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Arduino-Based Banana Sale Dehydrator Design

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Abstract— **One of the most profitable processed banana products is banana sale. To produce high quality banana sale, an effective and consistent drying process is essential. The purpose of this research is to create and build an Arduino microcontroller-based banana dehydrator that can optimize the drying process. It is equipped with a temperature and humidity sensor (DHT22) to track the environmental conditions inside the dehydrator. In addition, heating elements and fans are equipped to control air circulation and temperature. The designing starts with creating a comprehensive system design. This includes the system block design, electronic circuit schematics, as well as the physical design of the device itself. An Arduino program is designed to use data from the temperature and humidity sensors to control the heating elements and fans, ensuring an ideal drying environment. Intensive testing was conducted to ensure that the device operates properly and can achieve optimal drying conditions for banana sale. The test results show that the dehydrator is able to dry banana plantains with higher efficiency, maintaining the temperature and humidity inside the device within the desired parameters. In addition, it also improves the quality of the final product consistently. It provides a more efficient and affordable solution for small and medium entrepreneurs in the banana processing industry. Therefore, it is expected that this tool will help increase production, reduce operational costs, and improve the quality of banana sales throughout Indonesia.**

Keywords— **Banana Sale; Dehydrator; Arduino; Temperature Sensor; Humidity; Drying**

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I. INTRODUCTION

Banana sale is one of the processed banana products that has high economic value in various regions in Indonesia. Banana sale is usually produced through the drying process of ripe bananas, where proper drying is the key to producing a high-quality product. A quality banana sale is characterized by a soft texture, a distinctive sweet taste, and a longer shelf life. However, a non-optimal drying process can result in a product that is not up to standard, such as a texture that is too hard or even too mushy, as well as undesirable flavor changes [1].

Traditional drying methods, which are generally carried out by utilizing direct sunlight, often face various challenges. One of the main obstacles is the dependence on weather conditions, where the drying process can be hampered if the weather is cloudy or rainy. In addition, this method takes a considerable amount of time and does not always result in consistent temperature and humidity during the drying process. This often leads to variable and inconsistent end results, which in turn can affect the quality of the banana sale product produced.

The design of this tool is intended to meet the needs of the home industry to small and medium scale. With affordable cost and relatively simple technology, this tool is expected to be operated by anyone, including those with limited technical knowledge. It is expected that the use of this tool will improve the quality of banana sale products, speed up the drying process, provide better control to producers in managing their production. It is also expected to grow better, increase the competitiveness of local products, and provide greater economic benefits to the community.

In order to improve efficiency and consistency in the drying process, technological innovations are needed that can provide better control over temperature and humidity during the production process. Therefore, “Designing an Arduino-based Sale Banana Dehydrator” is a promising solution. Arduino, as a flexible and easy-to-use microcontroller, allows the integration of various sensors and actuators needed to regulate the conditions inside the dehydrator automatically and in real-time.

By using temperature and humidity sensors connected to the Arduino, users can monitor and control drying conditions more accurately. This allows the drying process to run more efficiently, reduces dependence on weather conditions, and minimizes variability in the end result. In addition, the use of this technology can also help reduce the time required for the drying process, thus speeding up the production of banana sale.

II. THE MATERIALS AND METHOD

Components and Software:

A. DHT 22 Sensor

The DHT22 module is a combined sensor of a temperature sensor and a humidity sensor. The DHT22 sensor has a calibrated digital output. This sensor has an accurate calibration with room temperature compensation adjustment with coefficient values stored in the integrated OTP memory. The DHT22 sensor has a wide temperature and humidity measurement range. In the DHT22 module there are NTC temperature sensor components (thermistors) and ICs on the back side of the sensor.

The DHT22 sensor as shown below with type AM2302 has a sampling of 0.5 Hz or one reading every two seconds. The operating voltage is 3 to 5 volts and the maximum current used is 2.5 mA. The measurement range of the DHT22 sensor is -40˚C to 80˚C with an accuracy level of ±0.5˚C then for temperatures 0 to 100% with an accuracy level of ±5˚C. More complete specifications are described in Table 2.2, one of which is that the DHT sensor has an accuracy level of ±2%; for humidity and ±0.2˚ for temperature [2]

B. LCD (Liquid Crystal Display) 16 x 2

Liquid Cristal Display (LCD) is an electronic component used to display characters, writings and letters, LCD uses liquid crystals as the main viewer. In the LCD module there is a microcontroller that functions as a character display controller equipped with memory and registers. The LCD module also has pins, one of which functions for the path to provide character data that you want to display. The picture below is an LCD (Liquid Crystal Display) [3].

