house, as shown in Fig 6 and Fig 7. And the yield amount of mashed mushrooms in the control house had more yield than the general house.

Table 1: Working conditions.

Temperature (°C)	Humidity (%)	Pump
More than 35	More than 75	Working
More than 35	Less than 75	Working
Less than 35	More than 75	Not working
Less than 35	Less than 75	Working
Equal 35	Equal 75	Not working

Table 2: Experimental results.

Time	Temperature (°C)	Humidity (%)	Pump
06.00	20.7	94.09	Not working
09.00	22.7	81.67	Not working
12.00	30	61.19	Working
15.00	33	50.37	Working
18.00	35.3	53.34	Working
21.00	22.3	63.55	Working
24.00	23.5	65.86	Working
03.00	22.1	71.56	Working

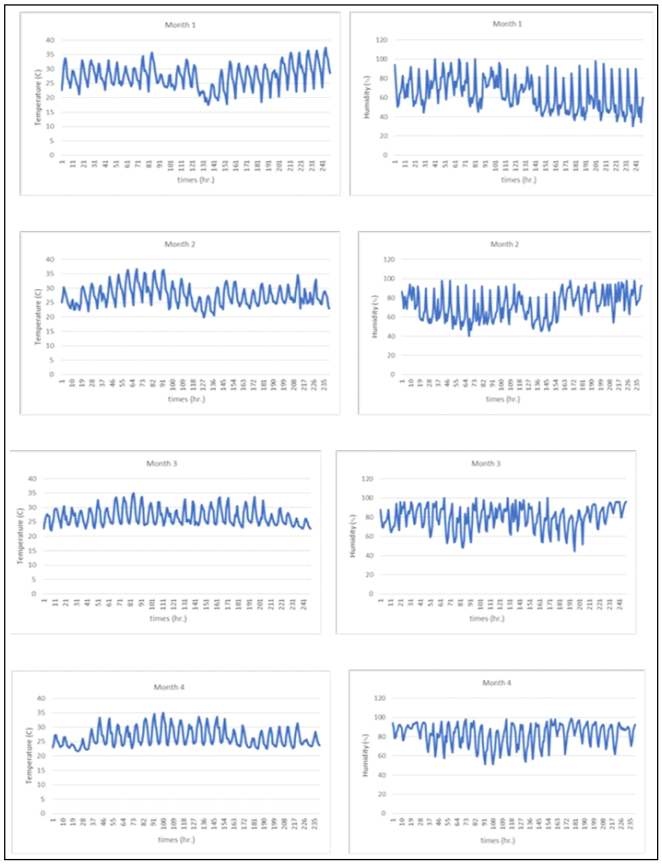

Fig 5: Temperature and humidity of mashed mushrooms.

Table 3: Temperature and humidity of mashed mushrooms.

Month	Temperature (°C)			Humidity (%)		
	Mean	Min	Max	Mean	Min	Max
1	24.64±5.567	12.6	38.3	63.44±16.679	30.17	98.4
2	25.58±6.039	15.8	43.2	71.82±14.305	40.14	97.8
3	24.78±5.213	15.9	37.2	79.74±12.087	44.37	97.83
4	24.2±5.298	16.6	36.1	82.15±11.439	50.95	98.8

Table 4: Temperature and humidity of mashed mushrooms (continued).

Factor	Mean	Std. Dev.	Std. Error	Min	Max
Temp.	24.95	5.557	0.175	12.6	43.2
Humd.	74.58	15.451	0.485	30.17	98.8



Fig 6: Productivity of mashed mushrooms in a control house.

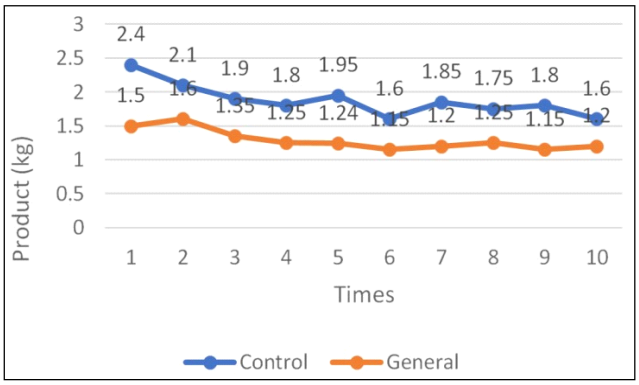

Fig 7: Yield amount of mashed mushrooms in control house and general house.

