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Design-Build Data Acquisition System of Temperature, Oxygen (O_2), and Carbon Dioxide (CO_2) Gas in Pineapple Fruit Storage Space with Arduino-Based

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ABSTRACT

The quality of Indonesian pineapple exports is still lower compared to the two countries in Southeast Asia, namely the Philippines and Thailand. Lack of optimization of postharvest pineapple quality is one of the causes. For this reason, a design of a data acquisition monitoring system was developed to monitor temperature conditions, oxygen gas (O_2) and carbon dioxide (CO_2) in the pineapple storage room. The method in this study is divided into two stages, namely hardware design and software design. The temperature reading test results obtained (DS18B20) has an accuracy of 98.29% with an error of ± 1.71%, the O_2 reading (Figaro KE-25) has an accuracy of 98.7% and the precision of ± 0.073%, and the CO_2 reading (MHZ-14a) has an accuracy of 94.5% and a precision of ± 0.19%. The device that has been realized is capable of displaying real-time measurement data output to a 20x4 LCD with IIC, and also storing data into a micro SD card in real time.

INTRODUCTION

Pineapple or *Ananas comosus* L. is a potentially considerable horticultural commodity in Indonesia. Despite the significant development in terms of production, the export quality of local pineapple fruit is still inferior to the two countries in ASEAN, namely the Philippines and Thailand (Statistika, 2019). Although geographically, Indonesia also has a potential that is not inferior to the two countries. Therefore, observation of the quality of pineapple fruit is needed. The quality of the fruit can be improved so as to compete with other countries, especially ASEAN countries.

Storage becomes the process of determining the quality of fruit after harvest. Errors in the storage process can make the fruit more rapidly degraded both microbiological, chemical and physical. Respiration rate marks the rate of change in plant material composition and is generally indicative of the shelf life resistance (Martinez et al., 2002) . A fruit respiration rate can be triggered by an increase in the temperature so that the degradation of the material lasts faster (Lozano, 2006). Fruit storage at low temperatures with closed air circulation is generally better because of the respiration process and the growth of bacteria or fungi becomes obstructed. However, this requires further observation for the application of the pineapple, because of the difference in the nature between the fruits and other fruits. So, old research saves pineapple fruit needs to be done to improve the quality of post-harvest fruit.

This research aims to determine the influence of air condition of storage space and the length of storage of mushroom growth causes decay in pineapple fruit and its weight shrinkage. Air conditions include temperature, O_2 (oxygen) gas and CO_2 (carbon dioxide) gas in the test chamber.

Observations in testing require an assistive device to detect changes in air conditions occurring. The growth of fungi that occur in the skin of the surface can still be seen with the naked eye and can be identified type using a light microscope, but to know the length of storage, temperature, the gas concentration of O_2 and CO_2 can not be seen directly, so it requires additional tools that can measure it.

Currently, measuring instruments used to measure temperature, O_2 and CO_2 gas concentrations in the fruit storage room do not have an automatic data logging system. As in the test the influence of temperature and maturity level of the fruit to the quality and length of the tomato keep keep (Saiduna and Madkar, 2013), and the influence of the shape of pineapple slices to the quality of fresh pineapple shelf is minimal (Maulidia et al., 2017). Therefore, the measuring tool is equipped with automatic data logging as well as real-time data appearance for easy data logging.