C. I2C module (Inter Integrated Circuit)

Using I2C Serial on the LCD can save the number of pins available in the Arduino and make the programming sketch simple and can keep the LCD from being damaged quickly. Below is an image of the I2C (Inter Integrated Circuit) Module [3].

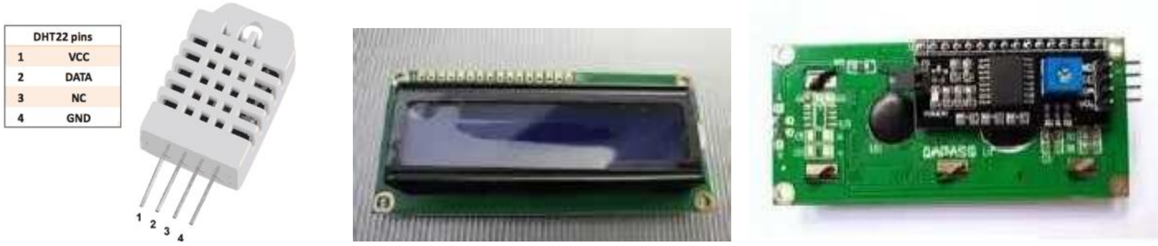

FIGURE 1. A. DHT22 Sensor. B. LCD C. I2C Module

D. Relay

Relays are electromechanical devices that use electric current to open or close switch contacts. The module consists of components that facilitate switching and connecting and act as indicators to show whether the module is powered and whether the relay is active or not. When current flows the relay coil will close (on) or open (off) due to the magnetic induction effect caused by the coil (inductance). Briefly, electromechanical relays are defined as devices that use electromagnetic forces to mechanically open and close switching contacts with electric power or electrical energy. Relays as electronic components have an important role in electronic circuit systems and circuits to operate devices that require large currents without being directly connected to small current regulating devices. This allows the relay to function as a safety device.

E. Arduino Uno

Arduino is an opensource electronic prototyping hardware platform based on flexible and easy-to-use hardware and software. Arduino is intended for artists, designers, and anyone interested in creating interactive objects or environments. Arduino boards usually have a base chip Atmel AVR ATmega8 microcontroller and its derivatives. The arduino programming language is a common programming language used to create software that is embedded in the arduino board. The arduino programming language is similar to the C++ programming language [4].

Arduino Uno in the picture above is an Arduino board that uses the ATmega328 microcontroller. In Table 2.2 it is explained that the Arduino Uno has 14 digital pins (6 pins can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a voltage source connector, an ICSP header, and a reset button. The Arduino Uno has a wide coverage area for everything needed to support a microcontroller-based application. Just connecting it to a computer via USB or providing DC voltage from a battery or AC to DC adapter can make the application work. Arduino Uno uses ATmega16U2 which is programmed as a USB-to-serial converter for serial communication to a computer via a USB port [5].

F. Axial Fan

Axial Fan is a tool that functions to produce gas fluid flow in the direction of the fan's work shaft. Axial Fans are fans that are widely used in everyday life and are the most widely used because of their ease of design and more economical prices than other types of fans. Axial fans have a design that is not too complicated and can produce large flow. Axial Fans are usually used as CPU coolers, motor vehicle engines and are also widely used in the industrial world. One of them is used in steam power plants as a Secondary Air Fan [6].

FIGURE 2. D. Relay. EArduino Uno. F. Axial Fan

G. Heating Elements

Electrical Heating Element is widely used in everyday life, both in households and industrial equipment and machinery. The heating element is a tool that functions as one of the work activities to get the temperature from the low temperature of a substance to a high temperature. As a source of heat generated by this electric heating element, it comes from a wire or tape with high electrical resistance (Resistance Wire), usually the material used is a niklin wire which is rolled up like a spiral shape and inserted in a sleeve / pipe as a protector, then electrified at both ends and coated by an electrical insulator that is able to transmit heat well until it is safe to use [7].

