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CUTTING-EDGE FISH DRYER: FUZZY LOGIC-DRIVEN TEMPERATURE CONTROL

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Article Info

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Abstract

Fish is a highly sought-after food both domestically and internationally, renowned not only for its delectable taste but also for its health benefits, owing to its high protein content and low fat content compared to other animal protein sources. However, preserving fish and maintaining its quality poses challenges, as it is prone to rapid spoilage. Drying is one of the most effective methods for fish preservation, wherein the reduction and elimination of water content hinder the growth of microorganisms. Fish drying techniques can be classified into two types: traditional and modern. Traditional methods, employed by fishermen, often lack proper hygiene and may be harmful to the environment. On the other hand, modern approaches provide a more controlled and hygienic drying process.

The effectiveness of fish drying is significantly influenced by various factors, including temperature, airflow, desired moisture content, drying energy, and drying capacity. Rapid drying can lead to surface material damage, hindering proper air movement and causing hardening. To avoid such issues, temperature and time parameters need careful adjustment, typically set around 50 °C to 60 °C to maintain standard nutrition. Drying techniques can be categorized based on whether they utilize direct sunlight or not. The use of electric heaters in drying ovens is a viable option for controlling temperature. The overall drying process encompasses washing, drying, and cooling (airing) the raw materials, aiming for a desired water content of 40% according to SNI 2721.3:2009 to ensure prolonged fish storage.

In modern technological developments, the fuzzy logic control system has emerged as an alternative approach for optimizing the drying process. By implementing fuzzy logic, the drying process can achieve higher precision with minimal variations, resulting in dried fish of superior quality. Integrating fuzzy logic control enhances the efficiency of the drying process, providing a more robust and consistent outcome.

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1. Introduction

Fish is a food in great demand at home and abroad, and apart from its delicious taste, fish is also prevalent because of its health benefits. high protein content and lower fat content compared to other animal protein sources. However, the quality of fish is very easy to decline and spoil. One of the efforts to preserve processed fish so that it can be stored for a more extended period of time is by means of preservation. The purpose of preserving fish is to keep fish as long as possible by eliminating the causes of spoilage. There are various types of fish preservation, one of which is drying[1][2].

Fish drying has the principle of reducing and reducing the water content of the material so that the growth of microorganisms will stop and be inhibited. There are two types of fish dryers: traditional and modern. The fishermen generally still do the drying in the traditional way using simple tools that are negligent about hygiene which can harm the environment. It is still often seen that processors only spread the fish on an ancak (net rack) on the side of the road, making it less clean and hygienic[3]. In island and village areas, Fish drying is usually done on relatively clean bamboo or wood and large fish are dried by hanging or dried on the tiles [4].

Drying fish is strongly influenced by temperature, airflow, desired moisture content, drying energy, and drying capacity. Drying too fast can damage the surface material being dried so that it cannot be balanced with the speed of air moving to the surface material. In this case, rapid drying may cause the surface material to harden, prevent the air in the material from evaporating due to clogging, and using too high a temperature may damage the material. The temperature and time are adjusted depending on drying and heating (hot air or other means of heating), but considering standard nutrition, the temperature is set to 50 °C and 60 °C.[5][6].

We can distinguish the processes and tools needed in fish drying between direct sunlight and not using the sun, which lies in the source used. In this study we can use an electric heater as a temperature heater in the drying oven. The process includes washing, drying, and cooling (airing) raw materials as needed. According to SNI 2721.3:2009, the desired water content is 40% so that the dried fish can be stored for a long time [7].

The fuzzy logic control system is an alternative control system currently used in technological developments, one of which is in the drying process. By using fuzzy logic, drying must work perfectly with minimal variations in the drying process, so that the dried fish can be of good quality [8][9].

2. Literature Review

2.1. Drying

Drying is a process that uses heat energy to remove most of the water from the material. Drying can be done with sunlight (natural drying) and also with special tools that work with electricity. The process of drying materials depends on the surface of the material, drying temperature, airflow, steam pressure and the energy source used, as well as the type of material being dried[10].