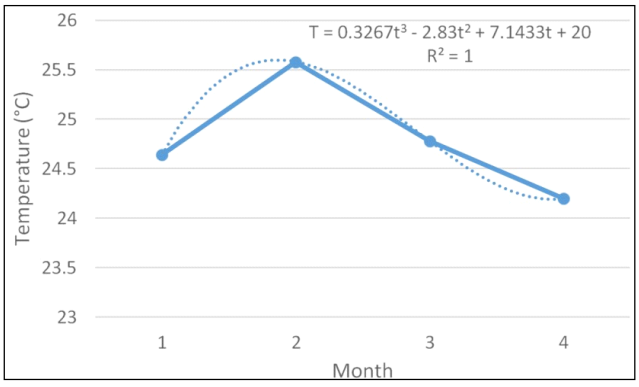

Fig 8: Mathematical model of temperature.

In the next step, we analyzed a mathematical model to determine the optimum temperature and humidity for mashed mushroom cultivation from March 17, 2022 to July 17, 2022. It was found that the mathematical model of the optimum temperature for mashed mushroom cultivation was, $T= 0.3267t^3-2.83t^2+7.1433t+20$, when the decision coefficient or coefficient of determination $R^2= 1$, such that the most suitable temperature range for cultivating mashed mushrooms was 24.95±5.557°C as shown in Fig 8 and the most suitable mathematical model of humidity for mashed mushroom cultivation from March 17, 2022 to July 17, 2022 was, $H= -0.8417t^3+4.82t^2-0.1883t+59.65$, when the decision coefficient or coefficient of determination , such that the most suitable humidity range for cultivating mashed mushrooms was 74.58±15.451% as shown in Fig 9.

For the forecasting the result through graphs between year and treatment as shown in Fig 10.

In addition, we created a mathematical model of the yield amount of mashed mushrooms against temperature and humidity. By the first step, Pearson's correlation analysis was used to study the relationship between yield amount of mashed mushrooms and climate, temperature and humidity data. For the second step, we used the method of classification of variables called factor analysis. In the last step, we use multiple regression analysis to create a mathematical model of the productivity of mashed mushrooms on climatic, temperature and humidity factors. Pearson's Correlation is shown in Table 5.

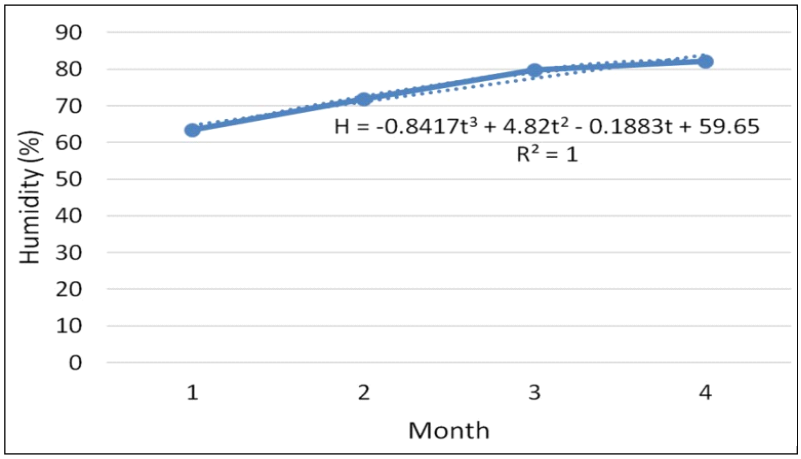

Fig 9: Mathematical model of humidity.

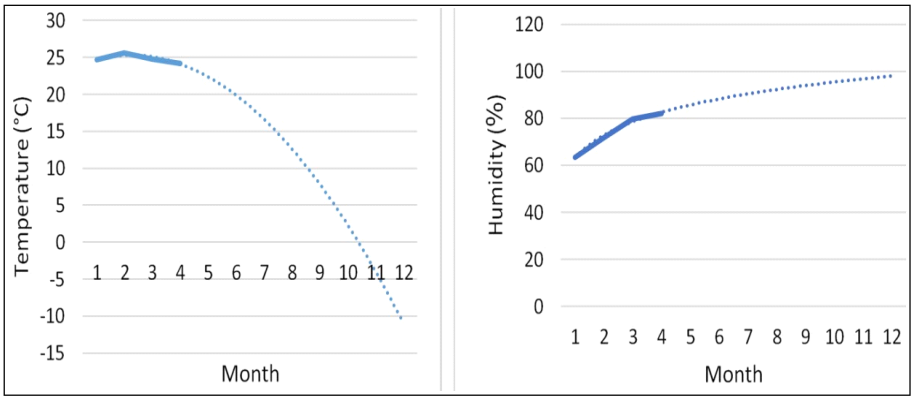

Fig 10: Forecasting between year and treatment.