H. SPST Switches

SPST switch is a Single-Pole Single-Throw switch or a single pole and single motion switch. This is the simplest switch, it only has 2 terminals where 1 terminal is used for incoming electric current and 1 terminal for outgoing electric current. This switch has a single movement in it, when no actuation is given, the switch is in one state, and when given actuation it will move to another state. This is a commonly used and very simple switch because it is usually used to control a single circuit [8].

I. Push Button Momentary

Push Button (PB) / Push Button Switch is a component that functions to connect and disconnect an electricity flow by pressing and releasing. Push Button is widely used in control circuits, because this component is one of the important components in a control system for signaling. The word momentary can be interpreted as momentary. So a Push Button that operates momentary can be interpreted that the Push Button works only for a moment when pressed [9].

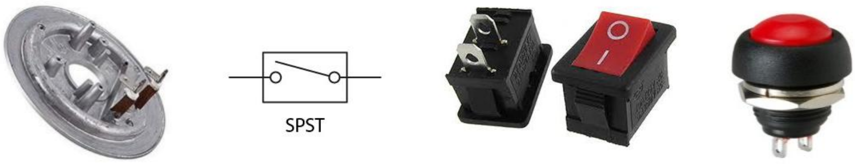

FIGURE 3. G. Electrical Heating Element. H.SPST Switches. I. Push Button Momentary

J. Software Mikrokontroller Arduino Ide

The Arduino software used is the driver and IDE, although there are still several other software that are very useful during Arduino development. Integrated Development Environment (IDE), a special program for a computer in order to create a program design or sketch for the Arduino board. The arduino IDE is a very sophisticated software written using java. Arduino Program code is commonly called a sketch and is made using the C programming language. Programs or sketches that have been written in the Arduino IDE can be directly compiled and uploaded to the Arduino Board.

In general, the program structure in the Arduino IDE is divided into two parts, namely setup and loop. The setup section is the area where the system initialization codes are placed before entering the loop (body) section. In principle, the setup is a part that is executed only once, namely when the program starts (start), while the loop section is the part that is the main core of the Arduino program. And this part is executed continuously. The following are the toolbar buttons and their functions [10].

Designing:

A. System Block Diagram

The design of the tool is done first to help and facilitate working on the tool, before entering the tool making stage. Tool planning starts from making a Block Diagram, where each block has an interrelated function that forms a system of tools made such as hardware and software design. After the tool design stage is complete, the next tool manufacturing stage can be carried out.

B. Hardware Design

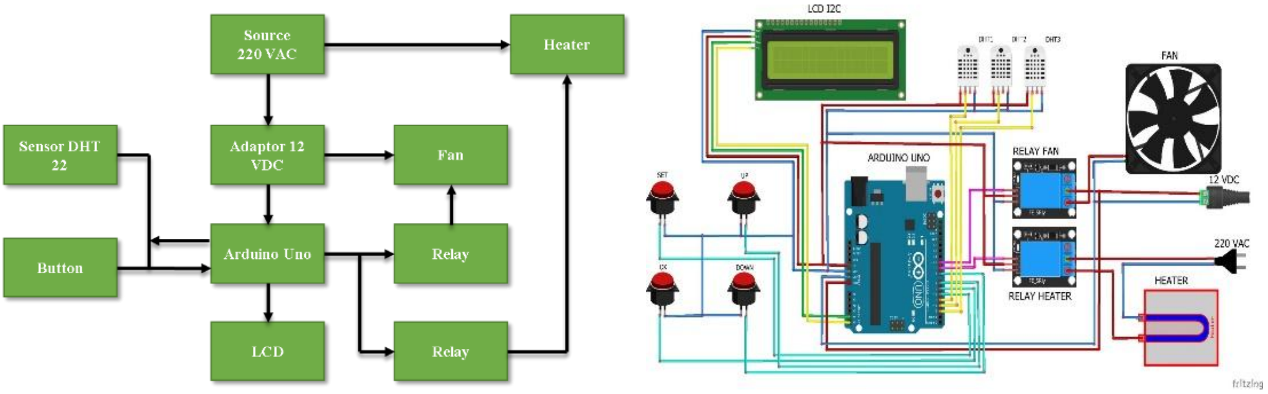

FIGURE 4. A. System Block Diagram B. Wiring Diagram Hardware

C. Software Design and System

Software serves to control the work of a hardware (hardware) in a system. At this stage it can be explained about how the work steps of the Arduino-based Banana Sale Dehydrator Tool Design, more details can be seen in the flowchart.

