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# Application of Capacitive Sensor for Measuring Grain Moisture Content Based on Internet of Things

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**Abstract**

*Moisture content is one of the factors that determine the selling value of grains. A good moisture content by standard is around 14%. Determination of moisture content is generally done using an oven, for farmers this method is quite complicated because farmers have to bring samples to the laboratory. This study aims to develop a real-time measurement of grain moisture content using an IoT-based capacitive sensor, which is able to measure the moisture content of crop yields in the form of grains and is monitored directly using Android in realtime. This research begins by designing a schematic of the circuit system, designing the structure of the tool, making the tool, carrying out the tool calibration process, testing the tool to measure the moisture content in different grain samples including rice, corn, green beans, and beans. grains with five variations of moisture content at 9%-27% intervals, validated the moisture content measuring instrument test with several observations including grain moisture content, tool response time, and tool error. Based on the results of the research, the calibration results of the research moisture content measuring instrument, the overall $R^2$ value is 0,9902; which means that the measurement results of the research instrument are close to the actual value. The results of the analysis of observations of moisture content obtained an average difference in reading values ranging from 0,19%-0,41% with an average percentage error obtained ranging from 1,18%-2,12% and an average response time reading of 26,33 sec.*

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## 1. Introduction

Postharvest is an activity that is carried out after harvesting an agricultural commodity. One of the post-harvest handlings is the drying process. Drying is a method used by farmers to remove most of the water contained in crops such as rice, corn, green beans, soybeans and other grain commodities. Usually the farmers do the drying of grains using a simple way, namely drying in direct sunlight. According to Hasibuan (2005), the grain drying process depends on several factors including moisture content, temperature, and time. These three parameters are related to each other, if at the time of drying the temperature is high, the moisture content in the grain will decrease rapidly and the drying time will be shorter, and vice versa.

Moisture content is also a factor in determining the selling value of grains, therefore it is very important to measure the moisture content of grains before they are packaged and sold. According to

Mushollaeni (2012), in general, grain yields have a moisture content of more than 25%. If grains that contain a very high moisture content are immediately packaged, it can cause damage, one of which is easy to grow fungus on the grains so that it has an impact on the quality of the seeds that are not good and their selling value decreases. In addition, it is possible that high moisture content accelerates the process of developing microorganisms, which in nature also damage the grain due to high humidity. Based on the Joint Decree of the Head of the Food Security Guidance Agency No.04/SB/BBKP/II/2002 stated that the moisture content contained in good grains based on SNI is 14%. But here the farmers cannot determine the amount of moisture content in quantitative terms, farmers only know that the dried grains are bitten or pressed using nails, if it feels hard, it indicates that the grains are dry and ready to be packaged and sold.

The method of determining the moisture content of grains is generally carried out using an oven, for farmers this method is quite complicated because to determine the moisture content of grains, farmers must bring samples to a laboratory that provides moisture content measurement services, in addition to the time required to obtain the moisture content of grains. measurement results can take hours and the costs incurred are not small. Therefore, farmers need a tool that can measure the moisture content of grain in real time so that farmers know that the moisture content of the grain has met the standards set for direct marketing, and this tool can also be applied to directly monitor the moisture content during the storage period so that damage does not occur which will reduce the quality and selling value of the grain.

Grains are included in one of the dielectric materials. Materials that have this property are materials that cannot conduct electric current. When the material is electrified, the atoms that make up the dielectric become unbalanced, resulting in electric charges appearing on the material. Therefore, a dielectric material has different permittivity values which make the capacitance value influential, changes in the capacitance value can be a parameter in determining the moisture content of grains (Hasnan, 2017). Previous research conducted by Valentin et al. (2020), also made a moisture content test device on dry cocoa pods based on an Arduino microcontroller, this study used a soil moisture sensor of type YL-69 equipped with a 1602 LCD which from the results of the research the tool designed succeeded in measuring the moisture content of cocoa beans with the largest error percentage obtained is 1,2%. The objective of this study is to develop a real-time measurement of grain moisture content using an IoT-based capacitive sensor, which is able to measure the moisture content of crop yields in the form of grains and is monitored directly using Android in realtime.

