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Development of Fuzzy Control Systems in Portable Cultivation Chambers to Improve the Quality of Oyster Mushrooms

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Abstract. Oyster mushroom (*Pleurotus sp.*) grows optimally at a temperature of 25-30 °C. To stimulate the growth of shoots and increase the growth, mushrooms need air humidity around 80-85%. Mushrooms that grow in environments with humidity below 80% will be affected by impaired absorption of nutrients, causing dryness and impaired growth or death. The purpose of this study was to design an automatic temperature and humidity control system based on fuzzy logic to improve the quality and productivity of oyster mushrooms in portable cultivation chamber. The design includes the control of temperature based on fuzzy logic to control the temperature actuator (fan), and on/off control system on the humidifier in the prototype chamber of mushroom cultivation. Performance testing includes the average mass and length of the oyster mushroom stems which then compared their effectiveness between (1) automatic control systems based on fuzzy logic; (2) on/off control system; (3) as well as cultivation methods with conventional systems. The results of performance testing of fuzzy based automatic temperature and humidity control systems produced a mean mass of 132.33 g and the average length of the stem was 6.23 cm. It can be concluded that the different treatments in the cultivation process (fuzzy, on/off, and conventional) have a very significant effect on the average mass and stem length results. Fuzzy control systems produce better mushroom productivity, more energy efficient and environmentally friendly.

Keywords: control system, fuzzy logic, humidity, oyster mushroom, temperature.

1. Introduction

Pleurotus sp. known as the oyster mushroom because the morphology resembles an oyster shell. The oyster mushroom morphology is very dependent on the place of growth. If it grows on the side of the substrate, the shape of the mushroom is often not stemmed or short-stemmed, which is located asymmetry (like shells). Oyster mushrooms are a type of wood remover mushroom that can grow on various media such as sawdust, straw, husks, cotton waste, tea leaf waste, corn husk, bagasse, paper waste, and other agricultural and industrial wastes containing ligno cellulose ingredients [1][2].

Oyster mushrooms grow throughout the year spread from cold climates to hot temperate tropical lands. Mushroom mycelium grows optimally at a temperature of 25-30 °C, while the mushroom body of most oyster mushroom species grows optimally at temperatures of 18-20 °C. The growth period of mycelium requires air humidity between 65-70%, but to stimulate the growth of shoots and the body of the mushroom requires air humidity around 80-85%. Shoots and mushroom bodies that grow in environments with humidity below 80% will be disrupted by absorption of nutrients causing dryness and disruption of growth or death [3][4]. The right temperature and humidity control system in agriculture is very important because it can improve the quality and quantity of agricultural products



[5][6][7]. Quality improvement of mushroom products can also be done by applying intelligent control systems to temperature and humidity. Fuzzy logic based control systems have been widely used as controllers in various applications, and have proven to be more effective and efficient compared to conventional control systems, especially in agriculture [8][9][10]. Fuzzy logic tends to be more practical to use because it is simple, easy to understand, flexible, set point control becomes more accurate, provides better results, and saves energy. So far there has been no automatic control system application based on fuzzy logic for the portable cultivation chamber of oyster mushrooms. Therefore, there is a need for research to test the automatic temperature and humidity control systems of portable oyster mushroom chambers based on fuzzy logic. The purpose of this study was to build a fuzzy control system for the portable cultivation chamber of oyster mushrooms, test the performance of the control systems, and test the quality of oyster mushrooms produced from fuzzy control systems compared to on / off control systems and conventional cultivation method.

2. Materials and methods

The tools used in this study include plastic container boxes as portable chamber prototypes, Arduino Uno R3 as the processor of the control system [11], SHT11 sensor as a temperature and humidity meter [12], 2x16 liquid-crystal display (LCD) as the data output viewer of the system, L298N driver as pulse-width modulation (PWM) regulator from the fan, 2 channel relay to turn on and turn off the humidifier, 12V DC fan as a temperature control actuator, humidifier as humidity control actuator. The materials used in this study include: oyster mushrooms as research material, planting media for oyster mushrooms, and water as a source of steam humidifiers. The research methods include the method of automatic temperature and humidity control systems based on fuzzy logic, on / off logic, and with conventional systems that are cultivated in the oyster mushroom chamber [13]. Oyster mushroom product testing methods include the average mass and length of the oyster mushroom stems.