Some research related to the design of the monitoring system such as (Argo et al., 2010), O_2 and CO_2 gas monitoring system in the storage cabinet (Chaudhry, 2013) created an Arduino-based air quality monitoring system to detect carbon monoxide gases using the MQ5 sensor, while the data output was delivered to the laptop via a serial port. Unlike the above studies (Muktiawan, 2016) made the monitoring system of rice and eggs in the Arduino-based storage space with the output delivered via wireless to smartphones. Furthermore,(Winata et al., 2016) makes the Arduino monitoring system use the Micro Secure Digital (SD) Card as the storage medium of the voltage measurement results from the solar panel automatically. Research related data acquisition systems have been conducted by several researchers, such as (Mardhiya et al., 2017) to measure the dissolved O_2 levels in an Arduino-based shrimp pond water. Dissolved O_2 levels were detected using dissolved oxygen (DO) sensors and the results were displayed in real-time via serial to PC (Personal Computer). Then, (Sandi et al., 2018) designed a detector data acquisition system to detect the oxygen gas, hydrogen gas, temperature, and the Arduino Mega-based pressure of 2560 with the output via the website. Unfortunately, these studies have not been specifically designed for use in refrigerated storage spaces, making it reasoned to make the system of acquisition of temperature and gas data within the cooled storage space.

The data acquisition system is capable of detecting temperature, O_2 gas, and CO_2 gas in the pineapple fruit storage space in real-time. The data acquisition system uses the Figaro 25 sensor to detect O_2 gases, the MHZ-14a sensor to detect CO_2 gases, and the DS18B20 sensor to detect Arduino-based temperatures. Furthermore, the measurement output is displayed to a Liquid Crystal Display (LCD) 20x4 resolution and data logger storage using a micro SD card.

METHODS

The method of the research began by studying the concept and system of tools to be made. Once that is followed by the preparation of tools and materials needed covering the needs of hardware and software. Based on data from the need analysis, then made the design of software and hardware. The design that has been done is used as the basis for the creation of the device, further integrating each device to form one system. System work tests are conducted to ensure successful performance of the system is calibrating well. The results of the calibration and test were then collected and created data to be compiled in a report.

System Design

1. Design of Hardware

Hardware design is the preparation stage between electronic components into a system that can work according to the desired function. The hardware used in this study include the DS18B20 sensor, the KE-25 sensor, the MHZ14a sensor, the Arduino Mega 2560, the 20x4 LCD with I2C, the Real Time Clock (RTC) DS-3231, and the Micro SD Card. The hardware diagram blocks presented on **Fig. 1**.

Hardware diagram blocks are divided into 3 parts i.e. input, process, and output. The input part consists of 3 sensors, 1 piece of RTC and 1 piece of power supply. The process consists of the signal-sensing circuit and the Arduino Mega. Meanwhile, the output part consists of a 20x4 LCD and a micro SD card. The signal-sensing circuit here uses an non-inverting amplifier circuit that serves to provide reinforcement to the output voltage from KE-25 sensor. The goal is to have the output of the sensor readable by the Arduino Mega.