## 2. Materials and Methods

This research was carried out to develop a real-time measuring tool for grain moisture content using an IoT-based capacitive sensor, which is expected to later be able to measure the moisture content of harvested commodities in the form of grains which are monitored directly using Android in realtime.

2.1 Schematic Design of Moisture Content Measuring Instrument Circuit

The following is a schematic of a real-time grain moisture measuring device circuit system using an IoT-based capacitive sensor, this schematic aims to provide an overview of the system design that will be made. The schematic of the circuit system for measuring moisture content can be seen in Figure 1.

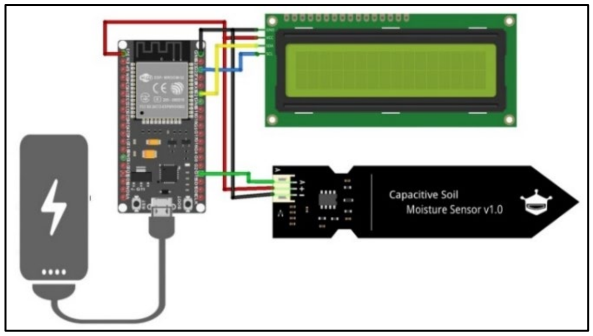


**Figure 1**. Circuit System Schematic

The working principle of the grain moisture measuring system in real time uses an IoT-based capacitive sensor, namely the capacitive sensor has a probe that acts as a capacitor. When the sensor is electrified, the probe will load an electric current. When the probe is inserted into the container containing the grain, the probe will discharge an electric current to the grain. Because these dielectric grains are electrified, making the atoms that make up the dielectric become unbalanced so that electric charges appear on the material. The level of moisture in the grain will affect the electrical resistance of the probe. Therefore, a dielectric material has different permittivity values which make the capacitance value influential. The higher the moisture content of the grain, the better the conductivity and vice versa (Hasnan, 2017). The value that appears from the sensor is an analog sensor value or ADC value, when the sensor measures the moisture content of grains, the ESP32 microcontroller will process the sensor reading data and then display the moisture content measurement results via the 1602 LCD and send the moisture content measurement data to Android via Blynk application, in this application the value of grain moisture content is also displayed in real time. The flow of the working principle of the system can be seen in Figure 2 below.

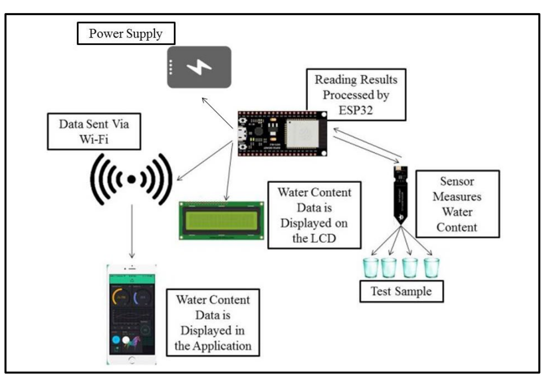


**Figure 2**. System Working Principle

2.2 Structural Design of Moisture Content Measuring Instrument

This grain moisture meter designed consists of a plastic housing with a length of 11cm, a width of 5,5cm and a height of 3,7cm which is used as a place to place the microcontroller and sensor module so that it is protected and looks neat, then at the top of the housing show results of measuring the moisture content of grains, and on the right side there is a capacitive sensor that will measure the moisture content of the grains. For more details, the following is the design of the structure of the research tool along with the descriptions listed in Figure 3.

