Temperature Monitoring Based on Internet of Things in Ribbed Smoke Sheet Fumigation

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Abstract. Ribbed Smoked Sheet (RSS) is processed latex in the sheet used as raw material for various rubber industries. In the RSS industries, the factor that significantly affects the quality of the final product is the smoke-drying process, and therefore enterprises must carefully monitor this process. This study aims to design an IoT-based device for monitoring the temperature of the RSS smoking room and increase work effectiveness and efficiency after the monitoring device is available. This study uses black box testing as a performance test equipped with compatible hardware and software. System testing and data analysis include performance tests, monitoring devices implementation, and work effectiveness and efficiency. The validation results showed that the designed device had functioned well. Implementing monitoring devices for smoking room temperature can increase the efficiency of monitoring time carried out by workers by 78.83%. The value of RSS quality also increased by 120% to 133% after implementing the devices, which means it is very effective.

Keywords: efficiency; IoT; ribbed smoked sheet; smoke drying process; temperature monitoring system

1 Introduction

Indonesia is the second-largest natural rubber producer in the world (Virginia & Novianti, 2020). One of the natural rubbers processed products with high economic value is Ribbed Smoked Sheet, commonly known as RSS. It is made directly from latex, which is treated and then made to coagulate. The coagulated latex sheets smoked in a drying room (Morshed et al., 2018; RRIS 2013)). RSS has high elasticity properties, so it's popularly used as raw materials for various rubber industries (Azahar et al., 2016).

One of the critical factors affecting the final quality of RSS is the smoking or drying process. The primary purpose of the smoking process is to eliminate the rubber sheet's moisture content so that it can be stored longer. The smoke also acts as a disinfectant, which renders the rubber sheet less liable to mold attack (Fagbemi et al., 2018).

During this smoking process, fresh rubber sheets were produced from squeezing coagulated rubber slabs and dried in rubber sheet smoke rooms in a smokehouse using old rubberwood or firewood as a source of heat and smoke (Naphon et al., 2018). The Smoking process is done by hanging rubber sheets and given smoke with temperature control of 40 - 60° C for six days (Ediati & Jajang, 2010).

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Improper smoking will cause product defects, such as blisters and bubbles on the sheet, or even burnt and oxidized sheet, caused by high drying temperature or rapid drying in the smokehouse. It is necessary to regulate and monitor the drying temperature to keep this process running properly (Fagbemi et al., 2018). The temperature monitoring process in the smoking room in many RSS industries in Indonesia is carried out by workers manually by checking the smoking-room one by one.

Filling the datasheet is done manually once an hour so that the monitoring time for each room takes longer for each room. The temperature monitoring device used so far is relatively simple using an LCD monitor. This device forces workers to check the temperature number on the monitor LCD with a close-range of sight, which causes worker fatigue.

Meanwhile, it is difficult for supervisors to monitor and supervise the worker's performance in the smoking room if there is an incident where the smoking room does not comply with the standard.

Based on these problems, an IoT-based temperature monitoring device is needed that is easy, efficient, and effective and shows real-time and accurate room temperature data to make it easier for supervision from supervisors and workers in the smoking-room location. IoT is a technology that can be used for control, communication, interaction with various hardware devices, and data sent over the internet network (Bernard & Quigley, 2019). This study aims to design an IoT-based RSS smoking-room temperature monitoring device and determine the increase in work efficiency and effectiveness after the monitoring device is in place. The research was conducted at Kebun Sumber Tengah PTPN XII.

2 Research Methods

2.1 Research Design

This research uses hardware in the form of a DHT22 temperature sensor, NodeMCU ESP8266, used as a microcontroller, smartphone OS Android is a monitoring tool. An LED light is used as a temperature warning indicator. In contrast, the software used includes the Arduino IDE as a programming application and the Blynk application as a temperature monitoring platform for the smoking room.

The design of this temperature monitoring device connects NodeMCU ESP8266 equipped with a WiFi module (Parihar, 2019) with DHT22 as a temperature sensor, placed in the smoking room. The data obtained from the device were validated using a temperature in the smokeroom. The data obtained will be sent using an internet connection.

They can be accessed using a smartphone via the Blynk application and sent to the server in time and temperature using an internet connection. NodeMCU ESP8266 is also connected to a relay, a simple electronic circuit that can cut and connect electricity (Tjandi & Kasim, 2019) and is connected to an indicator light.

The following in Figure 1 is a working system for the RSS smoke-room temperature monitoring device.