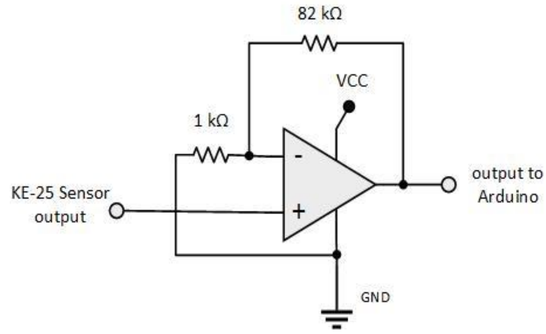


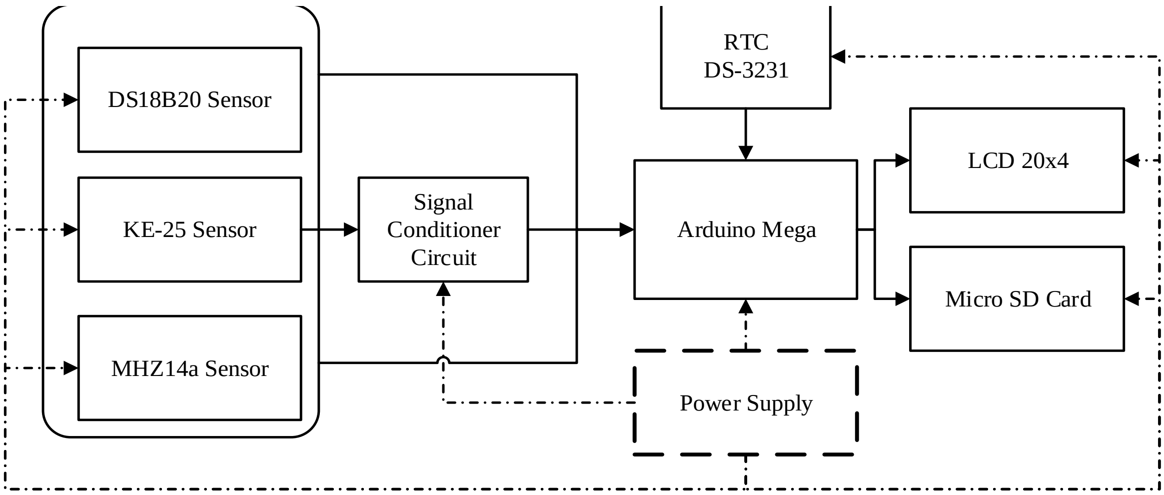
Figure 2. Schematic of signal conditioning circuit for O_2 sensor

In the schematic there is a signal conditioning circuit for O_2 gas sensors using IC LM358 with a non-inverting type of gain (not flipped). The use of this type is because the input from the O_2 gas sensor is positively charged, and the desired output is also positive. The other purpose of the signal-regulation circuit is to change the input voltage from the Figaro KE-25 sensor, which ranges from 0 to 60 mV to 0 – 5V, so that the Arduino can be easily read.

2. Design of Software

The software on this tool uses the Arduino IDE software version 1.6.7, with the basic C++ programming language already simplified into the Arduino libraries, making it easy to use and apply. Arduino IDE is instrumental in writing the program,

Figure 1. Hardware diagram blocks



compiling the program and uploading it into the Arduino Mega 2560. In detail, this design is depicted in a flowchart which can be seen in **Figure 3**.

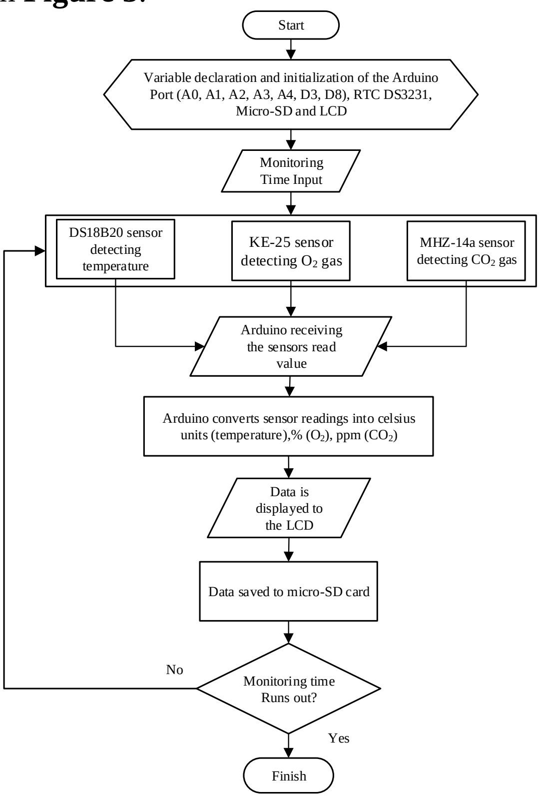


Figure 1. Software Design Flowchart

RESULTS AND DISCUSSION

Display of LCD 20x4 Character and SD Card Testing

Next to the data is displayed to the LCD, data is also recorded and saved into a micro SD card. This data recording is set through the program listing below :

```
// Writing the measurement data
myFile = SD.open("data_pengukuran.txt",
FILE_WRITE);
if (myFile) {
myFile.print(now.day(), DEC);
myFile.print("\t");
myFile.print(now.hour(), DEC);
myFile.print(":");
myFile.print(now.minute(), DEC);
myFile.print("\t");
myFile.print(kal_Celcius);
myFile.print("\t");
myFile.print(kal_oxy);
myFile.print("\t");
myFile.println(kal_ppm);
myFile.close();
Serial.println("SUKSES!");
}
else
{
Serial.println("GAGAL");
}
```