The purpose of drying is to increase the shelf life, reduce shipping weight, improve the taste of food and maintain the nutritional content of these ingredients. In addition, the purpose of drying is to reduce the moisture content of the ingredients in such a way that the development of microorganisms and the activity of enzymes causing decomposition can be prevented or even stopped, so as to preserve the dried material [9].

Limit the moisture content of the material to 30% or at least 40% If the dryness of the material is not maintained after drying, the moisture content will rise to 50%, which can stimulate microbes [5].

2.2 . Dried Fish

Dried fish is a food product by reducing water so that it becomes dry. Dried fish is an attempt to avoid spoilage so that the fish has a longer shelf life. Fish that are processed into dried fish can be consumed and sold without fear of rotting and being thrown away[11].

Fig 1. Dried Fish

2.3. Indonesian National Standard for Dried Fish

The standard requirements for the quality of salted/dried fish based on the Indonesian National Standard (SNI) can be seen in the table below [5].

Table 1SNI Dried Fish

No	Test Type	Unit	Requirements
1	Organoleptik		
	Min value	Number (1-9)	Min 7
2	Cemaran mikroba		
	ALT	colonies/gram	Max 1,0x105^{5}
	Escherichia coli	APM/gram	Max < 3
	Salmonella*	/25 gram	Negatif
	Vibrio cholerae *	/25 gram	Negatif
	Staphylococcusaureus*	colonies/gram	1 x 103
3	Chemical *		
	Water	%mass fraction	Max 40
	Salt	%mass fraction	Max 20
	Ash is insoluble in acid	%mass fraction	Max 0,3

Note : *) If Necessary

2.4. Water Content

Moisture content is the water content of a material whether in the form of grains such as coffee, cocoa, rice or solid objects such as wood, soil, walls, concrete and other similar materials. In fact, measuring humidity does not only include the several materials mentioned above, but also many are not mentioned above Measuring the moisture content of materials can be done in various ways and methods. Several ways to measure the moisture content are: Determination of the moisture content of foodstuffs is usually based on wet weight and the following formula is used for the calculation:[12]

$$water\ content = \frac{w1-w2}{w2-w0}\ x\ 100\% \quad \text{.......... (1)}$$

2.5. Arduino Mega

Arduino is a microcontroller board produced by the intelligent design company Arduino developed by Massimo Banzi, this board is open source hardware whose main component is the Atmel AVR type microcontroller IC. The purpose of making Arduino is to make it easier for users to experiment or as an embodiment of a microcontroller device[13].

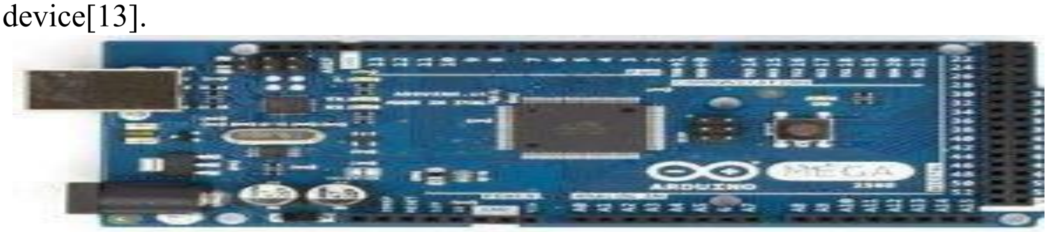

Fig 2. Arduino Mega

2.6. Thermocouple

Thermocouple is a type of temperature sensor used to sense or measure the temperature of two metal conductors joined together at the ends to create a "thermoelectric" effect. In 1982, Estonian physicist Thomas Johann Seebeck discovered the thermoelectric effect of the thermocouple, in which a metal conductor generates an electric voltage with a thermal differential gradient[14].

Fig 3. Thermocouple **2.7.**

Load Cell

load cell sensor is a sensor that detects the pressure and weight of a load. Load cell sensors are widely used as key components in digital weighing systems and can be applied to weighbridges used to measure the weight of trucks used to transport raw materials. Load sensors produce pressure in principle [15] [16] [17].

Fig 4. Load Cell **2.8.**

Solid State Relay

Solid State Relay or often abbreviated as SSR is an electromechanical switch with solid state characteristics. This single component is often used in industry as a control device. Solid State Relay (SSR) is the newest non-contact electronic switch, with advanced performance and performance[18].