Table 5: Pearson's correlation.

Correlations				
		Product	Temperature	Humidity
Product	Pearson correlation	1	-.024	.540
	Sig. (2-tailed)		.947	.107
	N	10	10	10
Temperature	Pearson correlation	-.024	1	-.591**
	Sig. (2-tailed)	.947		.000
	N	10	976	976
Humidity	Pearson correlation	.540	-.591**	1
	Sig. (2-tailed)	.107	.000	
	N	10	976	976

**Correlation is significant at the 0.01 level (2-tailed).

Table 6: Linear correlation.

Coefficients[a]		
Model	Collinearity statistics	
	Tolerance	VIF
Temperature humidity	.322	3.106
	.322	3.106

a. Dependent variable: Product.

The results showed that the yield amount of mashed mushrooms was significantly negatively correlated with temperature (X_1, r = -0.024) and significantly positively correlated with humidity (X_2, r = 0.540). Furthermore, when considering the relationship of individual climate variables with the yield amount of mashed mushrooms, it was found that temperature was significantly negatively correlated with the yield amount of mashed mushrooms (r = -0.024) and humidity was significantly positively correlated with the yield

Table 7: Multiple regression analysis.

Coefficients[a]

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
(Constant)	-1.479	.576		-2.568	.037	-2.841	-.117		
temperature	.055	.011	1.307	4.947	.002	.029	.082	.322	3.106
humidity	.028	.005	1.617	6.118	.000	.017	.039	.322	3.106

a. Dependent variable: Product.

amount of mashed mushrooms (r = 0.540), there was a correlation of each climate variable as well, that is, temperature was significantly negatively correlated with humidity (r = -0.591) and humidity was significantly negatively correlated with temperature (r = -0.591).

From the correlation of such climate factors, there was a possibility of linear correlation problems (multicollinearity) by checking from the Variance Inflation Factor (VIF) and the Tolerance of each climate factor as shown in Table 6.

It can be seen from Table 6 that the Tolerance for the climate factor is greater than 0.2 and the VIF for the climate factor is less than 5, indicating a low correlation between the climate factors. This will not cause a linear correlation problem.

In the next step, we used multiple regression analysis, it was found that the temperature has a significance level of 0.002 and humidity has a significance level of 0.000, both of which are less than 0.05, indicating that temperature and humidity affect the yield amount of mashed mushrooms as in Table 7.

By examining the coefficient of the independent variables and the yield amount of mashed mushrooms, it can be concluded that a mathematical model of yield amount of mashed mushrooms on temperature and humidity can be able to write

$$\hat{y} = -1.479+0.055T+0.028H$$

When $\hat{y}$ is the yield amount of mashed mushrooms, is temperature and is humidity, which the optimum temperature of mashed mushroom cultivation on average range was 24.95±5.557°C and the optimum humidity of mashed mushroom cultivation on average range was 74.58±15.451%.

CONCLUSION

In this research, the researcher used technology and innovation of smart farms in the mashed mushroom cultivation house and find a mathematical model of the optimum temperature and humidity for growing mashed mushrooms. Furthermore, find a mathematical model of the yield amount of mashed mushrooms against temperature and humidity. The results showed that the mathematical model of the optimum temperature for mashed mushroom was $T= 0.3267t^3-2.83t^2+7.1433t+20$, such that the average of the most appropriate temperature range was 24.95±5.557°C and the mathematical model of the optimum humidity for mashed mushroom was $H= -0.8417t^3+4.82t^2-0.1883t+59.65$, such that the average of the most appropriate humidity range was 74.58±15.451%. In addition, the mathematical model of yield amount of mashed mushrooms was $\hat{y}$= -1.479+0.055T+0.028H when temperature and humidity were determined.

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Conflict of interest

The authors have no conflict of interest.

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