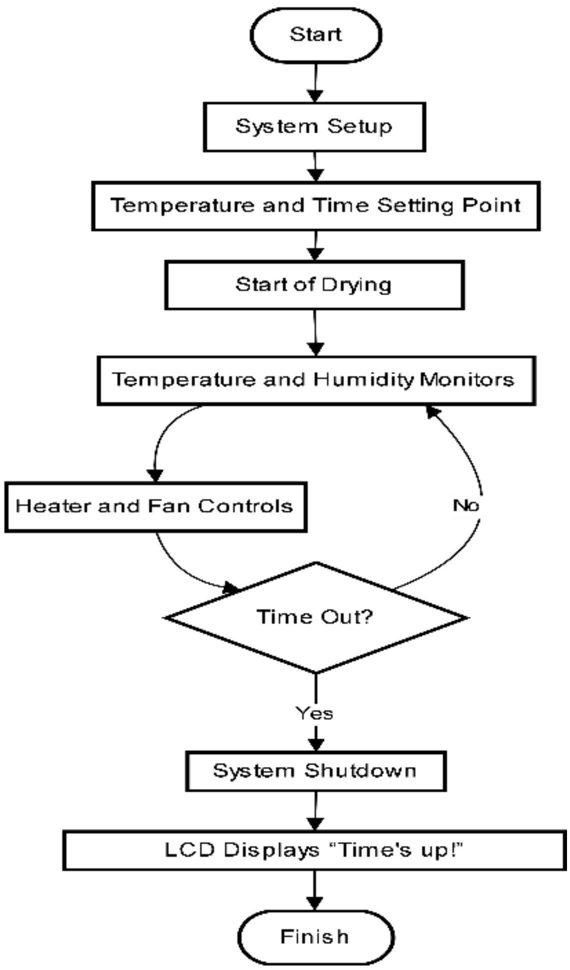

FIGURE 5. Flowchart System

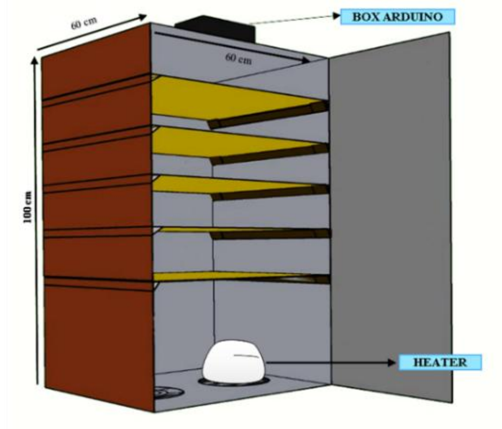

FIGURE 6. Box Front View

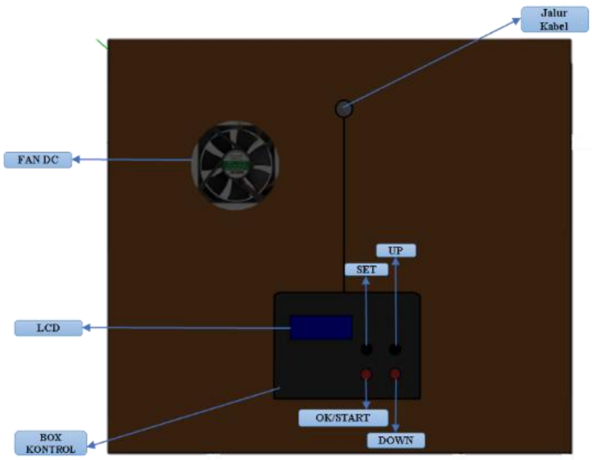

FIGURE 7 Box Top View

D. Mechanical Design of Dryer Box

This banana sale dryer is made in the form of a box with an overall size of 60 cm long, 60 cm wide and 100 cm high. At the top there is a controller box as the control center. On the inside of this controller box there is an Arduino, and a relay. On the outside of the top there is a setting button and LCD. At the top of this tool there is 1 DC fan that functions to reduce the heat temperature. At the bottom of the dryer box there are 2 heaters and there are 3 DHT22 sensors. The mechanical design form of the banana sale dryer can be seen in the following figure.