The display results obtained from this program are as follows :

Figure 2. Display data to 20x4 Character LCD

Next to the data is displayed to the LCD, data is also recorded and saved into a micro SD card. This data recording is set through the program listing below :

```
// Writing measuremant data
myFile = SD.open("data_pengukuran.txt",
  FILE_WRITE);
  if (myFile) {
  myFile.print(now.day(), DEC);
  myFile.print("\t");
  myFile.print(now.hour(), DEC);
  myFile.print(":");
  myFile.print(now.minute(), DEC);
  myFile.print("\t");
  myFile.print(kal_Celcius);
  myFile.print("\t");
  myFile.print(kal_oxy); myFile.print("\t");
  myFile.println(kal_ppm);
  myFile.close();
  Serial.println("SUKSES!");
   }
   else {
     Serial.println("GAGAL");
   }
```

After the program is executed, notifications appear from the serial monitor that the measurement data has been successfully recorded and stored.

Temperature Sensor Test (DS18B20)

The DS18B20 temperature sensor is a digital temperature sensor where the sensor has been calibinstalled by the manufacturer, and the output of this sensor is degrees celsius. This test is performed to determine whether the reading from the DS18B20 temperature sensor is good or not, referring to the standard temperature gauge (the HTC-2 digital thermometer). With accuracy and error calculations using the following equation (1):

$$A = 1 - \left|\frac{Yn - Xn}{Yn}\right| \times 100\ \%$$

$$\%Error = \left|\frac{Yn - Xn}{Yn}\right| \times 100\ \% \qquad (1)$$

where A = Accuraty (%), Xn = Temperature value is readable on the HTC-2 digital thermometer (°C), and Yn = temperature value is readable at the temperature sensor DS18B20 (°C).

Table 1. Temperature sensor test data

No.	Digital Thermometer HTC-2 (℃)	DS18B20 Sensor (℃)
1	5,50	5,75
2	6,00	6,20
3	6,50	6,60
4	7,00	7,10
5	7,50	7,80
6	8,00	8,20
7	8,50	8,80
8	9,00	9,20
9	9,50	9,80
10	10,00	10,30
11	10,50	10,90
12	11,00	11,20
13	11,50	11,70
14	12,00	12,30
15	12,50	12,80
16	13,00	13,20
17	13,50	13,60
18	14,00	14,10
19	14,50	14,70
20	15,00	15,20
21	15,50	15,80
22	16,00	16,10
23	16,50	16,50
24	17,00	17,00
25	17,50	17,30
26	18,00	17,90
27	18,50	18,30
28	19,00	19,00
29	19,50	19,50
30	20,00	20,00
31	20,50	20,60

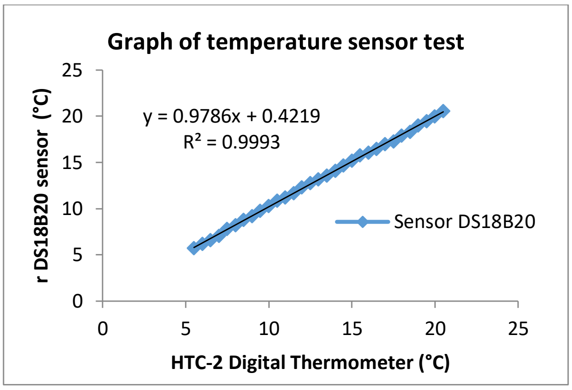


Figure 5. Graph of DS18B20 temperature sensor test

From this calculation, the average temperature sensor accuracy of DS18B20 is 98.29%, while the error percentage is 1.71%. Then, the process of plotting the comparison between the standard data measurement tool temperature is the HTC-2 digital thermometer with a temperature sensor DS18B20 using a linear regression analysis, resulting in the resulting graph as in **Figure 5**.