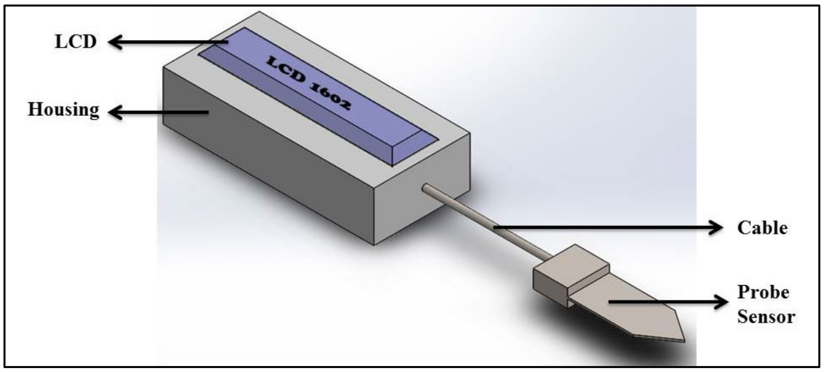


**Figure 3**. Structural Design of Moisture Content Measuring Instrument

2.3 Sensor Calibration

According to Yunita (2015), calibration is an activity that aims to align an output from a measuring instrument to match the established standards. Calibration ensures that the measurement results using a measuring instrument do not deviate from the specified accuracy standard value. The sensor calibration process is carried out by comparing the sensor reading value with the value from a standard measuring instrument. Capacitive sensor calibration is done using a grain moisture meter. Before calibrating the sensor, the grain moisture meter will be calibrated first using an oven. Therefore, an equation is needed in determining the moisture content using the oven method. Based on Nuryanti's research (2018), to calculate the moisture content of grains, a sample of 5 grams is prepared which will later be in the oven at a temperature of 105°C for 3 hours, to determine the moisture content of grains, it can be calculated using the following equation 1.

Grain Moisture Content (%) = $\frac{X-Z}{X-Y}\ x\ 100\%$ ........................................................................................ (1)

Information:

x = weight of crucible with sample before drying (g)

z = weight of crucible with sample after drying (g)

y = weight of empty crucible (g)

### 2.4 Measuring Instrument Test

Tool testing includes LCD testing and blynk application, this aims to see whether the moisture content measuring instrument in this study is able to display the results of measuring the moisture content of the test sample properly. It was only after the testing of the tool was successful, that the validation test of the moisture content measuring instrument included four different types of grains, consisting of rice, corn, green beans, and soybeans. Each sample will consist of five variations of moisture content with the test carried out 3 times. Moisture content is one of the factors in storage. According to Fitria (2017), a good moisture content so that grains are more durable and avoid damage to microorganisms must be below 10%. Therefore, in this study, the moisture content for the four types of grains tested will be varied at intervals of 9%-27%.

### 2.5 Moisture Measurement Tool Validation

Validation aims to check the correctness of the measurement results from the research moisture content measuring instrument. This agrees with the statement of Riyanto (2014), validation is carried out to ensure that the results of a measurement produce valid data. Therefore, the validation of the moisture content measuring instrument was carried out with several observation parameters including moisture content, the response time of the instrument reading and the error value.

#### 2.5.1 Moisture Content

The moisture content of the grains tested will be varied into five variations of moisture content at intervals of 9% to 27% with estimated variations in moisture content consisting of 9%, 13%, 17%, 23%, and 27%, each variation of the sample is prepared as much as one glass, the sample container used can accommodate 200g-250g test samples. Based on the research of Putri et al. (2015), to make variations in the moisture content of grains can be done by two methods, namely the drying method to reduce the moisture content of the grain and the soaking method which aims to increase the moisture content of the grain.

#### 2.5.2 Tool Reading Response Time

Observation of the response time of the reading tool aims to see how quickly the tool responds in measuring the moisture content of the grains being tested. The tool used to observe the response time of the reading tool is a stopwatch. Observation of the response time of the tool reading begins when the sensor is inserted into the container containing the test sample until the moisture content value that is read is in a stable state. Observations will be made on ten times of testing on a random sample. Based on Rawung's statement (2020), the observation of response time by testing on random samples aims to avoid bias in the data collection process and save time.

#### 2.5.3 Error

Error is the deviation value from the measurement results using standard measuring instruments with the measurement results of research measuring instruments. the error value gives an idea of how well the research tool is working. The error (difference in value) and the percentage error of the research moisture content measuring instrument can be calculated using the following formula (Putri and Suprapto, 2019). To look for error can be calculated using equations 2 and 3.