Fig 5. Solid State Relay

2.9. Tubular Heater

Heating elements are devices that convert electrical energy into heat energy with Joule heat. The working principle of the heating element is that the current flowing through the element encounters resistance, thus producing heat[19].

Fig 6. Tubular Heater

2.10. Fan

To keep the room cool, fans regulate the amount of warm air and allow air to circulate normally. Fans are used in air conditioners, air fresheners, exhaust fans, or dryers (mainly heat-producing components). Fans are divided into two types according to the direction wind. , namely centrifugal fans (airflow in the direction of the fan axis) and axial fans (wind parallel to the air axis)[20].

Fig 7. Fan

2.11. Keypad

Keypads with lots of buttons and lots of functions, usually the ability to send data to the processor. Keypads are found in cell phones, calculators, home phones, and many other things. On mobile phones, a single button press usually sends information as a number, and multiple presses send information as characters. When the Arduino keypad is used as input and data is sent to Arduino to be read, Arduino executes commands based on the buttons pressed[21].

Fig 8. Keypad **2.12.**

Arduino IDE

Arduino Integrated Development Environment (IDE) is a software for creating programs and entering them into the microcontroller. The program created using the Arduino IDE software is an illustration of the design to be made. Arduino IDE is used to help users for programming[22].

3. Method

3.1. Fish Dryer System Design

Manufacture of fish dryer with dimensions of length 69 cm, width 72 cm, height 80 cm. The tool body is made of aluminium plate which is coated with plywood on the outside and at the top there is a 12 volt fan box which functions as a source of air flow in the drying process and the air is directed through the air inlet pipe.

The control circuit consists of several main components, namely LCD 16x2, Arduino, jumper cables and relays. Temperature sensors in the form of a type-k thermocouple are placed in the drying chamber and are used to detect changes during the drying process. dried according to a predetermined value.

The sensor is then connected to Arduino. the code that is input to Arduino in the control programming contains the set point of the drying input, namely 50°C and 60 °C which are loaded in fuzzy logic. The programming application used for coding the controller is the Arduino Mega application. **3.2. Dryer Design Circuit**

The overall circuit in the fish dryer, namely among them is the type k thermocouple sensor, as a temperature detector, the Load Cell sensor as a scale on the object being dried, the LCD used with I2c functions to display the results from the type k thermocouple sensor input and the Load Cell sensor, heater as a room heater in the oven, 12V fan as a temperature decoder and as a cooler in the oven, SSR as on/of. The overall circuit image can be seen in the image below:.

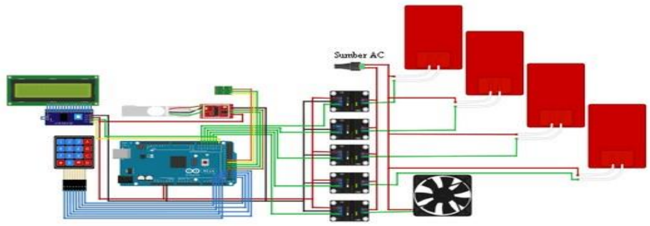

Fig 9. Design Circuit

3.3. Fuzzy Logic

The problems in this study can be simplified by using the fuzzy logic method, using 2 input variable and 1 output variable. a. Variable Input Temperature

The temperature input variable is divided into 3 types which can be seen in the table below:

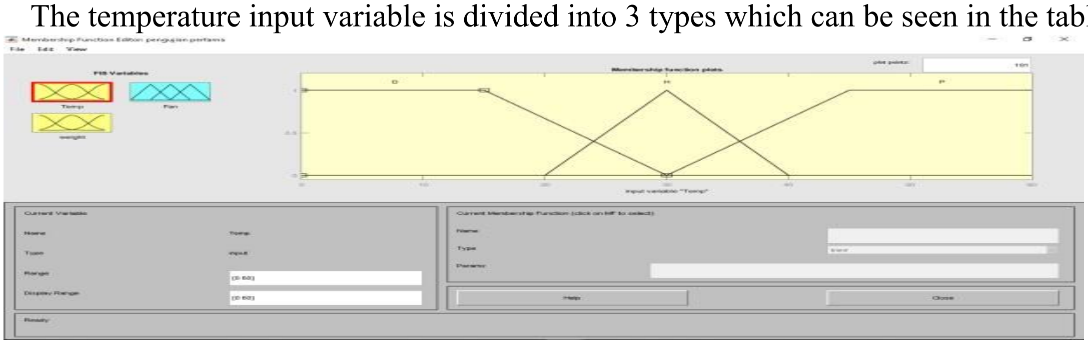

Fig 10. Variable Input Temperature b.