The graph in the image above shows a comparison of the DS18B20 temperature sensor measurements with a temperature value on the HTC-2 digital thermometer. The resulting result shows a chart that is approaching linear, i.e. with R^2 (coefficient of determination) of 0.9993.

Oxygen Sensor Testing (Figaro KE-2)

The Figaro KE-25 sensor is an oxygen gas detection sensor used in air space. Unlike the DS18B20 sensor, this sensor is still analogous to the sensor output which is still in the form of voltage (V). It has not been equipped with internal ADC so it requires a digital conversion process of analog value. This conversion process can be done using the ADC facility owned by the Arduino Mega 2560. Data retrieval of Figaro KE-25 sensor calibration is done 1 time with the gas concentration range set from 18.5 – 23.5%. The following is a test result data of O2 gas sensors compared to the readings in the Gas analyzer KXL-803.

Table 2. KE-25 oxygen sensor calibration data

No.	Konsentrasi Gas O_2 (%)	Tegangan Sensor Figaro KE-25 (mV)
1	18,5	915,49
2	19	941,00
3	19,5	960,14
4	20	972,90
5	20,5	998,68
6	21	1025,46
7	21,5	1053,40
8	22	1078,02
9	22,5	1108,13
10	23	1138,23
11	23,5	1157,37

Data in **Table 2** is then plotted into a graph using a linear regression method, so a graph can be seen in **Figure 6** against Gas Analyzer KXL-803 with R^2 (coefficient of determination) of 0.9939.