3. Results and discussion

Portable oyster mushroom chamber cultivation with an automatic control system of temperature and humidity that has been built has dimensions of 46-33-28.5 cm. In Figure 1 shows the results of the design of a portable prototype oyster mushroom chamber. The prototype chamber is made of a plastic container with a capacity of 30 L. In the lid section, there is a square shaped monitoring hole with 12 cm side dimensions which is covered with transparent glass. On the front there is a 2x16 LCD. AC / DC power supply (Sunace HL-1205AP model) has AC voltage input 100 - 245 Volt at 60 Hz and outputs 12 Volt DC voltage with 5 Ampere resistance. Oyster mushroom cultivation room has a capacity of 6 planting bags with dimensions of tube length of 20 cm with a diameter of 10 cm. To isolate this cultivation space from light contact from the outside system, the box surface is given a black stain. In the lid of the plastic box, there is a hole under the humidifier so that cotton can absorb water from the container. On the lid of the plastic box there is a humidity control actuator i.e. bottle caps type humidifier with a 5 volt DC voltage specification, a water vapor rate of 40 mL/h, and a maximum of the water vapor area is $\pm 5 \text{ m}^2$. In the right and left inner box body with a distance of 2 cm from the front side and a distance of 2 cm from the lid of the plastic container box, there is a temperature control actuator that is two 12 volt DC fans with a resistance of 0.15 A with dimensions of 8 x 8 cm. Inside there is a SHT11 sensor. The automatic temperature and humidity control system of the oyster mushroom chamber is arranged in an electronic box to meet 3 aspects of industrial design i.e. ergonomics, aesthetics and interface design. LCD functions to display SHT11 sensor reading data as a description of conditions in the cultivation chamber. Arduino Uno is connected to all components. This is because Arduino Uno is a controller for controlling the actuator components, and also provides output data displayed by the LCD from the results of processing input data sent by the SHT11 sensor. The component of the temperature actuator controller is the L98N driver which will provide a PWM signal according to the fuzzy logic program installed in Arduino Uno to regulate the rotating fan with rotation per minute (RPM) that matches the PWM. The step down regulator functions as an input DC voltage converter from a 12 volt power supply to a 3 volt DC input voltage used by control system components. The automatic control system scheme

is presented in Figure 2. The results of temperature and humidity control tests can be seen in Figures 3 and 4. In Figures 3 and 4, it can be concluded that this system can reach steady state within 5 minutes. While from the calculation, it can be concluded that the steady state error is divided into two i.e. the highest temperature error of 3.70% and the lowest error of 0.89%, while the highest humidity error is 0.78% and the lowest error is 0.11%. This error is still within the tolerance limit of the system specification with a maximum steady state error of 5% for upper errors and 2.5% for lower errors.

