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Editorial

The ASEAN Journal of Scientific and Technological Reports (AJSTR) Vol. 24 No. 3 (September–December 2021) (old name Thaksin University Journal; TSUJ) is the first issue under the name of AJSTR that is published in 2021. This issue is published 10 worth reading research articles. These exciting research articles were reviewed and answered by experts from various universities and institutions. We sincerely hope that some of the research papers will help guide and motivate our active researchers to produce and create their research more valuable shortly. The AJSTR has served our energetic readers and customers on the international level.

For this reason, all selected and accepted research articles will be written and organized in English. Furthermore, the new international editorial board of AJSTR has also been set up and started to administrate and manage all the journal's business simultaneously. From now on, the AJSTR and a new editorial team are ready to organize, manage, publish, and deliver all good quality articles written in well organized English to the world of academic society. I would like to introduce AJSTR editorial board members as below.

Asst. Prof. Dr. Sompong O-Thong
Journal Editor-in-Chief

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Research article

Application of Smart Farm System to Enhance Phoenix Oyster Mushroom Production

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Abstract: Phoenix Oyster Mushroom's production, which is considered an economic mushroom in Thailand, to reach the quantity and quality that is accordant with customers' demand, requires suitable temperature and humidity control. This research aims to develop and apply for the smart farm system (SFS) designed ET-ESP8266-RS485 board to control temperature and humidity, operate and show result data through an application on the smartphone. Also, it can collect the data and analysis to compare the Phoenix Oyster Mushroom farm installing with the SFS (the test set) and the Phoenix Oyster Mushroom farm non-installing with the SFS (the control set). The result found that the SFS's control system was able to show the temperature and humidity results accurately; the average error percentage was at a low level — equal to 0.61 and 1.19%, respectively. In addition, it was able to maintain the consistency of temperature and humidity at an average of 27.67 °C and 83.36%, respectively. In contrast, the control set maintained the temperature and humidity at 32.28 °C and 69.32%, respectively. The average productivity of the mushroom from the test set was 8.1 kg and 8.48 × 6.5 cm in size. It was 1.42 times or significantly ($p < 0.06$) higher than the control set, which provided the average productivity of the mushroom at 5. 7 kg and 7.37 × 5.66 cm in size. The user satisfaction assessment of 30 users from using the Phoenix Oyster Mushroom farm installed with the SFS was found that the users were satisfied at the highest level ($\bar{x}$ =4.54 and S.D.=0.52). The economic analysis determined that the agriculturists would break even at 28.10 kg of Phoenix Oyster Mushroom production. The research indicates that the developed SFS can create favourable conditions for Phoenix Oyster Mushroom growth, leading to higher quantity and quality and the convenience of well-managed farming.

Keywords: Phoenix Oyster Mushroom; Smart Farm; Humidity; Temperature

1. Introduction

Innovation research and development is an essential tool that helps the country pass over the middle-income trap, satisfies the national strategy and develops the country in various fields. Especially in an agricultural country where agriculturists are the economic founder. The farm sector has applied multiple technologies to decrease labour cost, time cost and emphasize working convenience and product quality consistency. Phoenix Oyster Mushroom (*Pleurotus pulmonarius*) is a commercially important mushroom. It is widely produced, distributed, and sold to generate a worthwhile income. It can be purchased fresh, dried, or processed. Therefore, agriculturists have highly successful opportunities because this mushroom market is wide and in high demand. Agriculturists can harvest the mushroom 4-6 times and achieve a high average yield at 250-300 g per kg of mushroom spawn bag. Mushrooms have a short period of incubation. It can be grown almost every season if the relative humidity (RH) is between 80 and 85%. The temperature is between 25-30 °C, except in the summer when the temperature is too high. The humidity is less than 65% [1], mushrooms cannot grow because the weather's humid condition strongly affects mushroom growth [2]. To obtain high-quality mushrooms that meet customer demand, agriculturists must focus on properly controlling two production factors: temperature and humidity [3]. Currently, climate change is extreme, so agriculturists need to apply modern technology to control the factors; hence, the smart farm system (SFS) controls the temperature and humidity to produce quality mushrooms. According to the favourable condition, agriculturists can obtain the data through a wireless measurement system or control application via smartphone, analyze the received data, and prepare the cultivation effectively. At present, researchers and scholars widely apply the technology of SFS to manage the agricultural farm. They integrate computer system knowledge, communication, sensor system, and biological technology with agriculture and engineering agriculture [4] by developing the internet of things (IoT) and connecting the data to a cloud system. The SFS has been applied to the agricultural system, expanding quickly [5-7]. For instance, they use a temperature and relative humidity control system through a water evaporative cooling system and automatic spraying via a programmable logic control system. The system is effective at developing agriculture and increasing productivity [8]. An automated system is a tool that processes quickly and accurately uses the worthly resources to improve product quality and decrease cost [9]. Productivity is also safe for consumers and the environment. Therefore, it leads to international technology competition [10-12]. Nowadays, there is an increase in the agricultural application of the SFSs, such as smart farm technology used to control organic vegetable plots.