III. RESULTS AND DISCUSSION

A. DHT22 Sensor Testing

TABLE I
DHT 22 sensor specifications 1

DHT22 Sensor Num	Working Voltage (VDC)	Input Voltage (VDC)
1	3 - 5	4,90
2	3 - 5	4,83
3	3 - 5	4,91

TABLE II
DHT 22 Sensor Specifications 2

Num	Temperature Readings Measuring Instrument (ºC)	Readings DHT22 Temperature (ºC)	Temperature Difference (ºC)	Temperature Average (ºC)	Percentage of Temperature Difference (%)
1	85,5	81,2	4,3	83,35	5.03
2	86,3	81,0	5,3	83,65	6.14
3	89,8	80,7	9,1	85,25	10.13
4	89,2	80,9	8,3	85,05	9.31
5	87,9	79,1	8,8	83,50	10.01
6	89,5	79,6	9,9	84,55	11.07
7	87,9	79,4	8,5	83,65	9.67
Overall Averages				84,00	8,77

The results of testing the DHT22 sensor at a temperature setpoint of 80 ºC provide important data regarding the accuracy and reliability of this sensor in controlling temperature during the drying process. In the dehydration process of banana sale, maintaining a stable temperature in accordance with the setpoint is crucial to ensure the final product has the desired quality, both in terms of texture and flavor. Tests showed that the DHT22 sensor, used as part of the temperature control system in the Arduino-based dehydrator, recorded an average temperature of 84.00 ºC. Although this temperature is slightly higher than the expected setpoint (80 ºC), this difference is still acceptable. The percentage difference in average temperature of 8.77% indicates a variation that needs to be considered, but this is still within acceptable limits for drying applications, where slight fluctuations in temperature will not significantly affect the quality of the banana sale.

Thus, the DHT22 sensor proved to be reliable enough to be used in the design of the Arduino-based banana sale dehydrator. The use of this sensor in an Arduino-based system allows for automation and efficient temperature control, which is crucial in improving productivity and quality of the final product in a small industry or home-based business producing banana sale.

B. Push Button Testing

TABLE III
Push Button Testing

`Num	Button	Function	Testing	Results
1	Set	To enter the settings menu such as temperature and time setpoints.	The Set button is pressed and the device successfully displays the settings menu on the LCD screen.	The button works well, the device responds by displaying the settings menu.
2	Ok	To confirm the selection and save the settings, and return to the main operation mode.	The Ok button is pressed and the tool successfully saves the settings and returns to the main operation mode.	The button works fine, the settings are saved and the tool returns to the main menu.
3	Up	To raise the temperature and time setpoint values.	The Up button is pressed and the value on the LCD screen successfully changes as desired.	The button works well, the value on the screen increases when the button is pressed.
4	Down	To lower the temperature and time setpoint values.	The Down button is pressed and the value on the LCD screen successfully changes as desired.	The button works well, the value on the screen decreases when the button is pressed.

From the test results, all buttons functioned properly. The “Set” button successfully brings up the settings menu to set the temperature and time, as desired. The “Ok” button works well to save the settings and return to the main operating mode. The “Up” and “Down” buttons also work perfectly in changing the setting values displayed on the screen.

All buttons respond quickly each time they are pressed, without any issues or delays. Overall, the button system on this tool has been tested and found to work well, supporting the operation of the tool perfectly. No repairs are required as all buttons are functioning as expected.

C. Relay Testing Results

1. *Relay Testing Results for Heater*: The heater is set to maintain the temperature inside the dehydrator according to the value at the setting point, with a slight tolerance drop of about 1 °C. This means that the relay will turn on the heater if the temperature is below the setting point value plus the tolerance value and will turn off when the temperature reaches the setting point value. If the setting point is 70 °C then the relay will turn on the heater at 69 °C and will turn it off at 70 °C. The relay successfully turns on the heater when the temperature drops below 69 °C and turns it off when the temperature reaches 70 °C. During the 2 and 3 hour tests, the average temperature inside the dehydrator chamber was stable with little fluctuation.