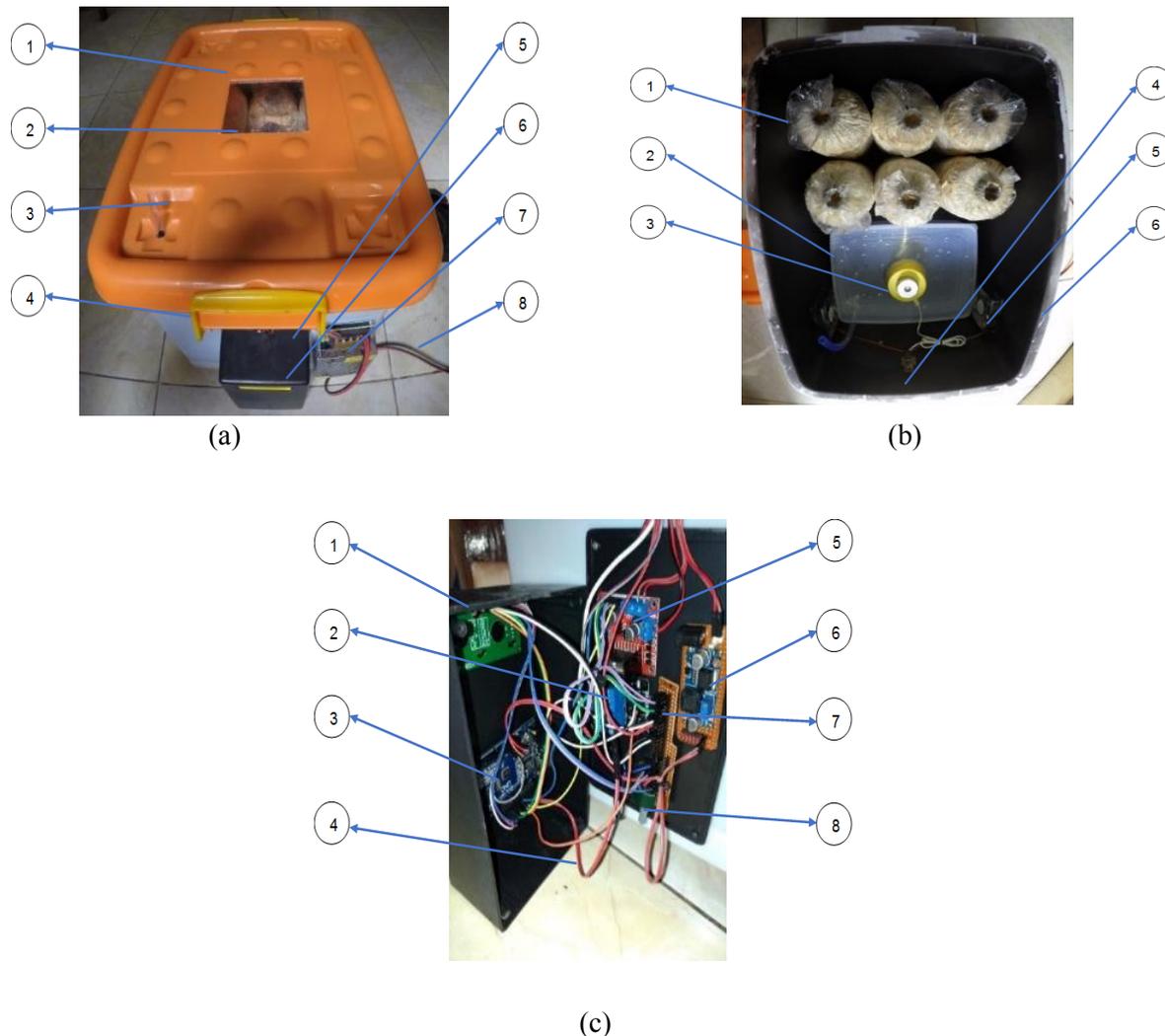


Figure 1. Portable oyster mushroom chamber: (a) the outer part includes: (1) the lid of the plastic container box; (2) monitoring holes; (3) clear plastic hose; (4) plastic container box bodies; (5) electronic boxes; (6) 2x16 LCD; (7) power supply; (8) power cable; (b) the inside includes: (1) oyster mushroom planting bags; (2) plastic boxes; (3) humidifier; (4) SHT11 sensors; (5) 12V DC fan; (6) black coloring of inner plastic container casing; (c) Automatic control components: (1) 2x16 LCD; (2) 2 channel relay; (3) Arduino UNO R3; (4) jumper cable; (5) L298N drivers; (6) regulators step down; (7) header male; (8) potentiometer.