The application of IoT in Phoenix Oyster Mushroom farm provides convenience to agriculturists to take care of the mushroom growing effectively [13]. Green oak salad has grown under controlled auto-light, automatic fogging system and automatic mist distribution exhibited consistent growth characteristics across three harvests, with an average width of 14.94 cm and a height of 15.66 cm [14]. Applying a smart irrigation system to a sweet corn field covering one rai at San Pa Tong District, Chiangmai increased sweet corn productivity from 1,200 kg/rai to 3,000-3,500 kg/rai [15]. Additionally, the mango farm that uses the internet of things (IoT) to control the light concentration has found the optimal value between 25,000-27,000 Lux. Temperatures are ideal between 20 and 34 ˚C, and RH is ideal between 40% and 60% [16]. Therefore, this study aims to obtain the output of temperature and humidity controls for growing Phoenix Oyster Mushroom using the SFS in a prototype mushroom farm to suggest agriculturists reduce the cost of time, labour, and resources. They can produce Phoenix Oyster Mushroom for household consumption and commercial furthering.

2. Materials and Methods

2.1 Design and building of Phoenix Oyster Mushroom automatic mushroom farm

The Phoenix Oyster Mushroom's automatic mushroom farm was designed and built as a closed-nursery farm in a household consumption size. The main structure was made from slotted angle steels 1.5 × 1.5 inches, designed to have width × length × high equal to 60 × 100 × 94 cm. LDPE plastic sheets were used to cover the roof and the 4-sides of the mushroom farm. Two designed mushroom farms were made identically. One mushroom farm was for the SFS installation with temperature and humidity sensor, including the control system (the test set). Another mushroom farm was for growing Phoenix Oyster Mushroom without the SFS installation (control set) as in Figure 1. Each mushroom farm put in 30 bags of mushroom spawns.

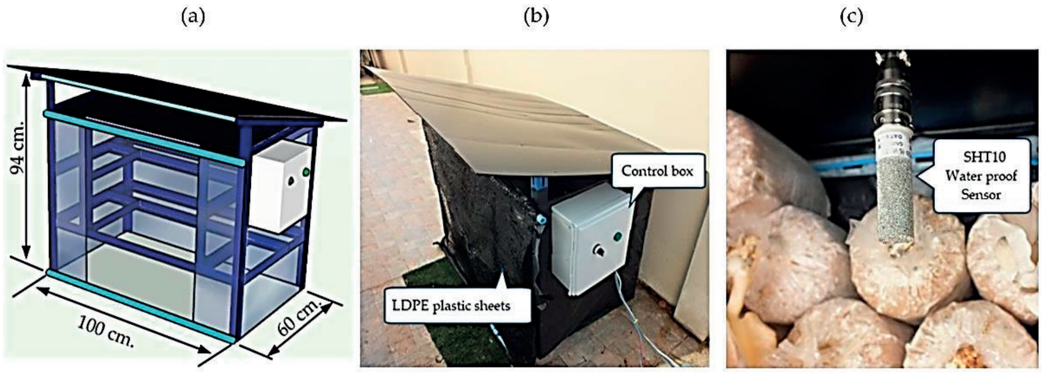

Figure 1. Phoenix Oyster Mushroom farms designed for the smart farm system installation (a) Phoenix Oyster Mushroom farm structure, (b) Phoenix Oyster Mushroom farm with smart farm system installation, (c) Temperature and humidity sensor within the mushroom farm.