Variable Input weight

The weight input variable is divided into 3 types which can be seen in the table below

Fig 11. Variable Input weight c.

Variable Output fan

The fan output variable is divided into 3 types which can be seen in the table below

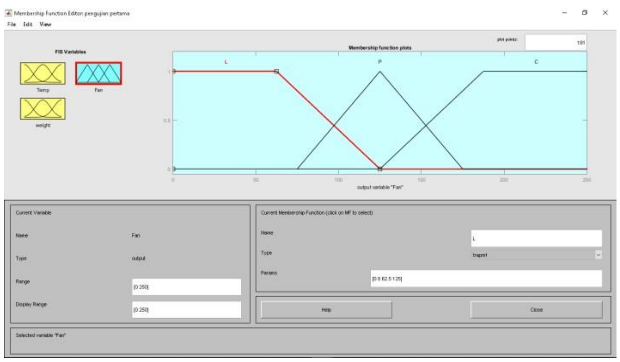

Fig 12. Variable Output Fan

3.4. Rule Based

From some of the input obtained, a rule is established that will produce a decision. This decision will result in several rules for temperature control in fish drying ovens. Here are some fuzzy control rules for drying ovens:.

If (Temperature is D) and (Weight is R) then (Fan is P) (1)
If (Temperature is D) and (Weight is B) then (Fan is M) (1)
If (Temperature is D) and (Weight is SB) then (Fan is M) (1)
If (Temperature is H) and (Weight is R) then (Fan is C) (1)
If (Temperature is H) and (Weight is B) then (Fan is P) (1)
If (Temperature is H) and (Weight is SB) then (Fan is M) (1)
If (Temperature is P) and (Weight is R) then (Fan is C) (1)
If (Temperature is P) and (Weight is B) then (Fan is P) (1)
If (Temperature is P) and (Weight is SB) then (Fan is M) (1)

4. Results and Discussion

4.1. Fish Dryer Design Results

Based on the results of this final project research, a fish dryer was produced with temperature control using the fuzzy logic method. The shape of the results of making the tool can be seen in Figure 4.1 where the tool length is 72 cm, 80 cm high, and 69 cm wide. Above the drying oven there is a control box.

Fig 13. Fish Dryer Design Results

The fish drying oven is made of aluminium plate covered with wood with the specifications described. There is a hole on the side of the oven to circulate air from the drying chamber and blow air through a pipe channel using a 220V AC fan. The fish dryer is equipped with an overhead control box which contains a microcontroller circuit. Inside the control box there is a 16x2 LCD which is used to provide information as shown in the Figure below.

The LCD displays information such as temperature monitoring, weight and fan Pwm. Next to the LCD there is a keypad that can be used to set the type of control used and the desired temperature set point.

4.2. Fuzzy Control System Test Results

Fuzzy control drying is carried out by adjusting the set temperature to 50 ℃ and 60 ℃. The test result data can be seen in the result data graph and shown in Figure 4.2. This graph displays temperature and current readings every 5 seconds for 30 minutes.