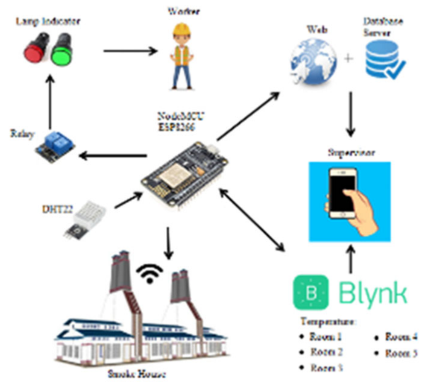

Fig 1. Working System of RSS Smoking Room Temperature Monitoring Device

2.2 Hardware Design

This stage integrates the pins on the ESP8266 NodeMCU to the DHT22 sensor component. This stage will produce an overall hardware design based on the system's operational design. The schematic of the overall system design is presented in Figure 2.

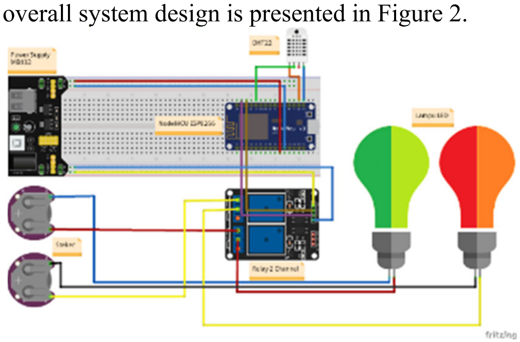

Fig 2. Overall System Design Schematic

The stages of the overall system design scheme are as follows:

The 3,3V pin on the ESP8266 NodeMCU is connected to the positive pole, and the GND pin is connected to the negative pole on the MB102 with 3.3V power. The use of this design is to provide a power of 3.3V to the NodeMCU ESP8266. The 3,3V pin on NodeMCU ESP8266 is connected to the VCC pin on DHT22, and the GND pin on the ESP8266 NodeMCU is connected to the GND pin on DHT22, and pin d4 on the ESP8266 NodeMCU is connected to the data pin on DHT22. The use of this design is to provide power to the DHT22 and connect data information so that the censoring results can be read by NodeMCU ESP8266.

The VCC pin on the relay is connected to the positive pole, and the GND pin is connected to the negative pole on the MB102 module with 5V power. The use of this design is to provide power to the relay by 5V. Also, the IN1 pin on the relay is connected to pin d1, and pin IN2 is connected to pin d2 on NodeMCU ESP8266 to connect data information so that NodeMCU ESP8266 can give commands to the relay to disconnect and connect the electric current. Standard pin 1 on the relay is connected to the power source through the green LED phase wire, and common pin 2 is connected to the power source via the red LED light phase cable.

Data received by the DHT22 temperature sensor will be processed by NodeMCU ESP8266, which is connected to the internet network from WiFi. The data is then sent online and displayed on the Blynk application and the web and provides a real-time warning on indicator lights.

2.3 Program Design

The program design for the temperature monitoring system is as follows:

Microcontroller Programming

Microcontroller programming is carried out on the NodeMCU ESP8266 using the Arduino IDE software, which has the C programming language. Arduino IDE is essential for writing programs, compiling them into binary code, and uploading them into microcontroller memory (Louis, 2016). Making programs on the system uses the addition of a library of sensor components, and the applications used include:

NodeMCU ESP8266 uses the #include <ESP8266WiFi.h> library

DHT22 temperature sensor using library #include "DHT.h"

The Blynk application uses the #include <BlynkSimpleEsp8266.h> library

Sending data to the server uses the #include <ESP8266WebServer.h> library and the #include <ESP8266HTTTPClient.h> library

Blynk Programming

The Blynk application is designed based on research needs to display time and temperature and set the minimum and maximum temperature range limits in real-time. To display the data read by the sensor, it requires programming or setting the IoT server according to research needs. The design was made by adding several existing widgets and giving the Arduino IDE command codes to connect and send data to the Blynk platform.

Web Programming

Web programming is done by sending PHP data PHP files to hosting. PHP file contains commands for transmitting data from the MySQL database server to the webserver to be displayed and accessed easily via the web.

System Testing

Performance Testing

Performance tests are carried out on the sensors used to determine whether they are following their functionalities and specifications. This performance test is carried out before the implementation of temperature monitoring in the field to minimize errors. In this performance test, functionality is validated by testing the functionality of each system component. The method used is black-box testing. Black-box testing is a test that focuses on the functional requirements of a system device and evaluates the requirements specifications and ensures the system functions properly (Larrea, 2017). Testing is done by counting the number of functional features running well and then compared with all the existing features. The instrument of validation for functionality that is being performed can be seen in Table 1.