2.2 Mushroom spawn bag

The studied mushroom spawns were bought from Phoenix Oyster Mushroom farm at Khuan Lang Sub District, Hat Yai District, Songkhla — an experienced place of growing Phoenix Oyster Mushroom. Sixty new mushroom spawn bags of 1 kg were selected. There were no tears around the mushroom spawn bags and the top of the bags was covered with dry cotton. The growth of white mycelium can be seen around the bottleneck without black mycelium or green mycelium growth.

2.3 SFS design for Phoenix Oyster Mushroom automatic mushroom farm

SFS design brings IoT technology to apply for controlling and displaying the measurement result needed to monitor and provide a favourable condition to mushroom growing efficiently [17, 4]. The control codes were sketched using Arduino IDE with Blynk application [18] to control a sensor through a smartphone using ET-ESP8266-RS485 board [19]. The controls were set to a temperature of 30 °C and humidity of no less than 80%. The temperature and humidity sensor: ET-SHT10 waterproof sensor [19] was installed to read the values and transmit the data to the board. Then, the result was displayed through the Blynk application for users to track, inspect, and manage the favourable condition values. If the temperature and humidity are not as specified, users can operate the board through smartphones. The temperature and humidity sensor then switches on the 220 voltages (AC), 100 watts water pump, push the water to mist spray head in the mushroom farm. The mist sprayer system runs until it reaches the temperature and humidity favourable condition for Phoenix Oyster Mushroom, then users can switch off the system. Meanwhile, the board inspects the sensor's value to compare it with the new setup value. It works as a continuous loop, as shown in the temperature and humidity control system diagram and the operation flowchart (Figure 2), electrical circuit design, and the user interface details on the control application (Figure 3).

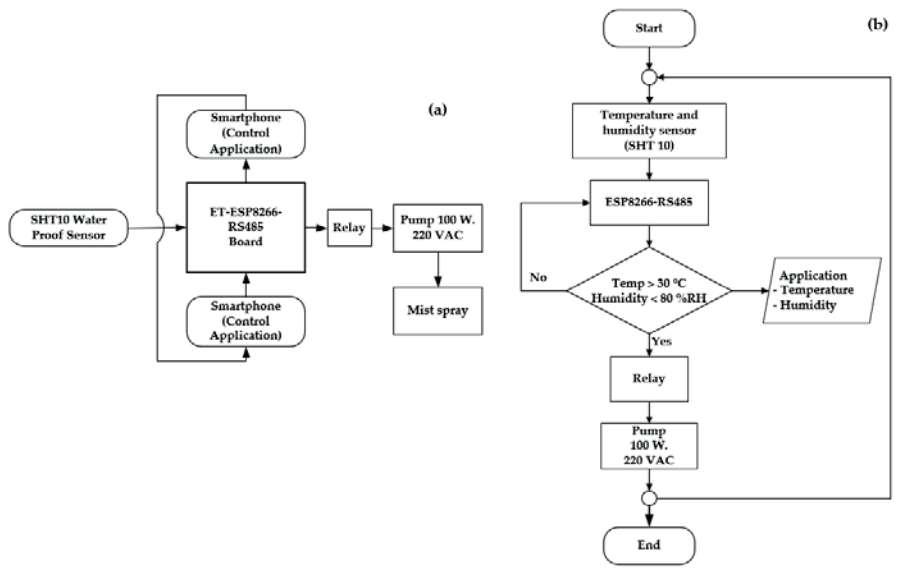

Figure 2 Diagram (a) Control system for temperature and humidity, (b) Operation flowchart