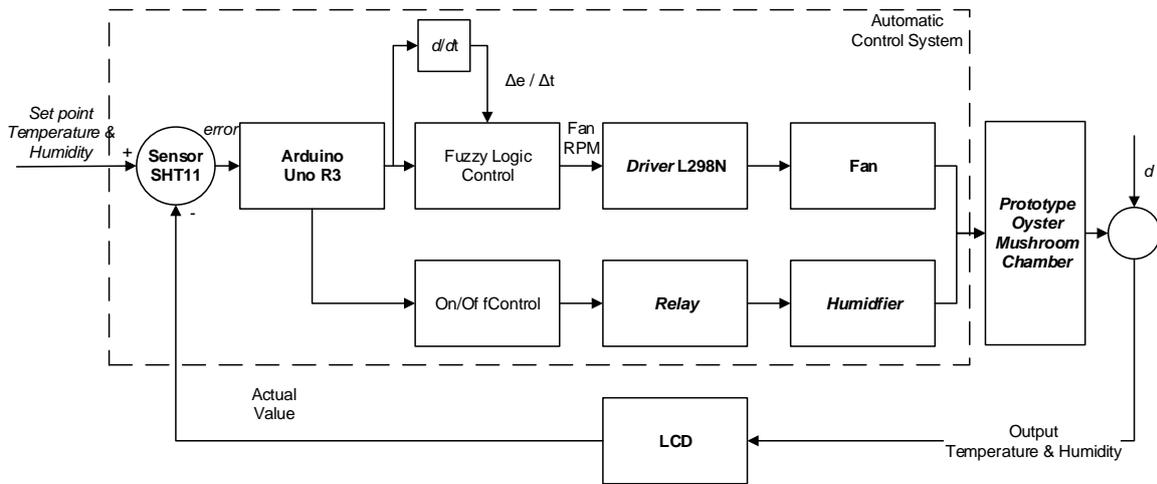


Figure 2. Automatic control system scheme.

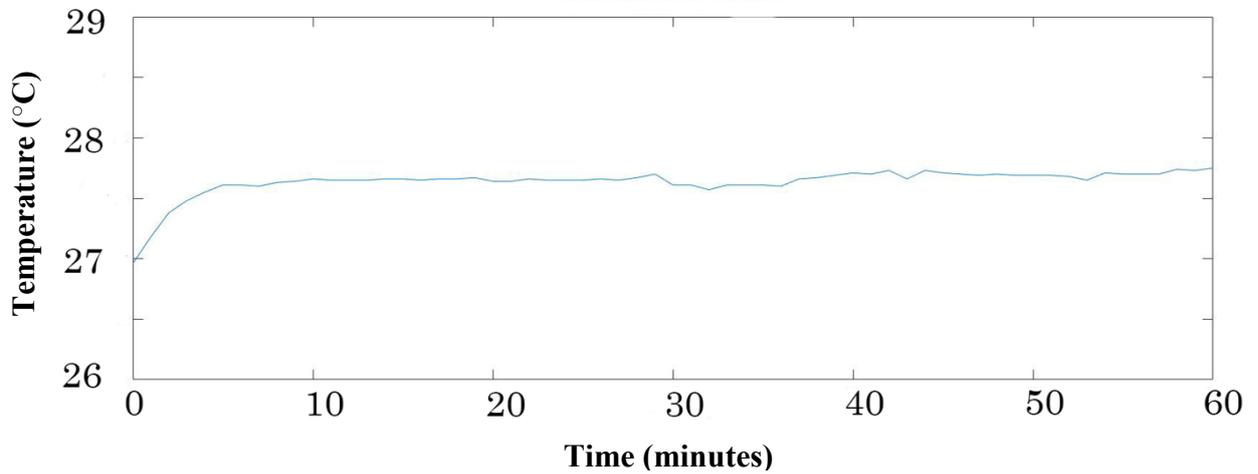


Figure 3. Temperature response on the control system.