DHT22 Sensor Testing

The DHT22 sensor data is compared with a standard room thermometer. Comparative testing is carried out in the smokeroom, and the value of reading data is taken 30 times with an interval of 30 minutes of data collection time for 15 hours. The minimum number of samples used in comparison testing is 30 data (Alwi, 2015).

Field Testing

Field testing scenarios for the RSS smoking process carried out include:

Monitoring is carried out on the RSS smoking process. The device is placed in 1 smoking room for 24 hours, starting from the RSS entering the smoking room until before the RSS is reversed. The data per day will then be sent in real-time to the Blynk application and the webserver.

Efficiency and Effectiveness Testing

1. Efficiency

Measuring the level of efficiency requires realization data on the RSS smoking process. The stages of measuring the level of work efficiency are as follows:

a. Calculate the time used in monitoring the smoking process in each room before using the temperature monitoring device
b. Calculate the actual time spent in the curing process after using the temperature monitoring device

2. Effectiveness

Measurement of effectiveness can be done only by measuring the outcome. The stages of measuring the level of work efficiency are as follows:

a. Collecting data on the quantity of production quality of RSS 3 before and after the use of temperature monitoring devices for 24 hours
b. Calculating the target quantity for the production quality of RSS 3
c. Distribution of performance-effectiveness questionnaires before and after using temperature monitoring tools as a determining material for action and performance evaluation distributed to workers and supervisors.

Table 1. Functionality Validation Instruments

Function	Statement
NodeMCU ESP8266	The function of the sensor readings can be displayed on the Arduino IDE monitor serial
DHT22 Temperature Sensor	The sensor function used can read temperature data properly
MB102	The function of flowing electricity through the breadboard to Node MCU and Relay
Blynk Application	The function displays data from sensors that are used online and in real-time
2 Channel Relay	The function of disconnecting the power supply and turning the indicator lights on and off
Webserver	The function displays online and real-time sensor reading data

Data Analysis

Analysis of Performance Testing

Testing aspects of functionality using the Guttman scale as a measurement scale. The answer to each instrument item is "Yes" or "No" which is a firm answer when using the Guttman scale (Vimalrajkumar et al., 2016). The calculation for functionality aspect uses the standard calculation from ISO / IEC 9126 (2001) to analyze data from the functionality testing results using the following equation:

$$X=1- A/B$$

In this analysis, variable A is the number of instrument items with the answer "No", while variable B is the total number of items tested. The measurement interpretation of ISO / IEC 9126 is 0 <= X <= 1. This device is said to be good in terms of functionality if X approaches 1.

Analysis of the Implementation Monitoring Devices

In the implementation of monitoring smoking process, the monitoring result data is displayed through the Blynk application and a web server that displays information in the form of a datasheet and then analyzes the suitability of the tool designed with real conditions in the field.

Efficiency and Effectiveness Analysis

1. Efficiency

The efficiency measured in this study is time efficiency. Time efficiency is calculated based on the ratio between the time after using the device and the time before using the device than compared with the existing standards.

$$\text{Efficiency: } \frac{Time\ after\ tool\ use}{Time\ before\ tool\ use} x100\%$$

Table 2. Efficiency Standards

Percentage (%)	**Criteria**
>100	Not efficient
90-100	Less Efficient
80-90	Efficient Enough
60-80	Efficient
<60	Very Efficient

Source: Minister of Home Affairs Decree No. 690.900.327 (1994)

Effectiveness

2. The purpose of measuring the effectiveness is to determine the effect of the implementation of the device on the decrease in the number of quality RSS3 (low quality) so that the monitoring device can be said to be effective if it can reduce the number of quality RSS3.

$$\text{Effectiveness: } \frac{Number\ of\ quality\ targets\ RSS\ 3}{Number\ of\ actual\ quality\ RSS\ 3} x100 \quad (3)$$

Table 3. Effectiveness Assessment Criteria

Percentage (%)	**Criteria**
>100	Very effective
90-100	Effective
80-90	Effective enough
60-80	Less effective
<60	Ineffective

Source: Minister of Home Affairs Decree No. 690.900.327 (1996).