Error (difference in value, %) = NS – NU ........................................................................................ (2)

Error percentage (%) = $\frac{NS-NU}{NS}$ x 100% ........................................................................................ (3)

Information:

NS = measurement results from standard measuring instruments (g)

NU= measurement results from research measuring instruments (g)

2.6 Data Analysis

Data analysis is needed in research observations. Observations in this study used a descriptive data analysis system which included 1) Average, 2) Standard Deviation, and 3) Regression Analysis. According to Husnul et al. (2020), descriptive data analysis aims to simplify the numbers obtained from research results, this simplification is useful as information that provides an overview of the data obtained so that researchers can make a decision and the data presented is easy to understand.

## 3. Results and Discussion

Based on the research that has been carried out, the design of an instrumentation system and a prototype of a grain moisture measuring device using an IoT-based capacitive sensor have been successfully created and tested. The results of the design of a grain moisture measuring device using an IoT-based capacitive sensor can be seen in Figure 4 below.

Based on the test results of the tool, the designed moisture content measuring instrument is able to display the results of measuring the moisture content of the test sample well, as evidenced by testing on display and application that display the results of moisture content measurements on the test sample. LCD and application test results can be seen in Figure 5.

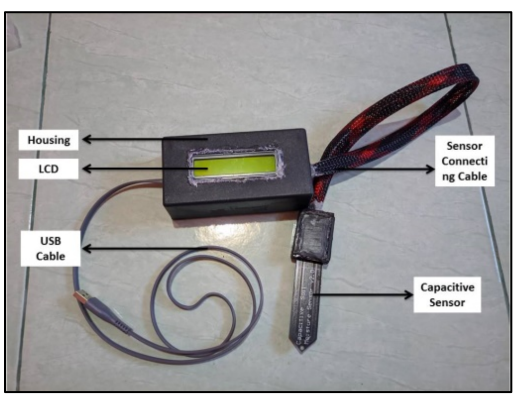


**Figure 4**. Prototype of Research Grain Moisture Content Measuring Instrument

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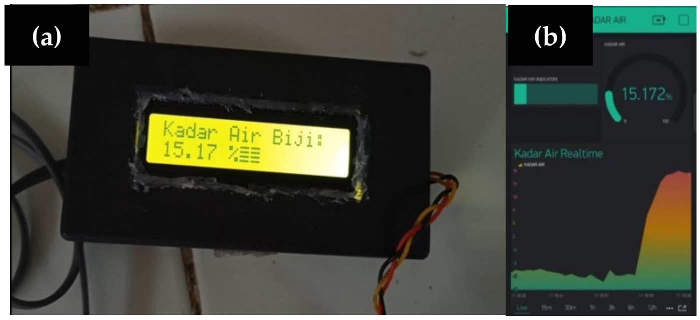