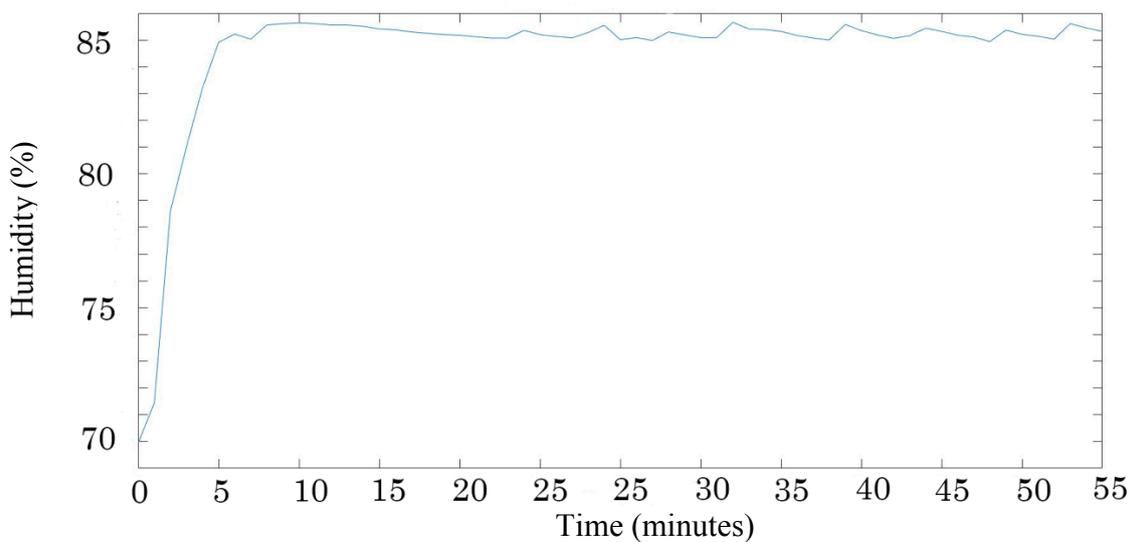


Figure 4. Moisture response in the control system.

Product testing is done by comparing the results of the mass and length of the oyster mushroom stem between the fuzzy logic-based control system, on/off logic-based control system, and with conventional systems as shown in Figure 5. Figure 6 shows the results of the average oyster mushroom mass from the fuzzy logic control system which obtained a mass average of 132.33 g, with a standard deviation of 11.50. Whereas, in the treatment of cultivation with on/off logic-based control systems, the average mass yield was 104.00 g, with a standard deviation of 7.21. Then, in the treatment of cultivation with the conventional method, the average mass yield was 83.00 g, with a standard deviation of 11.79. The final result of this analysis states that the results of the average oyster mushroom mass in the three treatments had a very significant effect.

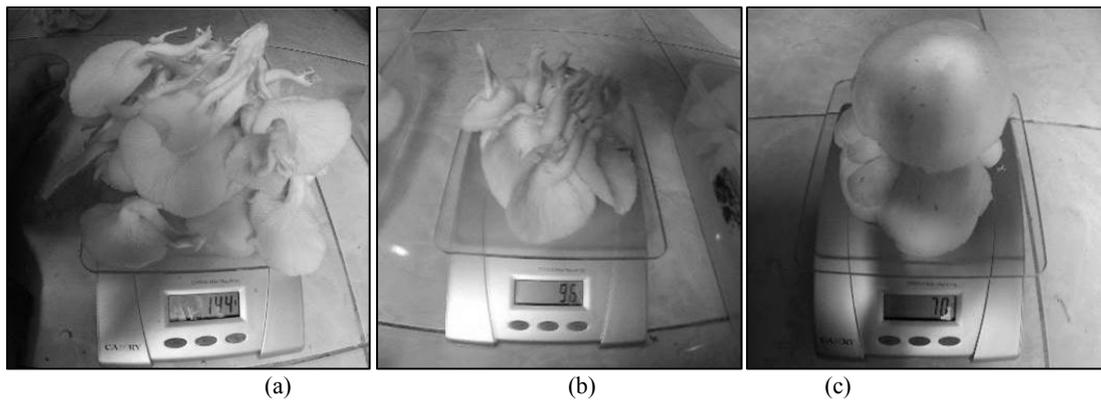


Figure 5. The results of oyster mushroom products with some treatments: (a) fuzzy control; (b) on/off control; (c) conventional cultivation