3 Results and Discussion

3.1 Results of System Monitoring Program Design

The command code is made in the C programming language in the Arduino IDE application, then compiled into binary code. The command is sent to the Blynk application and also the Webserver via NodeMCU ESP8266. Also, there is a command to read the numeric input on the

Blynk application, which is then linked to the on-off relay command code using the numeric values in that variable.

The command to send data to the webserver is made using a PHP file sent to the hosting. PHP files are created using the Notepad++ application, which will then be uploaded using the FtpCafe application. The PHP file is a command to read code from the Arduino IDE via NodeMCU ESP8266, then reads the MySQL database data and displays it on a webserver.

Results of Designing an RSS Smoke-Room Temperature Monitoring Device

Sensor components and modules are used and assembled on a container using a wooden box. The results of the design and assembly of tools can be seen in the following figure.

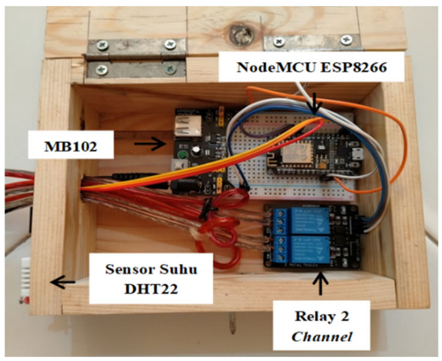

Fig.3. Positioning the sensor in a wooden box

When the device is connected to the power supply and WiFi is turned on, NodeMCU will send data online. The temperature data captured by DHT22 sensor is indicated by the appearance of an" online" notification on the Blynk application that provides real-time temperature information. The temperature data for each unit of time will be recorded on the webserver. The light indicator will light up when the temperature is not up to the standard.

3.2 Results of System Testing

Device Performance Testing

This performance testing is carried out about the functional tools that have been designed to record time and temperature data.

1. Functionality Test Validation Results

Validation of functionality was carried out in research as a designer for monitoring the temperature of the RSS smoking room. The results of testing for functionality validation are in table 4 below.

Table 4. Functionality Test Results

No	Statement	Yes	No
1	The NodeMCU ESP8266 function in the form of sensor readings can be displayed on the Arduino IDE monitor serial	1	0
2	DHT22 temperature sensor function can read temperature data well	1	0

3	The MB102 function supplies electricity through the breadboard to the NodeMCU and Relay	1	0
4	The Blynk application function displays data from sensors used online and in real time	1	0
5	2 Channel Relay function disconnects the power supply and turns the light indicator on and off	1	0
6	The MB102 function supplies electricity through the breadboard to the NodeMCU and Relay	1	0
7	The webserver function displays online and real-time sensor reading data	1	0

The calculation of validation for testing functionality uses the ISO / ICE 9126 (2001) equation as follows:

A = function that does not work (not) x number of testers = 0

B = all evaluated functions x number of examiners = 6 x 1 = 6

X = 1- A / B = 1 - 0/6 = 1 - 0 = 1

Based on the test results above, it can be concluded that X = 1, which means that the design results of the tools and monitoring systems that are running have met the functionality aspects according to ISO / ICE 9126. Thus, the designed device can be concluded that it is feasible to be implemented in monitoring the temperature of the RSS smoking room.

2. Test results comparison of the DHT22 sensor with a standard thermometer

Based on the result of testing the comparison of the reading value of the DHT22 sensor with the thermometer in the smoking room, the average temperature error value is 0.34°C. The DHT22 sensor datasheet has a temperature reading scale of -40 C to 80 C with an accuracy of ± 0.5 ˚C (A. Abdulrazzak et al., 2018). The test results are within the DHT22 temperature sensor error tolerance, and the sensor is functioning correctly. Test result data can be seen in the following graph in figure 5.

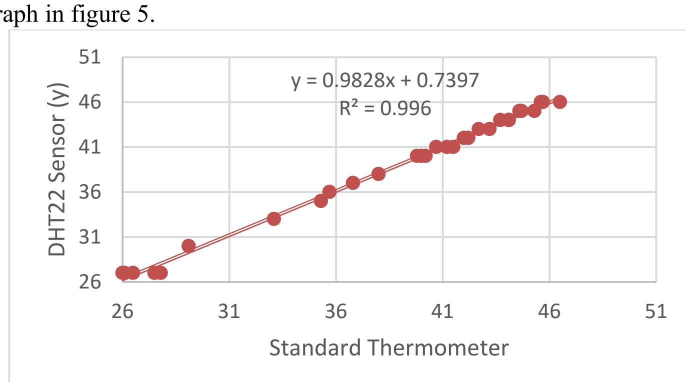

Fig.4. Graph of the Relationship Value of the Standard Measurement Device and the DHT22 Sensor

Based on the graph of the value relationship of the standard measuring instrument with the DHT22 sensor, it can be seen that the correlation line between the two variables is positive or have a linear relationship. The regression results were y = 0.9828x + 0.7397. The regression value shows that an increase of 1 value in variable x will increase by the coefficient of variable x on variable y. A correlation value close to 1 indicates that the two variables are very strongly related (Costa, 2016).