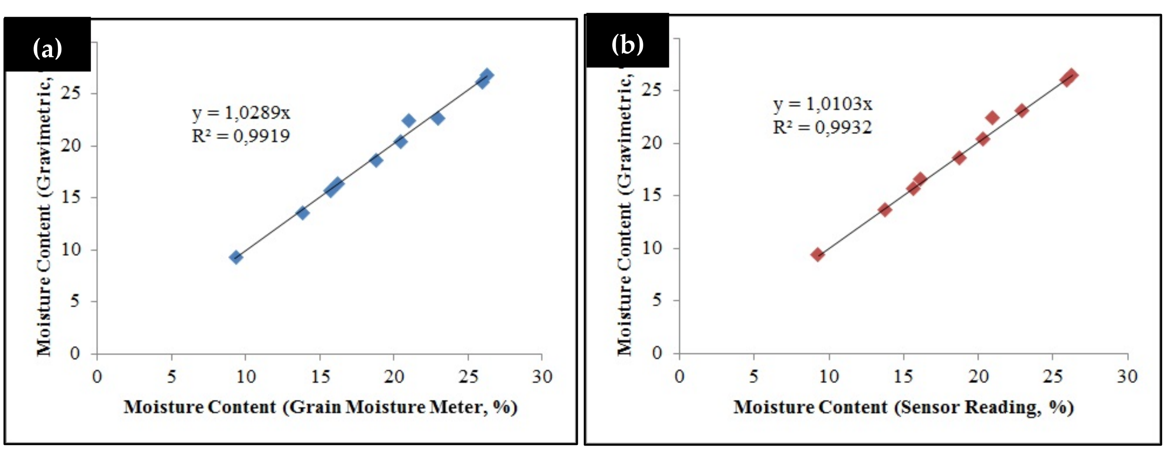

**Figure 5.** Test Results on (a) LCD and (b) Blynk Application

In the tool calibration process, the ADC value that appears on the sensor is converted directly into a percent unit of moisture content through the ESP32 programmer. For script code programming conversion of ADC values to percent units of moisture content can be seen in Figure 6.

```
float grainmoisturepercent;
int grainMoistureValue;
analogReadResolution(10);
grainMoistureValue = ((analogRead(33)/1,0054));//y=1,0054x ==> x = analogRead(Pin)/1,0054;
grainmoisturepercent = (100.00-((grainMoistureValue/898.00)*100));
Serial.println(grainMoistureValue);
```

**Figure 6**. Script code calibration

Calibration is carried out by comparing the results of sensor moisture content readings with moisture content readings from standard measuring instruments (gravimetric and grain moisture meter methods). The samples used in this calibration process are rice samples and corn samples, each consisting of 10 variations. The use of 2 types of test samples aims to save time this agrees with the statement from Gandjar and Rohman (2018) one type of test sample can already be used for the calibration process. The use of a small number of test samples in the calibration process also aims to save time and money. The following are the results of tool calibration on grain samples, which can be seen in Figure 7.



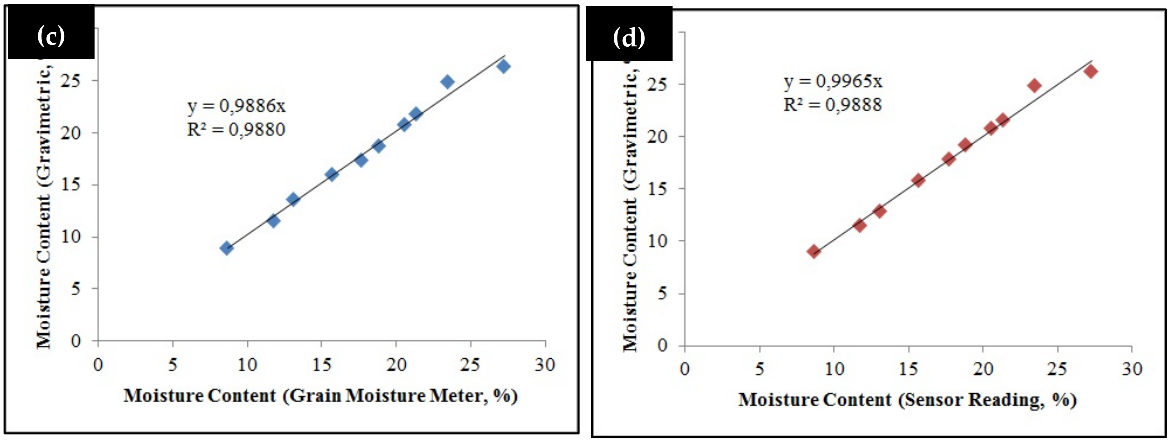



**Figure 7**. Graph of calibration results on (a) Grain Moisture Meter (rice), (b) Sensor Reading (rice), (c) Grain Moisture Meter (corn), and (d) Sensor Reading (corn)

Based on the calibration results of the research moisture content measuring instrument, the $R^2$ value obtained shows the research moisture content measuring instrument designed to be accurate because it is close to the value 1. The accuracy of the sensor reading can be seen from the $R^2$ value obtained. This agrees with Subandriyo's statement (2020), the fit of the regression model is influenced by the value of the coefficient of determination or the value of $R^2$, the closer to 1 the better. The calibration results obtained have been able to prove that the research moisture content measuring instrument is able to measure the moisture content of the test sample properly. The results of the calibration of research tool can be seen in Figure 8.