TABLE IV
Relay Testing Results For Heater

Setting Point Temperature	Duration	Lowest Temperature	Highest Temperature	Average Time of Temperature Stabilization	Description
70 °C	2 and 3 Hours	69,1 °C	71,6 °C	2 minutes	The temperature fluctuates up and down
80 °C	2 and 3 Hours	79,0 °C	81,7 °C	2 minutes	The temperature fluctuates up and down
90 °C	2 and 3 Hours	88,8 °C	91,7 °C	2 minutes	The temperature fluctuates up and down

2. *Relay Testing Results for Fan*: The Fan function is set to suck hot air out of the dehydrator chamber when the temperature reaches the setting point value, so that the temperature is maintained according to the setting point value. The relay starts to turn on the Fan when the temperature reaches the setting point value and will turn off when the temperature drops back below 70 °C. plus the tolerance value. The fan works effectively in preventing the temperature inside the dehydrator from getting too hot or keeping the temperature stable.

TABLE V
Relay Testing Results For Fan

Setting Point Temperature	Duration	Lowest Temperature	Highest Temperature	Average Time of Temperature Stabilization	Description
70 °C	2 and 3 Hours	69,1 °C	71,6 °C	Active when the temperature is > 70 °C	Effective, keeping the temperature within the regulated range
80 °C	2 and 3 Hours	79,0 °C	81,7 °C	Active when the temperature is > 80 °C	Effective, keeping the temperature within the regulated range
90 °C	2 and 3 Hours	88,8 °C	91,7 °C	Active when the temperature is > 90 °C	Effective, keeping the temperature within the regulated range

D. Testing Tools for Drying Bananas

1. *Testing at 70 °C*: At 70 °C, banana drying takes between 2 and 3 hours. The bananas initially weigh about 9 grams, with a humidity of 81.20%. After drying, the weight was reduced to between 1 and 4 grams, and the moisture dropped to 11.8% to 15.1%. At this temperature, the bananas were only completely dry after 3 hours, indicating that the process works quite well but takes longer than with higher temperatures. The average weight loss was 77.43% and the average moisture loss was 83.93%.

TABLE VI
The Results of Banana Drying Tests at 70 Degrees Celcius

Number	Temperatures (°C)	Duration (Hour)	Weight (Gram)		Moisture (%)		Banana Condition
			Beginning	End	Beginning	End	
1	70	2	9	3	81,20	15,1	Still wet
	70	2	9	4	81,20	15,1	Still wet
2	70	3	8	1	81,20	11,8	Dry

	70	3	7	0	81,20	11,8	Dry
Average			77,43%		83,93%		

2. *Testing at 80 °C*: At 80 °C, the bananas dry out slightly faster. Within 2 to 3 hours, the weight of the bananas drops from 9-11 grams to 1-4 grams, and the moisture is reduced to 8.3% to 10.5%. At this temperature, the bananas were dry after 3 hours, indicating that 80 °C is more efficient than 70 °C. The average weight loss was 69.69% and the average moisture loss was 88.04%.

TABLE VII
The Results of Banana Drying Tests at 80 Degrees Celcius

Number	Temperatures (°C)	Duration (Hour)	Weight (Gram)		Moisture (%)		Banana Condition
			Beginning	End	Beginning	End	
1	80	2	9	4	82,00	10,5	Still wet
	80	2	11	5	82,00	10,5	Still wet
2	80	3	9	2	82,00	8,3	Dry
	80	3	9	1	82,00	8,3	Dry
Average			69,69%		88,04%		

3. *Testing at 90 °C*: At 90 °C, the bananas dry much faster, taking only 2 hours to dry completely. The weight of the bananas drops from 7-9 grams to 1-2 grams, with a final moisture between 7.9% and 8.8%. This temperature proved to be the most effective as the bananas dried in the shortest amount of time. The average weight loss was 83.73% and the average moisture loss was 89.81%. From the test results, it can be seen that the higher the temperature, the faster the bananas dried and the greater the moisture loss. A temperature of 90 °C is most effective for fast drying, making it a good choice if drying speed is a priority. However, it is important to consider the impact of high temperatures on the final quality of the sale bananas, such as possible changes in texture and flavor that may not be as desirable. This Arduino-based dehydrator successfully demonstrates its ability to control temperature and dry banana sale effectively. The Arduino allows for more precise temperature settings, so that drying can be tailored to specific needs. These results provide a strong basis for further development of this device in other food drying applications.