It can be concluded that the DHT22 sensor value will increase by 0.9828 for every 1 unit temperature increase in the standard measuring instrument. The correlation value R^2 = 0.996 indicates that the value is close to 1, which means that the relationship between the value of the standard measuring instrument and the DHT22 sensor is powerful. Temperature comparisons were carried out with time intervals of 30 minutes to obtain some significant temperature changes in the RSS smoking room. The DHT22 sensor can be concluded to have a good level of accuracy because it can record temperature data according to the environment in the RSS smoking room. Thus, the use of the DHT22 sensor for monitoring the RSS smoking room temperature can provide accurate data information on smoking room temperature / by field conditions.

Implementation of Temperature Monitoring in Smoking Room

The implementation of data recording in the RSS smoking process aims to retrieve real-time data in the field and send the data in real-time to the Blynk application which can be accessed by the supervisor and presented in a web form that is easily accessible by the company. The implementation was carried out in the smokeroom of Sumber Tengah Garden, PTPN XII. Implementation of the tool is carried out for 24 hours starting on Friday, July 3, 2020, at 09.32 WIB to July 4, 2020, at the same hour.

Monitoring temperature implementation starts when the designed device is installed in the smokeroom and has turned on the power supply switch on the MB102 module to retrieve the smoke-room temperature data. The smoke-room temperature data will be sent to the IoT server using the Blynk application in real-time and disconnect the electricity from the temperature warning indicator light and send data to the web so that data information can be accessed easily along with the time. The following is a picture of the state of the LED light indicator, the Blynk application display, and the webserver with room temperature settings on the first day, namely a temperature range of 40°C - 45°C.

Fig 5. Lamp indicator when the smoking-room temperature is too high (red led is on)

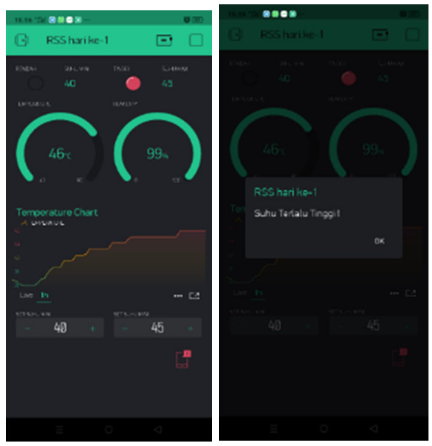

Fig.6. Display of Blynk Application when the temperature of the smoking room is too high

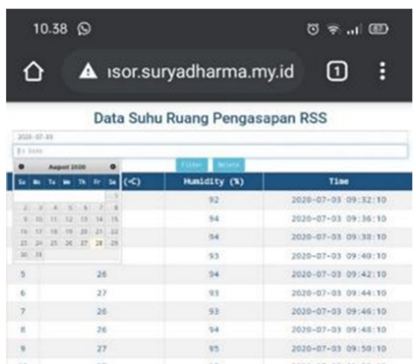

Fig.7. Display of the RSS Smoking Room Temperature Webserver

Efficiency of Temperature Monitoring Performance in Smoke Room

Data for time monitoring the smoke-room temperature carried out by workers in each smokeroom on July 3, 2020, can be seen in Table 6.

Table 5. Time data for temperature monitoring before and after device implementation

No	Time	Monitoring time (Second)	
		Before	After
1	10.00 WIB	19	14
2	11.00 WIB	21	17
3	12.00 WIB	22	15
4	13.00 WIB	22	18
5	14.00 WIB	24	17
6	15.00 WIB	20	15

7	16.00 WIB	22	14
8	17.00 WIB	20	16
9	18.00 WIB	18	14
10	19.00 WIB	21	18
11	20.00 WIB	19	17
12	21.00 WIB	22	17
13	22.00 WIB	17	15
14	23.00 WIB	19	17
15	24.00 WIB	21	18
Average		**20,47**	**16,13**

Based on the data, it can be seen that the implementation of the device influences the length of time the process of monitoring the temperature of the smokeroom. Workers do not need to record room temperature on the datasheet. But the data has been automatically recorded online to the web and can be accessed via the company web server.