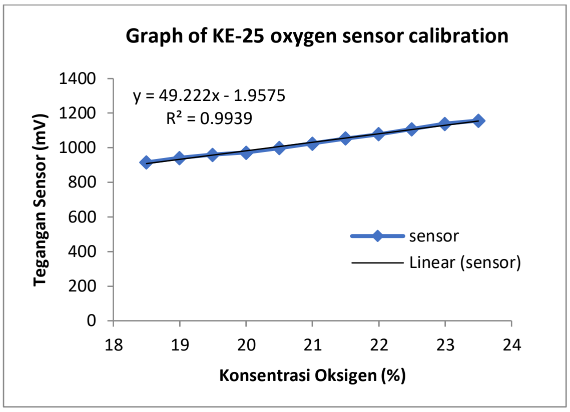


Figure 6. Graph of calibration Figaro KE-25 oxygen sensor

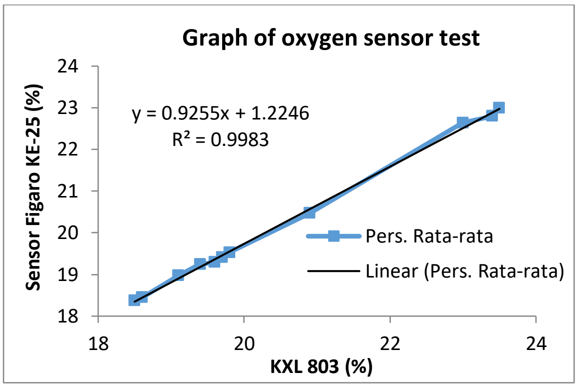


Figure 7. Graph of Figaro KE-25 oxygen sensor test against Gas Analyzer KXL-803

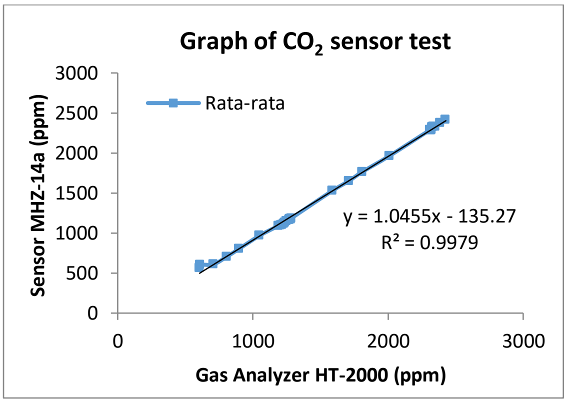


Figure 8. Graph of MHZ-14a CO_2 sensor test against Gas Analyzer HT-2000

From the chart above, it is known that the readings on the oxygen sensor have a linear value against the KXL-803 Gas Analyzer with R^2 (coefficient of determination) of 0.9939. Furthermore, these results were incorporated into the Arduino program to convert the voltage value of

Figaro KE-25 oxygen sensor to a magnitude of oxygen concentration (%). After that, the data retrieval of Figaro KE-25 sensor returned by 3 times each sample with gas concentration range is set from 18.5 to 23.5% to verify the conversion result. The following is the result of the average O_2 gas sensor test data compared to the readings in the Gas analyzer KXL-803.

From this test can be calculated the accuracy value of oxygen sensor with the reading result of gas analyzer. After calculation, the average value of the oxygen sensor's accuracy was obtained by 98.57% with an error of 1.43%. Then for the value of standard deviation (ΔS) resulting from each repetition of average of ± 0.014 or ± 0.073% of the measurement value, meaning the sensor has a good level of accuracy and measurement precision.

CO_2 Sensor Testing (MHZ-14A)

The MHZ-14a sensor is a sensor used in detecting CO_2 gases in this study. CO_2 gas test chart shown in **Figure 8**.

After calculation, obtained the average value of the accuracy of carbon dioxide sensor is 94.58% with error 5.42%. Then for the value of ΔS (standard deviation) resulting from each repetition of average of ± 2.29 or ± 0.19% of the measurement value, meaning the sensor has a good level of accuracy and measurement precision.

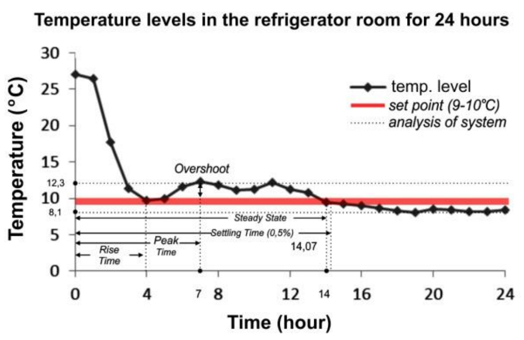
Overall Analysis

This analysis is done to know the performance of the device thoroughly by applying the tools directly into the storage space of pineapple fruit. This application process is done for 24 hours in a home refrigerator, starting from 6 February 2020 at 10.02 WIB to 7 Febuari 2020 at 10.02 WIB. Storage conditions on the storage space done is when there is no fruit (empty) pineapple.

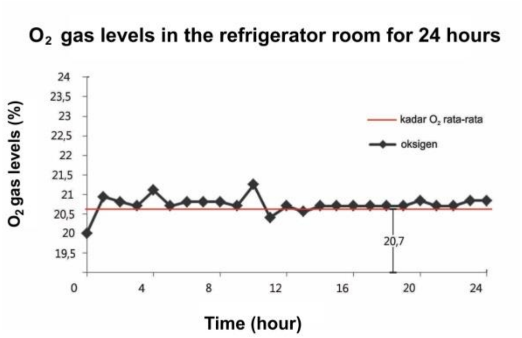
Table 3. Measurement data for temperature, O_2 gas, and CO_2 gas in refrigerator for 24-hour (without pineapple)