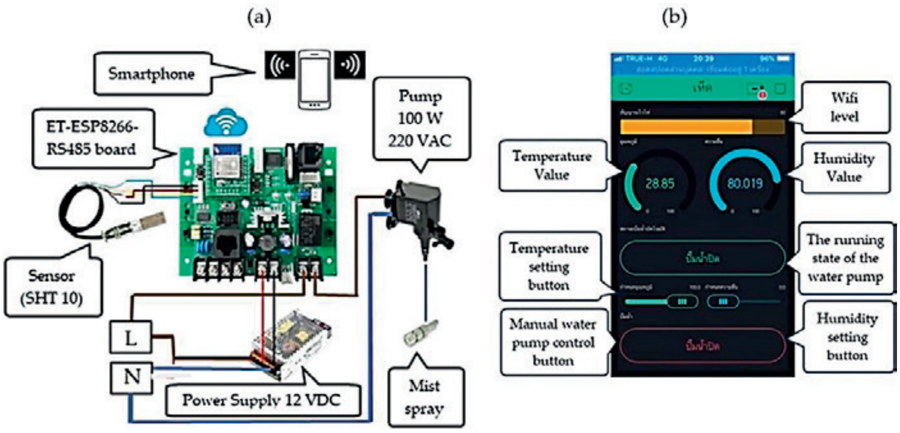

Figure 3 Diagram (a) Electrical circuit design, (b) Control application user interface

2.4 Accuracy test of the temperature and humidity sensor on the developed smartphone system

The built mushroom farm (section 2.1) was installed with the smartphone system, then the control system that developed for control of the board operation and the temperature and humidity sensor. Display of measured values through the connection of application on the smartphone and inspection of the consistency of temperature and humidity sensor measurement was compared with the standard instrument's values for every 10 minutes over 10.00 am-3.00 pm. The duration is which the temperature of the day is high and the humidity of the day is low. After that, the measured values of the temperature and humidity were calculated for the average to find the error percentage (% error) according to equation 1 [20]. The information was used to estimate the SFS's performance to produce Phoenix Oyster Mushroom.

$$\%\ \text{error} = \frac{|E_{mea} - E_t|}{E_t} \times 100 \qquad (1)$$

Where

E_{mea} is the measured value from the measurement.

E_t is the real measured value from the standard measuring instrument.

2.5 Study of the efficiency of SFS for Phoenix Oyster Mushroom production

The experiment was conducted after-only with a control group experimental design [22]. The mushroom spawn bags were randomly assigned to two conditions: the test set and the control set. After installing and inspecting the SFS's operation, the mushroom spawn bags were put in the mushroom farm. For the test set and the control set, the mushroom production data were collected according to the harvesting process. The mushroom's quality was evaluated by observing the mushroom spawn bags almost full of white mycelium. Then the top of the plastic bags was opened, pulled the sheet and plastic bottleneck with cotton out from the mushroom spawn bags. The bags were stacked up in piles waiting for their growth and productivity harvest. The bloom cap and curved-down cap margin (edge) are required to pick up specifically because mushrooms are not sticky, and they can stimulate regeneration. The harvested Phoenix Oyster Mushrooms were weighed and measured their size according to Ratchadaporn and Suwalak methods [21]. The average of mushroom productivity was collected stimulus while the temperature and humidity data were continuously recorded, covering the mushroom spawn bags. The mushroom productivity was harvested 4 times simultaneously. Following that, the gathered data was analyzed and compared the statistical value using the t-test (Two-Sample assuming equal variances) [22] between the test and control set to evaluate the efficiency of the SFS's operation.

2.6 The satisfaction assessment of users for Phoenix Oyster Mushroom production

Thirty Phoenix Oyster Mushroom farms installed with the SFS were used as the sample group (30 people) to assess user satisfaction (Figure 4). The sample group was selected based on the people who have settled in Khao Rup Chang Sub-district, Muang District, Songkhla Province and did have not enough own land for agriculture. These people work in general employment jobs, selling hawker items, so their income is not stable according to Quality-of-Life Development and Income Enhancement for Fundamental Community Project database. After the sample group had tried using the developed Phoenix Oyster Mushroom farms for 1 month, the user satisfaction was assessed using a rating scale of 1-5 levels. It revealed the data as a percentage and standard deviation [22].