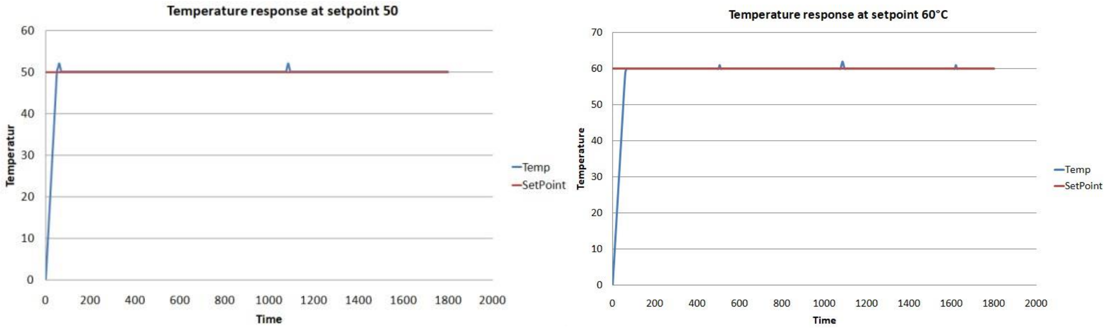

Fig 14. Fuzzy control system Test Results Temperature 50°C and 60°C

For fuzzy control and drying conditions with a temperature setpoint of 50 °C, the maximum temperature reached is 52 °C. This condition is a temperature change that is quite high from the set point temperature. This is possible because the dryer is designed to use a high temperature heat source heater, which is not optimal for use at low temperatures, but has a minimum temperature of 26°C and an average temperature in the drying chamber of 49.26°C. is. With a temperature control set point of 60°C, the minimum temperature achieved is 24.4°C, the maximum temperature is 62°C, and the average temperature in the drying chamber is 55.5°C. Based on the graphical analysis above, the temperature setpoint for fuzzy controlled drying is 50°C, which has quite a large temperature variation compared to the temperature setpoint of 60°C.

4.2. Fish Drying Test

Table 2 Fish drying test with a set point temperature of 50°C

Time (m)	Temperature (°C)	Set point (°C)	Weight (g)	Wind speed (m/s)	Differ-ence	Error (%)
0	49°C		500g		1	0,02%
10	49°C		486g		1	0,02%
20	49°C		472g		1	0,02%
30	49°C		458g		1	0,02%
40	49°C		444g		1	0,02%
50	50°C		430g		0	0,00%
60	52°C		416g		2	0,04%
70	51°C		402g		1	0,02%
80	50°C		388g		0	0,00%
90	49°C	50°C	375g	1.5 - 2 m/s	1	0,02%
100	49°C		361g		1	0,02%
110	49°C		347g		1	0,02%
120	50°C		333g		0	0,00%
130	49°C		319g		1	0,02%
140	49°C		305g		1	0,02%
150	50°C		291g		0	0,00%
160	50°C		277g		0	0,00%
170	50°C		263g		0	0,00%

180	50°C	250g	0	0,00%
			Rata - Rata Error =	0,01%

From the results of testing the fish dryer with a temperature set at 50°C, the average percentage error value that is read is 0.1%, so that the value read by the sensor can work optimally.

Table 3. Fish drying test with a set point temperature of 60°C

Time (m)	Tem- perature (°C)	Set point (°C)	Weight (g)	Wind speed (m/s)	Difference	Error (%)
0	59°C		500		1	0,02%
10	59°C		485		1	0,02%
20	59°C		485		1	0,02%
30	59°C		470		1	0,02%
40	59°C		455		1	0,02%
50	60°C		440		0	0,00%
60	62°C		425		2	0,03%
70	61°C		410		1	0,02%
80	60°C		395		0	0,00%
90	59°C	60°C	380	1.5 - 2 m/s	1	0,02%
100	59°C		365		1	0,02%
110	59°C		350		1	0,02%
120	60°C		335		0	0,00%
130	59°C		320		1	0,02%
140	59°C		305		1	0,02%
150	60°C		290		0	0,00%
160	60°C		275		0	0,00%
170	60°C		260		0	0,00%
180	60°C		245		0	0,00%
				Rata - Rata Error =		0,01%

From the results of testing the fish dryer with a temperature set at 60°C, the average percentage error value that is read is 0.1%, so that the value read by the sensor can work optimally.

5. Conclusion

Based on the results and discussion of the system that has been made, several conclusions are obtained, namely: The design of the fish dryer works according to the design designed. The results of the drying test were carried out by testing 2 times with different temperature settings. These results indicate that drying fish at 50°C for 3 hours resulted in a decrease in fish weight of 13% per 10 minutes and a final moisture content of 30% with a temperature error rate with a setpoint temperature of 0.01%. and for a temperature setpoint of 60°C the weight of the fish decreased by 15% per 10 minutes and the final water content in the fish was 27%, the temperature error rate with a temperature setpoint of 0.01%.

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