Time efficiency level:

$$\frac{Time\ after\ tool\ use}{Time\ before\ tool\ use} x100$$

16,13/20,47 x100% = 78,83%

Based on the calculation of the time efficiency level of using the RSS room temperature monitoring device, it can be seen that the efficiency value is 78.83%. This value is included in the efficient criteria referring to the Minister of Home Affairs Decree No. 690.900.327 (1994). This value shows that the temperature monitoring device can increase the efficiency of time in workers monitoring process.

Effectivennes of Temperature Monitoring Performance in Smoke Room

1. RSS Quality 3

RSS 3 is the final class / low-quality RSS. Product defects in RSS 3 in the form of immature, bubbly, or moldy sheets are caused by the smoke-room instability temperature (Morshed et al., 2018). Before implementing the device, data was collected in the form of a target for RSS quality in June and July and the daily percentage of RSS 3 in the last 25 days (June). The target number of RSS 3 in June and July is 1.12% of the total production, and the average number of RSS 3 production in the last 25 days (June) is 0.93%. The implementation of the smoke-room temperature monitoring device on July 3, 2020, produced RSS with a decrease in smoking on the 6th day on July 8, 2020, with a percentage of RSS 3 of 0.84%.

Based on the production data after implementing the device, the percentage of the total quality of RSS 3 was 0.84%. It was obtained from (number of RSS 3 / total RSS) x 100% and was smaller than the average presentation in the last one month, which was 0.93 % with the quality target in June and July is the same, namely a maximum of 1.12%.

The effectiveness of the number of RSS 3 before the implementation of the device:

$$\frac{Number\ of\ RSS\ 3\ targets\ for\ June}{Actual\ number\ of\ RSS\ 3\ for\ June} x100\%$$

1,12/0,93 x100% = 120%

Level of effectiveness number of quality RSS 3 after using the device:

$$\frac{Number\ of\ RSS\ 3\ targets\ for\ June}{Actual\ number\ of\ RSS\ 3\ for\ 8\ July} x100\%$$

1,12/0,84 x100% = 133%

Based on the calculation, it can be seen that the percentage value of the effectiveness of the number of quality RSS 3 before the implementation of the device is 120%. This value is included in the very effective criteria of the Minister of Home Affairs Decree No. 690.900.327 (1996). The percentage value of the effectiveness of the number of quality RSS 3 after implementing the tool is 133% and is included in the very effective criteria referring to the Minister of Home Affairs Decree No. 690.900.327 (1996). Comparing the effective value of the tool against the total quality of RSS 3 before and after implementing this device is obtained that the value of effectiveness after implementation is greater than before tool implementation.

2. Performance of RSS Smoking Room Workers

The worker performance analysis in the smokeroom was carried out by giving a questionnaire to smoke-room workers. The analysis shows that workers feel more comfortable after using the devices. This device can improve worker performance effectively

3. Performance of RSS Smoking Room SupervisorAnalysis of the smoke-room supervisor performance's effectiveness was carried out by giving a questionnaire to the Engineering and Processing Assistant of Kebun Sumber Tengah. The questionnaire was to compare the RSS smoke-room temperature monitoring device before and after the tool's design with the Blynk application indicator. Based on the comparative data, it is known that the level of comfort of the supervisor after designing the tool is greater compared to before the design of the device. The new smoke-room temperature monitoring device can increase the supervisor's performance in monitoring room temperature as a performance evaluation measure.

4. Company evaluation of the RSS smoking process

Analysis of the effectiveness of the company's evaluation of the RSS smoking process was carried out by providing a questionnaire to the Manager of Kebun Sumber Tengah. The questionnaire was to compare the RSS smoking room temperature datasheet before and the database after the device's design.

Based on the comparative data, it is known that the level of comfort of the supervisor after designing the tool is greater compared to before the design of the device. The new smoke-room temperature monitoring device can increase the supervisor's performance in monitoring room temperature as a performance evaluation measure. A new smoke-room temperature monitoring device can increase the effectiveness of evaluating the smoking process with accurate data.

4 Conclusion

An IoT-based device for monitoring the temperature of the RSS smoking room has been designed. This device has been validated, and all components had functioned well. Implementing monitoring devices for smoking room temperature can increase the efficiency of monitoring time carried out by workers. The value of RSS quality also increased after implementing the devices, which means it is useful.

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