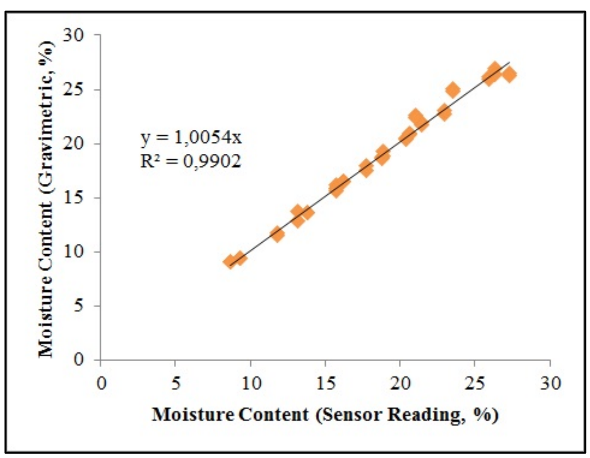



**Figure 8**. Calibration Chart of Research Moisture Content Measuring Instrument

3.1 Moisture Content

Based on the research that has been carried out, the results of measuring the moisture content for the 4 test samples can be seen in Table 1 below. The accuracy of the moisture content measuring instrument in this study was also supported by the results of measuring the moisture content of grains in all samples including rice, corn, green beans, and soybeans, which in this study obtained an average difference in value with a range of 0,19%-0,39%. The difference in the values obtained is close to the value 0, so it can be said that the moisture content measuring instrument in this study has a good level of measurement accuracy. According to Arland et al. (2018), the smaller the difference in the values obtained, the greater the level of accuracy of the measurement results of a measuring instrument. The results of the validation of moisture content can be seen in Figure 9.

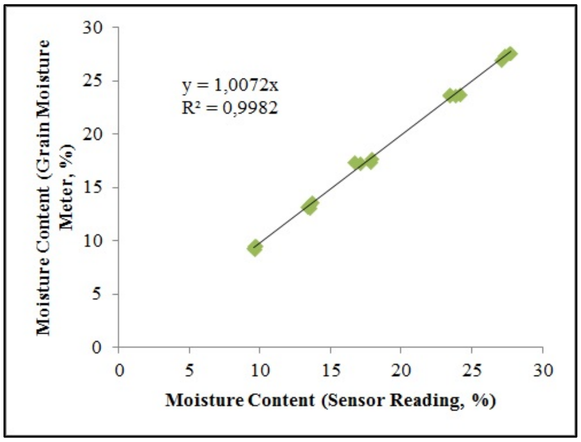



**Figure 9.** The Results of the Validation of the Moisture Content Measuring Instrument for All Test Samples

Based on Figure 9, the combined results of moisture content measurements in all test samples obtained an $R^2$ value of 0,9982; where the value of $R^2$ obtained is close to the value of 1, which means that the measurement results of the research moisture content measuring instrument are close to the actual value. This agrees with Subandriyo's statement (2020), the fit of the regression model is influenced by the value of the coefficient of determination or the value of $R^2$, the closer to 1 the better.

**Table 1**. Results of Observation of Grain Moisture Content

| Sample Type | Test sample to- | Moisture content (%) | | Error (%) |
|---|---|---|---|---|
| | | Grain Moiture Meter | Research Measuring Tool | |
| Rice | 1 | 9,63 | 9,55 | 0,08 |
| | 2 | 13,57 | 13,10 | 0,47 |
| | 3 | 17,87 | 17,36 | 0,51 |
| | 4 | 24,13 | 23,69 | 0,77 |
| | 5 | 27,10 | 26,99 | 0,11 |
| Average | | | | 0,39 |
| Corn | 1 | 9,67 | 9,24 | 0,43 |
| | 2 | 13,50 | 13,44 | 0,06 |
| | 3 | 17,07 | 17,22 | 0,15 |
| | 4 | 23,43 | 23,65 | 0,22 |
| | 5 | 27,30 | 27,39 | 0,09 |
| Average | | | | 0,19 |

| Sample Type | Test sample to- | Moisture content (%) Grain Moiture Meter | Moisture content (%) Research Measuring Tool | Error (%) |
|---|---|---|---|---|
| Green bean | 1 | 9,53 | 9,31 | 0,22 |
| | 2 | 13,40 | 13,14 | 0,26 |
| | 3 | 17,93 | 17,74 | 0,19 |
| | 4 | 23,87 | 23,56 | 0,31 |
| | 5 | 27,70 | 27,55 | 0,15 |
| Average | | | | 0,23 |
| Soybean | 1 | 9,73 | 9,54 | 0,19 |
| | 2 | 13,73 | 13,60 | 0,13 |
| | 3 | 16,70 | 17,40 | 0,70 |
| | 4 | 23,43 | 23,72 | 0,29 |
| | 5 | 27,77 | 27,55 | 0,22 |
| Average | | | | 0,31 |