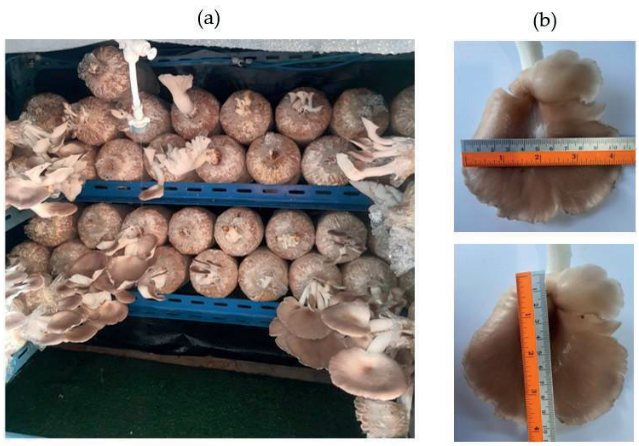

Figure 4. Phoenix Oyster Mushroom farm installing with smart farm system (a) Productivity of Phoenix Oyster Mushroom,(b) measurement of mushroom size (width × Length cm)

2.7 Economic analysis of the results

Economic results were analyzed to determine the breakeven quantity using fixed cost, variable cost per unit, and unit price data. The term "fixed cost" refers to the price of the equipment required to build a farm structure. The variable cost is the price of mushroom spawn bags and the amount of electricity consumed. Equation 2 was used to calculate the breakeven quantity [23].

$$BEQ = \frac{F}{P-VC} \quad (2)$$

Where

BEQ is the breakeven quantity (kg)

F is a fixed cost (baht)

P is the price per unit (baht per kg)

VC is the variable cost per unit (baht per kg)

3. Results and Discussion

3.1 Results of the accuracy of temperature and humidity sensor of developed SFS

After measuring the temperature and humidity values continuously every 10 minutes from 10.00-15.00 o'clock of the day, it found that the temperature and humidity sensor of the developed control system in the automatic mushroom farm installed with the SFS provided values of the temperature and humidity approximately equal to the real values from the standard measuring instrument over the testing duration as in figure 5.

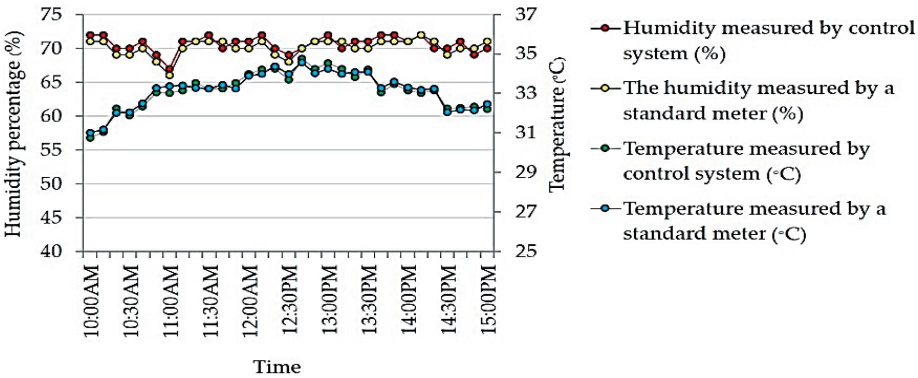

Figure 5. The developed control system's measured temperature and humidity values compared to the real values from the standard measuring instrument.

Figure 5 shows that the developed control system's temperature and humidity sensor had accurate reading efficiency, especially when agriculturists wanted to calculate and find the error value according to equation 1. The measured values had the error percentage of the temperature in the range of 0.52-0.67 and the error percentage of the humidity in the range of 0.96-1.45, averages at 0.61 and 1.19, respectively (Table 1).

Table 1 The error percentage values are inversely proportional to the level of reliability of the data.

Time	Error Percentage (%)	
	Temperature	Humidity
10.00-11.00 am	0.67	1.45
11.10-12.00 am	0.62	1.19
12.10-13.00 pm	0.67	0.96
13.10-14.00 pm	0.58	1.18
14.10-15.00 pm	0.52	1.19
Average	**0.61**	**1.19**

Table 1 showed that the developed SFS read the temperature and humidity values accurately when continuously compared to the standard measuring instrument. The values are also displayed through the smartphone; therefore, agriculturists could manage and effectively produce Phoenix Oyster Mushrooms in the automatic mushroom farm.

3.2 The results of the study of the performance of developed temperature and humidity system's operation

After the tests run of the temperature and humidity sensor operation of the developed SFS, put the mushroom spawn bags in the test set and found that the developed control system could control the temperature, and humidity values at less than 30 °C and RH 85%, respectively. The installed sensor reads the temperature and humidity values and continuously transmit the reading data through the Blynk application on smartphones for 4 harvest cycles, 7 days per cycle, as in figure 6.