Hours to -	Temp. (°C)	O_2 (%)	CO_2 (ppm)
0	27,0	20,0	410
1	26,5	20,9	459
2	17,7	20,8	488
3	11,4	20,7	704
4	9,7	21,1	645
5	10,0	20,7	611
6	11,6	20,8	635
7	12,3	20,8	577
8	11,8	20,8	513
9	11,1	20,7	547
10	11,3	21,3	493
11	12,2	20,4	498
12	11,3	20,7	503
13	10,8	20,6	454
14	9,5	20,7	454
15	9,2	20,7	454
16	9,0	20,7	454
17	8,7	20,7	454
18	8,3	20,7	454
19	8,1	20,7	454
20	8,5	20,8	459
21	8,4	20,7	469
22	8,2	20,7	454
23	8,2	20,8	454
24	8,4	20,8	454

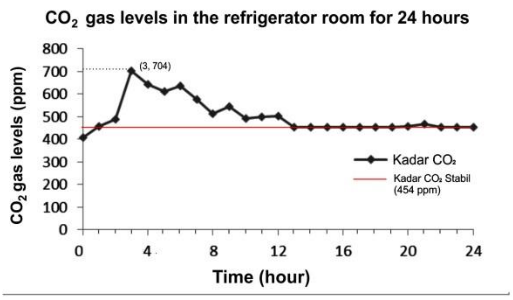
Data on table 3 is further plotted into 3 (three) pieces of the graph, namely the graph of the temperature relation to time, the concentration of O_2 ¬ time and the concentration of CO_2 ¬ against time. As for the temperature relations graph against the time shown in **Figure 9a**.



(a)



(b)



(c)

Figure 9. Graph of **(a)** temperarure, **(b)** O_2, and **(c)** CO_2 measurements against time in a 24-hour refrigerated storage space

This graph (**Fig. 9a**) has a response character LHP (left-hand plane) is a chart that has a muted pattern and output the final response in the form of steady state, so it can be approached with a transient response system analysis. At an hour to 13.3 the temperature on the storage room has reached settling time (0.5%) with a temperature of ± 10 ° C and the temperature has been stable (steady state) after 14 hours. Settling Time (Ts), i.e. the size of time stating the response has entered 5% or 2% or 0.5% of the steady state. From these results can be known that the cooling process in the refrigerator takes 4 hours to the desired set point, while reaching the stable position of the desired set point is to take up to 14 hours or with slurries time for ± 14 hours 4 minutes (0.5%).

This graph (**Fig. 9b**) has an undefined pattern and tends to be stable from start to finish. In the initial conditions O_2 concentrations in storage space by 20%. After that, there is a change in the O_2 concentration value at the 1st hour, which is 20.9%. On average, O_2 gas levels in the refrigerator from the start to the 24^{th} hour are 20.7%, and do not see significant decline or increase in O_2 concentration levels after the 14 to 24 hour.

The graph of measurement results in CO_2 (**Fig. 9c**) shows the value of CO_2 that increases and decreases to stabilize at the 13th hour with a CO_2 concentration of 454 ppm. If viewed from the health, the content of CO_2 in the cooling chamber enters into second category, where the CO_2 gas concentrations have been effect on human health if it is continuously inhalation [12].

CONCLUSION AND SUGGESTION

Based on the research results, it can be concluded that :

1. The system of data acquisition temperature, O_2 gas, and CO_2 has been successfully realized in the storage room of refrigerated pineapple fruit, with the characteristics of each sensor as follows :
   a. Temperature sensor has an accuracy value of 98,29% with *error* of ±1,71%.
   b. O_2 sensor has an accuracy value of 98,7% and ±0,073% for its precision,
   c. CO_2 sensor has an accuracy value of 94,5% and ±0,19% for its precision.
2. The realised device has been able to display real-time measurement data output to 20x4 LCD with IIC, and also performs data storage into the Micro SD card together.

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