3.2 Tool Reading Response Time

Based on the results of the research that has been carried out, the following are the results of observing the response time of reading the tool which can be seen in Figure 10. The observation of the response time of the tool aims to see how long it takes the tool to read the moisture content of the sample until the reading is stable. Based on the results of the study, the average time required for the tool to read the moisture content of the sample is 26.33 seconds. The difference in response time occurs because the capacitive sensor is classified as an analog sensor, where the analog sensor produces an output in the form of a signal that continuously changes its reading, so it takes time for the reading to be completely stable (Munandar, 2021).

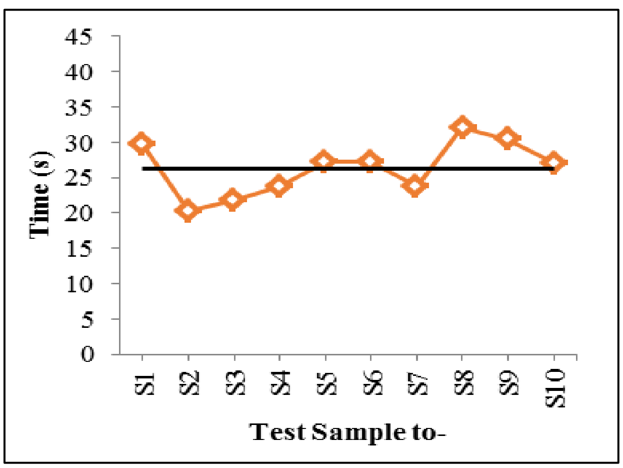



**Figure 10.** Response time observation

3.3 Error

The results of the observation of errors obtained from measuring the moisture content of grains in real time using a capacitive sensor can be seen in Table 2.

**Table 2**. Tool error analysis

| Test Sample to- | Error Percentage (%) | | | |
|---|---|---|---|---|
| | Rice | Corn | Green bean | Soybean |
| 1 | 0,83 | 4,38 | 2,31 | 1,95 |
| 2 | 3,42 | 0,44 | 1,94 | 0,97 |
| 3 | 2,84 | 0,92 | 1,08 | 4,17 |
| 4 | 3,19 | 0,91 | 1,27 | 1,21 |
| 5 | 0,42 | 0,34 | 0,54 | 0,77 |
| Average | 2,14 | 1,40 | 1,43 | 1,81 |

Based on the results of the analysis of the percentage error in measuring the moisture content of grains in the table above, each test sample has a different error value. The higher the error value obtained, the more often the research tool needs to be set and recalibrated. On the contrary, the lower the error value obtained, the better the reading of the grain moisture content by the research tool works. According to Mustofah and Utami (2019), the maximum percentage of moisture sensor error is no more than 5%. The average percentage of errors obtained from the results of the analysis in the table above, ranges from 1,40% to 2,14%. The percentage of error obtained in this study did not exceed the maximum limit set, so it can be said that the moisture content measuring instrument in this study worked well.

## 4. Conclusion

Based on the results of the research that has been carried out, it can be concluded that a real-time measuring tool for grain moisture content using an IoT-based capacitive sensor can measure moisture content in samples of rice, corn, mung beans, and soybeans well. This can be proven from the results of the calibration of the grain moisture measuring instrument, the overall $R^2$ value is 0,9902, which means that the measurement results of the research moisture content measuring instrument are close to the actual value (standard measuring instrument). The validation results of grain moisture content measuring instruments tested in real time using IoT-based capacitive sensors show several observation parameters (0,19 to 0,39), a percentage error obtained in the range of 1,40 to 2,14 percent, and an average response time of 26,33 seconds.

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