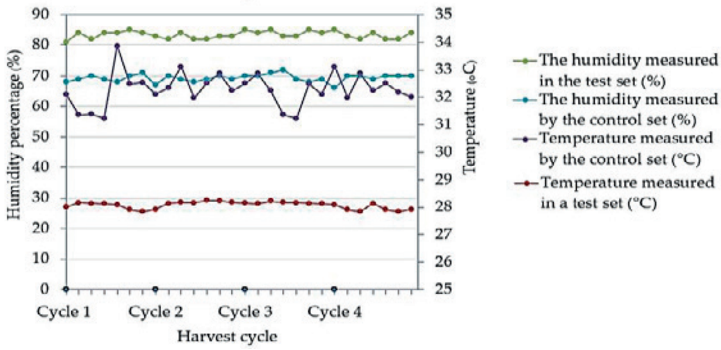

Figure 6. The measured temperature and humidity values of the Phoenix Oyster Mushroom automatic mushroom farm installed with the smart farm system (the test set) and the Phoenix Oyster Mushroom farm non-installing with the smart farm system (the control set).

From figure 6, Comparing the measured temperature and humidity values of the test set with the control set showed that the test set's measured temperature and humidity values had an average of 25.58-29.22 °C and RH 81-85%, respectively. The values were suitable for the mushroom's growth, indicating that the temperature and humidity control system of the automatic mushroom farm installed with the SFS could operate effectively. Meanwhile, when considering the level of the temperature and humidity values of the control set; found that the measured values were not suitable for the growth of the mushroom as the reason that the temperature which is higher than 30 °C, in the range of 31.23-33.86 °C and the humidity was lower than 80%, in the range of 68-72%. In addition, the mushroom farm of the control set had a variation of temperature and humidity values over the Phoenix Oyster Mushroom growing condition; thus, it might be one of the factors that affect the delay or growing of mushrooms.

3.3. Comparison result of Phoenix Oyster Mushroom productivity between productivities from the automatic mushroom farm installing with the SFS and the mushroom farm non-installing with the SFS.

After considering the Phoenix Oyster Mushroom productivity weight, which was collected from the test set and the control set, found that the productivity weight produced from the test set has an average quantity of 8,100 g or 8.1 kg, more than 1.42 times or significance ($p > 0.06$) of the productivity weight which is produced from the control set — 5,700 g or 5.7 kg (Table 2).

Table 2 Phoenix Oyster Mushroom productivity between productivities from the automatic mushroom farm installing with the smart farm system (the test set) and the mushroom farm non-installing with the smart farm system (the control set).

		Harvest Cycle				
		1	2	3	4	Total
Phoenix Oyster Mushroom Production from the test set	Weight of whole Phoenix Oyster Mushroom productivity (g)	2,400	2,100	2,100	1,500	8,100 1/
	Average weight of Phoenix Oyster Mushroom productivity per bag (g)	80	70	70	50	270
	Average mushroom Size (width × Length cm)		8.48 × 6.52			55.29
Phoenix Oyster Mushroom Production from the control set	Weight of whole Phoenix Oyster Mushroom productivity (g)	1,800	1,500	1,500	900	5,700
	Average weight of Phoenix Oyster Mushroom productivity per bag (g)	60	50	50	30	190
	Average mushroom Size (width × Length cm)		7.37 × 5.66			41.71

1/t-test comparision, significant level at p=0.06

Table 2 indicates the efficiency of the temperature and humidity control system that affected the growth and production of the Phoenix Oyster Mushroom. Over the harvesting periods, it was found that mushroom productivity weight was higher than the control set every time the test set was provided. The productivity of the test set per mushroom spawn bag per harvest cycle was average up to 50-80 g. The productivity per mushroom spawn bag per harvest cycle of the control set and the agriculturists in general produce were 30-60 and 40-50 g, respectively. The mushroom grower group at Ban Tung Pan, Lampang province, used the temperature and humidity control system. The developed system could enhance the mushroom productivity average by 10.1 kg per one-time harvest cycle [24]. Consideration of Phoenix Oyster Mushrooms size found that the test set provided the average of the mushroom size, which had width × length × at 8.48 × 6.52 cm, higher than the average of mushroom size at 7.37 × 5.66 cm in the control set. These sizes indicate the physiological maturity of the mushroom.