TABLE VIII
The Results of Banana Drying Tests at 90 Degrees Celcius

Number	Temperatures (°C)	Duration (Hour)	Weight (Gram)		Moisture (%)		Banana Condition
			Beginning	End	Beginning	End	
1	80	2	9	4	82,00	10,5	Still wet
	80	2	11	5	82,00	10,5	Still wet
2	80	3	9	2	82,00	8,3	Dry
	80	3	9	1	82,00	8,3	Dry
Average			69,69%		88,04%		

4. *Production Capacity*: The dehydrator used in this study consisted of 5 containers arranged in tiers, which allows for greater capacity to efficiently dry bananas. With each container capable of holding a portion of 3 sweet banana slices in a single production run, the drying process becomes more even due to the distribution of bananas across the different levels of the container. This also allows hot air and moisture flow to circulate effectively within the appliance. Each container will play an important role in keeping all the bananas exposed to sufficient heat without overlapping, so that the quality of the final product, the banana sale, is maintained. With this design, the drying time can be shortened as the heat reaches all the bananas more evenly. The regulated temperature and time of the device will also ensure that the bananas in each container are dried with good consistency. This analysis shows that the use of 5 containers in the dehydrator not only increases the production capacity, but also the efficiency in the drying process of the sale bananas.

E. Power Consumption and Electricity Costs

TABLE IX
The Distribution of Power Consumption and Electricity Costs Based on Different Temperature Settings

Number	Temperatures (°C)	Heater Power (Watt)	Duration (Hour)	Power Consumption (kWh)	Electricity Cost (Rp)
1	70	792	1	0.792	1.071

2	70	792	2	1.584	2.143
3	70	792	3	2.376	3.214
4	80	792	1	0.792	1.071
5	80	792	2	1.584	2.143
6	80	792	3	2.376	3.214
7	90	792	1	0.792	1.071
8	90	792	2	1.584	2.143
9	90	792	3	2.376	3.214

Description:

- Heater Power (Watts): 792 watts based on a current of 3.6 Amperes at a voltage of 220 volts.
- Duration of Use (Hours): Variation of usage time to see power consumption.
- Power Consumption (kWh): Calculated by the formula (Power (Watt) × Time (Hour) / 1000.
- Electricity Cost (Rp): Calculated at a price of Rp 1,352. every 1 kWh.

Based on the results of testing the heater power consumption at temperatures of 70 °C, 80 °C, and 90 °C. The heater power consumption is stable at each temperature tested. This is because the heater's power depends on its current and voltage specifications, which are 3.6 amperes at 220 volts, resulting in 792 watts of power. Thus, even though the temperature produced is different, the power consumption per hour remains the same, at 0.792 kWh. The duration of heater use has a direct impact on power consumption and electricity costs. The longer the heater is used, the greater the power consumption. For example, in 1 hour of use, the power consumption reaches 0.792 kWh at a cost of around Rp 1,071. If the heater is used for 3 hours, the power consumption will be 2.376 kWh with an electricity cost of around Rp 3,214.

At lower temperatures such as 70 °C, the drying process may take longer, although the power consumption per hour remains the same. On the other hand, higher temperatures can speed up the drying process. Too high a temperature, however, risks damaging the product quality, despite saving time. Therefore, 90 °C seems to be the ideal choice, as it provides a faster drying time without significantly affecting the quality of the bananas. For optimal drying of sale bananas, a temperature of 00°C can be considered the best option. This temperature is quite efficient in terms of power consumption and cost, while maintaining the quality of the final product.

I. Conclusion

The device for drying sale bananas has been successfully built as planned, covering all important aspects from the drying method to the temperature and time settings. Components such as DHT22 sensors, relays, and other materials were well chosen, supporting the device's more efficient performance compared to traditional methods, requiring only 3 hours of drying. The use of Arduino was effective in automatically controlling the temperature and time, with 90 °C proving the most optimal, drying the bananas in 2 hours. At this temperature, the weight of the bananas dropped significantly from 7-9 grams to 1-2 grams, with a moisture reduction of 7.9% to 8.8%. The average weight loss of 83.73% and humidity of 89.81% indicated high efficiency in the drying process. Implications for further research include optimization of drying temperature and time for different types of fruits, as well as integration of more advanced technologies such as IoT-based control systems for remote monitoring and increased automation, which can improve productivity and industrial scale.

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