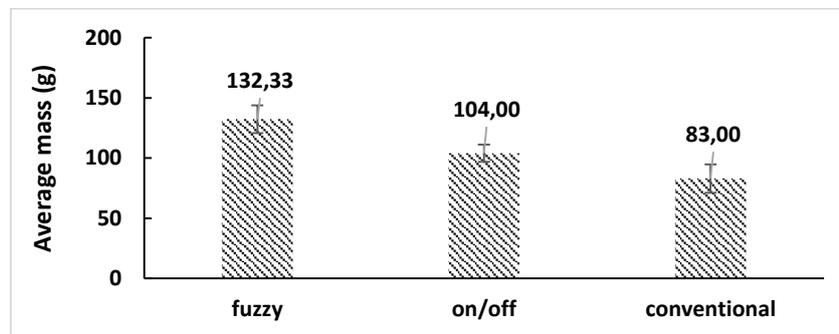


Figure 6. The average yield of oyster mushroom mass.

Figure 7 shows the results of the average length of the oyster mushroom stems cultivated with 3 different treatments i.e. with a fuzzy logic-based control system, on/off logic, and with conventional methods. In the cultivation treatment with fuzzy logic-based control system, the average stem length is 6.23 cm, with a standard deviation of 0.87. Whereas, in the cultivation treatment with on/off logic-based control system, the average stem length was 6.05 cm, with a standard deviation of 0.39. Then, in the treatment of cultivation with conventional methods, the average length of the stem is 5.72 cm, with a standard deviation of 0.70. The system that uses fuzzy control produces better performance compared to other treatments. From the results of measurements of the weight and length of oyster mushrooms, it can be concluded that the control system based on fuzzy logic can improve the quality of oyster mushroom products using portable cultivation chamber.

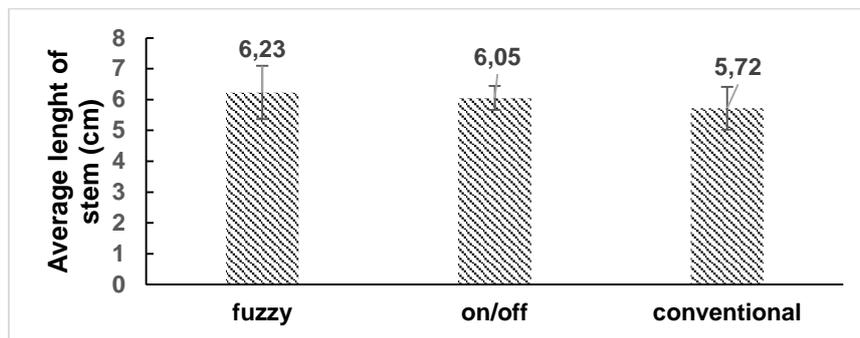


Figure 7. The results of the average stem length of oyster mushrooms.

4. Conclusion

From the research carried out, a prototype design of automatic control system of temperature and humidity for oyster mushroom cultivation based on fuzzy logic has been developed. The results of the automatic control system of temperature and humidity generated by the system can reach steady state within 5 minutes. With the highest temperature error of 3.70% and the lowest error of 0.89%, the highest humidity error is 0.78% and the lowest error is 0.11%. The temperature recovery speed of this automatic control system is 0.1 °C per minute and moisture recovery is 2.4% per minute. The performance test results of automatic temperature and humidity based control systems based on fuzzy logic produce a mean mass of 132.33 g and a mean stem length of 6.23 cm. Different treatments in the cultivation process (fuzzy, on/off, and conventional) have a very significant effect on the average mass and stem length results.

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