This test indicated that the application of the temperature and humidity control system of the SFS could be managed the suitable temperature and humidity conditions for the growth and productivity of Phoenix Oyster Mushrooms. If the temperature and humidity are higher or lower than the suitable level, it decreases mycelium growth, reduces mushroom growth, and cannot fully grow. Therefore, it affects on decrease the overall productivity. If the humidity is too high, the mycelium will be soaked, so it cannot deliver food to the mushrooms so that the mushrooms will shrink and die. If the humidity is too low, the mushrooms will rough, with a crack, and cannot grow [2].

3.4. The result of satisfaction assessment on the Phoenix Oyster Mushroom farm installing with the SFS

The result of satisfaction assessment from 30 users revealed that their satisfaction level for using the Phoenix Oyster Mushroom farm installing with the SFS is at the highest level (Table 3). The users were satisfied at the highest level ($\bar{x}$ =4.54 and S.D.=0.52). The highest satisfaction level was at 4.77 (Mushroom productivity), followed by 4.75 (Convenience of using), 4.55 (Structure and design) and 4.53 (The speed of responding to work orders), while high satisfaction level was at 4.10 (Application performance). The satisfaction results indicated that the Phoenix Oyster Mushroom farm provided good mushroom productivity. It is very convenient to use. The size of the structure is designed to suit people who have no own land. As well as the operation of the system is easy to understand.

Table 3 User satisfaction level with using the Phoenix Oyster Mushroom farm installing with the smart farm system

Opinion	$\overline{X}$	S.D	Satisfaction level
1. Structure and design	4.55	0.33	highest
2. Convenience of using	4.75	0.58	highest
3. The speed of responding to work orders	4.53	0.56	highest
4. Application performance	4.10	0.65	high
5. Mushroom productivity	4.77	0.46	highest
Mean	4.54	0.52	highest

3.5. The results of economic analysis

According to economic analysis, the fixed cost was equal to 2,800 baht. The variable cost of Phoenix Oyster Mushroom production per kilogram was 37.03 baht, while electricity consumption was 3.55 baht. The Phoenix Oyster Mushroom was sold at a wholesale price of 140 baht per kilogram (market price, Mueang District, Songkhla Province as in February 2021). Then, using equation 2, the breakeven quantity (BEQ) was 28.10 kg.

4. Conclusions

The application of SFS is to control the environment, which results in favourable mushroom growth. This developed SFS was capable of accurately controlling temperature and humidity for at least 5 h between 10.00 AM and 3.00 PM with an average error percentage of 0.61 and 1.19%, respectively. In other words, it is extremely accurate at controlling temperature and humidity at levels of up to 99.39 and 98.89%, respectively. The Phoenix Oyster Mushroom farm installed with SFS was capable of maintaining temperature and humidity consistency at an average of 27.67 °C and 83.36%, respectively, to promote mushroom growth. The productivity of Phoenix Oyster Mushroom farm installing with SFS was 1.42 times higher than that of Phoenix Oyster Mushroom farm non-installing with SFS. Thirty users who used the Phoenix Oyster Mushroom farm installing with SFS were satisfied at the highest level ($\bar{x}$ =4.54 and S.D.=0.52). According to the users, the Phoenix Oyster Mushroom farm installing with SFS increased productivity and facilitated mushroom production. And according to economic analysis, the breakeven quantity for agriculturists was 28.10 kg of mushroom yields. Additionally, the Phoenix Oyster Mushroom farm installed with SFS was small and compact, making it ideal for people with limited land or who live in dense urban areas. It can also provide urban and rural residents food security in both normal and emergencies in the Covid-19. However, this study is a study on developing an automatic economical-size Phoenix Oyster Mushroom farm for communities. Communities can grow Phoenix Oyster Mushroom to enhance income and occupation; thus, agriculturists need to expand the mushroom farm size and study further factors, including the production capacity of agriculturists to extend commercially. We hope this finding will lead to more research in this vital field.

5. Acknowledgements

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Author Contributions:

Funding:

Conflicts of Interest: The authors declare no conflicts of interest.

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